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Technical, Environmental and Socio-economical Contexts

WasteSafe 2009

9-10 November 2009
Khulna, Bangladesh

Editors
M. Alamgir, Q.S. Hossain, Q.H. Bari, I.M. Rafizul,
K.M.M. Hasan, G. Sarkar & M.K. Howlader

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Preface

Now-a-days, environmental problems in the urban areas due to improper management of solid wastes have been recognized as an important concern to the stakeholders irrespective of countries position. As a results solid wastes management strategies and technologies are currently undergoing rapid development. However, the strategies in Least Developed Countries have not been well-defined and properly addressed; rather it remains still in the primitive stage. However, the situation needs to be improved which depends completely on the change of the attitude of the individual citizen, the community and the authority directly or indirectly responsible, otherwise environmental degradation will make a threat for the sustainability of the inherent socio-economic settings as the Charles Darwin stated – ***It is not the strongest of the species that survive, nor the most intelligent, but the most responsive to change***.

This *International Conference on Solid Waste Management: Technical, Environmental and Socio-economical Contexts – WasteSafe 2009* is organized at Khulna, Bangladesh to exchange the views and experiences at international level and to understand the solid waste management concept as a whole. It is expected that the researchers and professionals will unfold the prevailing reality in this sectors, innovative ideas, latest findings and experiences in this forum in order to provide the necessary guidelines through which a safe and sustainable system for solid waste management can be designed based on the local socio-economic settings, technological capabilities and present needs. It will open the eyes how a system can be made effective within limited resources and enormous constraints.

This is the first ever International Conference exclusively on Solid Waste Management to be held in Bangladesh. WasteSafe 2009 is organized by the Department of Civil Engineering, Khulna University of Engineering & Technology in close cooperation with Bauhaus University Weimar, Germany; Khulna City Corporation, Bangladesh; Asian Institute of Technology, Thailand; Bauhaus International Research & Education Centre, Germany and Lublin University of Technology, Poland. International and professional supports are provided by the IWWG (International Waste Working Group) and ORBIT Association. The event also aegis of Department of Environment, Ministry of Environment & Forests, Government of Bangladesh.

Technical papers were invited through website (www.wastesafe.info), poster and information bulletin from the academicians/researchers/professionals/social activists working on solid waste management around the world well before the Conference date. This conference is a follow up of the earlier research activities on solid waste management at KUET, took place with the financial support of European Commission in close cooperation of Asian and European organizations. Such activities were (i) Workshop and Seminar on Geoenvironmental Engineering in March 2003 at Khulna, (ii) Seminar on Solid Waste Management in May 2004 at Khulna, (iii) Seminar & Stakeholders' Dialogue in March 2005 at Dhaka, (iv) Seminar on SWM in February 2007 at Khulna, (v) National seminar on solid waste management in February 2008 at Khulna, and (vi) Workshops on solid waste management in January-February 2009 at six major cities of Bangladesh.

After review, total 87 technical papers including 7 Keynote papers were selected for publications into the Conference Proceedings and Oral Presentation in the inauguration session, 5 Keynote Sessions and 14 Technical sessions. Academicians, researchers, professionals and other personalities from 13 different countries - Australia, Bangladesh, China, Germany, Greece, India, Italy, Japan, Nepal, Philippines, Poland, Sri Lanka and Thailand - submitted their scientific contributions in this conference. Papers have been lightly edited to homogenize the style and to revise the contents based on reviewers' comments. However, the final responsibility for the contents, quality and the presentation of the papers is held by each individual author.

I would like to acknowledge the great efforts of the authors, who jointly and/or individually contributed by submitting papers. I might appreciate the supports received from the reviewer's who did it perfectly. The contribution of the members of all committee are gratefully acknowledged. Heartiest thanks to Prof. Q.S. Hossain, Prof. Q.H. Bari, I.M. Rafizul, KMM Hasan, G. Sarkar and M.K. Howlader for putting their excellent joint efforts with me for editing the proceedings including composing the text, figures, tables and photographs, which is indeed a tedious job.

Finally, great appreciation is due to the European Commission for co-financing this International Conference through a three years (2007-2009) partnership project "Safe and Sustainable Management of Municipal Solid Waste in Bangladesh through the Practical Application of WasteSafe Proposal – *WasteSafe II*" under EU-Asia Pro Eco II Programme.

Muhammed Alamgir
Khulna, November 2009

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Environmental Sustainability of Municipal Solid Waste Management in Bangladesh

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ABSTRACT

In the urban areas of Bangladesh, the existing practices of municipal solid waste (MSW) management are standing far behind than the needs in all aspects; as a consequence, the urban environmental sustainability is in large threat and becomes a striking issue to the concerned stakeholders. Due to inherent constraints and the reality, the changes should start standing on the foot of the existing system since each urban authority follows a system in spite of its degree of success. The refinement of the existing system should be taken setting a target which is achievable in the present perspectives and the capabilities of the city authority. To materialize the target perfectly, the community participation must be ensured and the levels of awareness and commitment should be raised following sustainable initiatives developed based on the interactive dialogue among the concerned stakeholders. The achievements should be evaluated in a regular basis and make it public through an open source information. An environmental watchdog need to establish to look after and evaluate the sustainability of the ongoing system and the liberty to work independently and freely must be ensured by the concerned authority.

INTRODUCTION

Bangladesh is currently undergoing a period of unprecedented rapid economic growth and urbanization. Most cities of Bangladesh face environmental problems caused by inadequate provision of sanitation and waste management facilities. Recently solid wastes problems draw noticeable attention to the concerned stakeholders since it creates nuisance in the daily urban life as well as other problems such as drainage clogging resulting water logging in some parts of the cities. Every city authority generally follows a non-integrated and weakly managed system, which is almost similar in nature throughout the country (Ali 2004, Visvanathan et al. 2004, Enayetullah & Sinha 2003, Ahmed & Rahman 2000 and Alamgir 2009). However, all the tiers of MSW management at Bangladesh are in the primitive stage and needs modernization through innovative and appropriate approach in association of local conditions for its proper management. Such improvement needs necessary resources and infrastructures development, which can be established only in phases with very strong determination. Some revolutionary steps also need to take which is not so easy in the present circumstances. As the present environmental degradation in the urban areas cannot be ignored, attention should be given to find out the loopholes of the existing system and the necessary ways should be find out to run it within the existing capabilities of the city authority in particular and the community in general. In this context, the prime task is to ensure the proper functioning of the adopted system and to minimize adverse environmental impacts as much as possible. The starting point of this is to identify the weak aspects of the existing system and to make a sustainable and affordable plan considering the real position of the city authority and the area concerned.

Realizing the facts exist in the existing management practice, present and future needs, it is evident that there is no single solution or the best solution. The possible remediation technique of such problems should be considered locally to ensure sustainability of the adopted system as well as environment. In this backdrop, the first step is to prepare a conceptual framework based on the existing waste components and the relevant aspects (Alamgir et al. 2006). Then practical initiatives need to aware the people to stop throw out of wastes irrespective of size, shape, type and place, but to store them in a designated place by any means. To ensure primary collection adopting a system which is regular, effective and trustworthy by the community concerned. The scenarios of the on-site storage, compost plant, recycling factory and the ultimate disposal sites (UDS) should bring into control to ensure a reasonable degree of environmental sustainability. The system should be designed in such a way that the designated goal should be achieved by any cost. The community participation, which is a sociological process, must be ensured conducting proper dialogue and regular communication that will develop their ownership on the system (Bidlingmaier 2009). To this endeavor, an independent supervising body, which can be named as 'Environmental Watchdog' should be formed and the city authority must ensure its effective functioning without interference.

PRESENT SCENARIOS OF SOLID WASTE MANAGEMENT IN BANGLADESH

General characteristics of MSW in Bangladesh can be identified as high biodegradability and moisture content, while its management is mostly controlled by city authority in an inefficient ways which fails to achieve minimum levels of environmental sustainability, as described briefly in the followings.

Solid Waste Characteristics

The general nature of MSW in the urban areas of Bangladesh is almost same and very much similar to that of the cities of Least Developed Asian Countries (LDACs). The wastes are generated at a rate of 0.325-0.485 kg/cap/day, obtained from different source of generation such as 75-85% residential, 11-22% commercial, 1.0-1.5% institutional, 0.50-1.25% municipal services, and 0.4-2.50% others. The composition is 68-81% food & vegetables, 7-11% paper & paper products, 3-5% polythene & plastics, and 9-16% others. The wastes contain high portions of volatile solids (43-71%), while ash residue from 29 to 57% and have high moisture content (56-70%). The bulk density of MSW ranges from 400 to 600 kg/m3. The size of the components of MSW varies from 2 to 200 mm. Other properties are encountered as pH (acidity/alkalinity) from 7.7 to 8.7. Average value of some chemical constituents is 11.50% carbon, 0.91% nitrogen, 0.76% potassium and 0.33% phosphorous. Recent study shows that the generations of hospital waste in four major cities are: Dhaka is 0.22%, Chittagong is 0.20%, Khulna is 0.42% and Sylhet is 1.74% of total generated MSW. Study also shows that the generation rate of hospital waste varies from 0.70 to 1.2 kg/bed/day and the percentage of hazardous portion varies as 10% to 30%. More details can be obtained at WasteSafe (2005) and Alamgir & Ahsan (2007). An estimated figure of MSW generation, collection efficiency and disposal scenario of Bangladesh based on the study of WasteSafe (2005) are shown in Table 1. Each day huge amount of MSW is disposed in the dumping sites, which produces significant amount of GHG for emission into the atmosphere.

Table 1 Generation, collection and disposal of MSW in Bangladesh (after Alamgir et al. 2008)

City/Town	No of City/Town	Solid Waste Generation, Gg/year	Collection Efficiency, %	Solid Waste Disposal, Gg/year
Dhaka	1	1950	45	877
Chittagong	1	480	42	202
Khulna	1	190	54	103
Rajshahi	1	62	47	30
Barisal	1	48	38	18
Sylhet	1	78	37	29
Pourashavas	298	1755	44	772
Other Urban Centers	210	620	43	267
Total	**514**	**5183**	**Avg (~44%)**	**2298**

Note: 1Gg=1000Tons

Management System at Organizational Level

In Bangladesh, city authority is responsible for overall management of MSW in urban areas as per the Municipality Act. The attempts taken by city authority do not work well due to severe financial constraints, required infrastructures, absence of appropriate and sustainable technology, lack of motivation, awareness and participation, and the absence of effective legislation. However, some Non-Governmental Organisations (NGOs), Community Based Organisation (CBOs) and Private sectors have been started to work with city authority's initiatives to solve this striking social and environmental problem. But the situation remains unchanged. Generally, Conservancy Department is responsible for solid waste management including other utility services. There is no independent wing with sufficient authority to deal the MSW problems in the municipality; however, recently city authority has taken the initiatives to change the administrative set-up to develop an independent wing to deal MSW problems. In such initiatives only Dhaka City Corporation has set-up a Department of Solid Waste Management, however, still it needs to ensure the participation of the city dwellers and the capabilities to take prompt and necessary decision.

Present Situation at Various Tiers of MSW Management

Wastes irrespective of types are generally deposited in secondary disposal sites either by the city dwellers/NGOs/CBOs/City authority/private sectors. NGOs/CBOs have initiated door-to-door collection system of waste from generation points for some collection fees in a very limited scale. In general, city authority collects wastes from the secondary disposal site (SDS) and disposed to the designated ultimate disposal site (UDS). Wastes are recycled and reused in the generation points, during collection, in SDS and even in UDS by the informal sectors. Composting is mostly done by the NGOs, in a very small scale by city dwellers and recently private sectors and also by city authority. However, major portions of wastes remain unmanaged - throwing them in the adjacent spaces, roadsides and drains etc. resulting from inadequate infrastructure facilities provided by city authority, lack of people's awareness and commitment. A portion of clinical wastes is managed by NGOs and the remaining follows to the same path of MSW.

ENVIRONMENTAL IMPACTS

As the existing management system in all the urban areas of Bangladesh are running in an inefficient way with inadequate infrastructures, the environmental degradation in the urban areas is evident, which cannot be overlooked any more. Some important issues from existing solid waste management are discussed in the followings.

Not to Store but Throw Away

Significant parts of MSW in Bangladesh, like most of the LDACs, remain unmanaged and hence littered in the close vicinity of the generation points. Despite the absence of proper management practices in the other tiers of MSW management, the source storage plays very important role. The majority of solid waste comes from residential and commercial areas. If proper handling of wastes cannot be adopted at source, the total management system is verged to collapse. It is observed that in the urban areas of Bangladesh, more than 40% waste generators do not store, just throw away. People from all cross-section of society used to do it. It occurs in home, office, markets, stations/terminals, recreation place and even in the class room. In some instants, it is observed that in spite of the presence of bins, people do it from their inherent habits and ignorance. In this backdrop, it can be concluded that the absence of peoples' awareness, commitment and motivation lead to continue such unpleasant and catastrophic habits.

Other point is realized that due to the absence of proper and efficient primary collection system, people thought that what then happens to all the binfuls if the wastes are stored? The primary collection of waste is one of the most important connectors in building smoothly running chains among all the elements of MSW management. The success of any management system of MSW greatly depends on the efforts and success of primary collection. Therefore, the frequency and reliability of waste collection also has tremendous impacts on source storage practices rather than throw out. Due to this throw out malpractice, urban environment including the drainage system suffers very much. The study reveals that the littering of solid wastes is very much responsible for the clogging of city's drainage system, as shown

Figure 1 Situation of a drain due to throw out of waste

in Figure 1. As a water logging in some part of city occur only for the mismanagement of solid wastes. So, the urban environments suffer in various ways due to *'Not to store but throw out'* dilemma.

On-site Storage

Figure 2 shows the placement of two SDS – open and container type- by the city authority in a busy street, which reduces the effective width and creates traffic congestion with serious socio-environmental associated problems. Another improper steps of the city authority; construction of brick masonry type dustbin for secondary disposal – on a footpath obstructing the movement of pedestrians and on the drain hampering the drainage facilities, one of the most important facilities of the city. Recent involvement of private sector and NGOs to manage SDS also did the things improperly. Through this improper step, the road spaces in the turning point and the footpath cum drain along the road sites have been reduced significantly, which consequently add more traffic congestion and inconveniences to the city dwellers and subsequently degrade urban environment.

In slums and also in the old part of each city where the buildings are very close to each other and the streets are very narrow there is no space available for SDS. So, special measure should be taken. The problems due with on-site storage in the existing MSW management system can be outlined as:

- Most of the SDSs are located either roadsides or at the corner of intersection or besides the drain, reducing effective road width and obstacle traffic and pedestrian movements and drains are filled-up.
- Existing Dustbins do not meet the requirements resulting littering as deposited at the surroundings.
- In addition of SDS, the collection vehicles i.e. trucks standing for long time at the sites due to manual collection and inefficiency, causing further obstruction at the general utility of the streets.
- Uncontrolled and improper scavenging further deteriorates the situations.
- Movements of incoming and outgoing vehicles at the busy hours of the day add more traffic congestion and creates public nuisance due to the existing waste carrying facilities.

(a) Open on-street storage (b) Demountable container in a busy street

Figure 2 Improper placement and management of SDS in the urban areas

Compost Plant

Compost plants mostly run by NGOs, private sector, city authority in a limited scale with the help of NGOs and also barrel composting has recently introduced to individual family level. Mostly mixed MSW are the input collected and supplied by small NGOs, CBOs or even by city authority. Lot of efforts is required for segregation conducted at the plant areas as shown in Figures 3(a). As the quality of compost depends on input MSW, required quality cannot be ensured since once wastes are mixed, proper segregation is impossible, moreover, wastes starts to degrade quickly. It is also observed that some plants collect partially decomposed wastes, and then sorted it manually, which is very susceptible to health hazard due to direct contact. Most of the plants are developed ignoring the essential aspects to be followed in terms of appropriate technology and required infrastructures, such as facilities for wastes delivery and residual removal, active composting, maturing, screening, packing and store of products, storage of equipment and personal items of workers and an office, and a demonstrated plant to explain the benefit of compost. The screening process of matured compost as practiced presently (Figure 3b) in the compost plant in Bangladesh creates severe health hazard to the workers. Training and technical advice are not readily available to the interested people. Health and hygiene aspects are ignored, no control of flies, odour and seepage of leachate. As the wastes are not well segregated, the quality of compost cannot be ensured and moreover, in most plants the quality of the products is not examined explicitly. Due to this uncertainty of quality, peoples are hesitate to buy the compost, so this sector still remains a losing concern and fails to attract more investment and involvement. As the odour and other aspects causing nuisance are not controlled at least to an acceptable level, some compost plants are forced to shut-down by the neighbours and home or barrel composting does not received expected encouragement.

(a) Sorting of MSW at the compost plan (b) Screening of compost without protection

Figure 3 Manual activities at the compost plant

Recycling and Recovery

In Bangladesh, generally recovery/recycling is carried out in three phases. Phase one is the source separation, where the generators separate refuse of higher market value such as papers & paper products, bottles, fresh containers, plastic materials, tin, glass, metal, old clothes, shoes etc. and sell to street hawkers. Hawkers are collected reusable and recyclable materials from house to house and sell to the nearest small recycling shops. In second phase, the poor children of slum dwellers or street children collect different items of low market value from on-site storage. The final phase is the recovering of reusable and recyclable materials from UDS. Scavengers are salvaging recyclable wastes mainly when collection vehicles are being unloaded immediately as shown in Figure 4(a). These patter of recovery from SDS and UDS occur in a very unhygienic and causing environmental degradation. Undesirable and most unhygienic practices of sorting hospital wastes for recycling is shown in Figure 4(b), such practices should be stopped immediately. An attempt to convert MSW into charcoal through briquette process was taken by a city authority as shown in Figure 4(c) without any appropriate investigation of environmental impacts due to unwanted gas emission during productions and while using the product. Integrated approach is completely absent in recycling sector although huge activities are conducting mostly by informal sectors ignoring the consequences of the environment. As this sector has very positive impacts on the overall management of MSW, attention and support must be provided to give the informal sector into a formal shape.

(a) Scavenging at UDS (b) sorting of medical wastes (c) Briquetting to convert MSW

Figure 4 Scavenging of MSW for recyclable materials in an unhygienic way

Ultimate Disposal Sites

All the environmental pollutions are present in the existing UDS of Bangladesh, typical one is shown in Figure 5. The environmental impacts of eight open dumping sites in six major cities of Bangladesh is shown in Tables 2 as studied in WasteSafe (2005). The studied UDSs are located at Matuail and Gabtali - two sites in Dhaka, Halishahar and Raufabadh - two sites in Chittagong, Rajbandh in Khulna, Shishu Park in Rajshahi, North Kawnia in Barisal and Lalmati in Sylhet. To develop Table 2, regional adjustments based on professional judgment were made in hazard scoring assessments. The relative threat to health and the environment was evaluated by Indian Health Service (HIS) report and Resource Recovery and Conservation Act (RCRA) based on the consideration of factors that may contribute to the likelihood that a site might pose a hazard.

Figure 5 Scenarios of UDS: open dumps

Table 2 Potential threat to the environment caused by UDS in Bangladesh (after WasteSafe 2005)

Hazard Point Factors	Name of the location of studied eight UDS							
	MTL	GBT	RFB	HLS	RJB	SSP	NKW	LLM
Waste contents	30	30	30	30	30	30	30	30
Rainfall	2	2	4	4	2	4	4	4
Distance to drinking water aquifer	8	8	0	8	8	8	10	10
Site Drainage	8	8	8	4	8	8	4	8
Potential to create leachate at site	4	2	4	4	4	4	4	4
Distance to domestic water source	4	2	2	2	0	4	4	4
Site accessibility	2	4	4	4	4	4	4	2
Frequency of burning	0	0	0	0	0	2	2	2
Site materials exposure to public	4	2	4	4	4	4	4	4
Degree of public concern over site esthetics	4	4	4	4	4	4	4	4
Total Points	**66**	**62**	**60**	**64**	**64**	**72**	**70**	**72**

Note: MTL – Matuail, GBT – Gabtali, RFB – Raufabadh, HLS – Halishahar, RJB – Rajbandh, SSP – Shishu Park, NKW – North Kawnia, LLM – Lalmati; Low hazard – Points 13 or less, Moderate hazard – Points 14 – 29, High hazard – Points 30 or more.

Problems with Special MSW Streams

In the existing MSW management practice in Bangladesh, there is no provisions to handle huge amount of wastes generated in the cities during mass festivals. It is observed that during festival time or after the festivals, such as religious, nationals, new years and even marriage ceremony in some instances or anniversary of different organizations, there are no scope and capabilities of city authority to tackle the pressure due to suddenly generated huge amount of solid wastes. The wastes remain in the streets, along the footpaths and other open spaces of the cities for long time and deteriorate the city environment after the decomposition. Collection of such wastes from the street of city is shown in Figure 6. Moreover, in UDS, there is no control or inspection about the streams of wastes to be disposed. All types of special wastes-both the hazardous and non-hazardous including infectious items of medical wastes are disposed there with the general streams of MSW. As a result the contamination levels due to the presence of UDS have increased.

Figure 6 Removal of animal extracts from street

Natural Disaster – Floods

Figure 7 Scenario of SDS during floods

Floods during the rains are inevitable in Bangladesh as the geography cannot be changed and the mountains cannot be shifted. Bangladesh severely experienced some recent big floods and the impact of floods adversely affected the urban life and the management of solid wastes further lead the situation to environmental disaster. Extreme rainfall, floods and other natural calamities can create the critical strain in total solid waste management breakdown. So effective management system has to be mindful of geological and hydrological condition of the area, including under extreme conditions.

During the devastating flood in the year of 2004 and 2007, the total solid waste management system in some major cities and other urban areas were collapsed. The usual practice of the city people in such conditions is to throw their waste into the floodwaters, which severely deteriorates health and environmental standards. Even the UDSs were nearly inundated under water. During the flood, the city authority did not take any specific measures to collect wastes. There was spillage of wastes at every road intersection where some high land was available. But in several areas where floodwater levels allowed it, the community based waste management remained active. The common situation of secondary disposal sites, using haul container and big box type container, at the inundated areas is shown in Figure 7. Flood is an inevitable natural disaster in Bangladesh and it can be expected that in every year some areas of the major cities will be inundated and remain under water for several days. Therefore special attention should be given to run the existing MSW management system and precaution should be adopted to tackle any possible hazards. During the flood period, special task force should be formed to provide door-to-door collection of MSW at least in the areas, which are inundated. Awareness and motivation campaign should be enhanced to motivate the people not to throw or deposit any wastes into the water bodies. Temporary SDS needs to be arranged at the available high lands (dry land) in the inundated areas. Even country boats can be arranged for waste transport.

MEASURES FOR ENVIRONMENTAL SUSTAINABILITY IN THE EXISTING SYSTEM

To keep the city clean, hygiene and environment-friendly, generated solid waste should be managed in a scientific way. However, acknowledging the drawbacks of the existing management and the practical situations, appropriate measures should be taken to ensure the environmental sustainability. To set-up the strategic plan, one can start considering the solid waste management components such as (i) Contain & Collect, (ii) Sort & Recovery, (iii) Transfer & Treat, and (iv) Dispose & Make Safe, in the perspectives of two important aspects such as (a) Source & Streams, and (b) Health & Environment. With these components and the aspects, a conceptual framework as stated in Table 2, can be followed. The questions cited in this conceptual framework should be answered first to take any counter measures against the drawbacks of the existing systems.

Integrated management of MSW is an interactive correlation among the concerned stakeholders and the management aspects. Based on the several relevant issues, the appropriate strategies or measures and the authorities responsible for the implementation should be identified for the success of any existing system. Since solid wastes generation is a social and economical issue, its management through community based approach will play a positive role. The participants i.e. stakeholders involved either directly or indirectly in MSW management have different attitude, role and importance. Such as, the 'formal sectors' consider MSW as a health and environmental hazard and try to take every step to protect the environment against it. On the other hand to the 'informal sectors', the MSW is an economical resource from which marketable products can be collected. Therefore an interaction between these sectors should be established to find the counter measures to find a way which ensure environmental sustainability in the existing system. The role of the participants such as (i) Community, (ii) Informal Sector, (iii) Transfer & Treat, and (iv) Municipality, (v) Formal Private Sectors, (vi) NGOs, and (vii) Others (Volunteers/ Educationalists/ Researchers). To make proper strategies the key issues to consider can be listed as (i) Inadequate Solid Waste

Management Policy/ Municipal Act/ Ordinance, (ii) Lack of adequate fund/resources for Entrepreneurs/ CBOs /NGOs, (iii) Lack of community awareness and willingness to pay, (iv) Lack of operational capacity of Local Government Bodies, NGOs/CBOs, (v) Need for networking and compiling adequate database on solid waste management. Details on the participants' role and the key issues can be obtained in WasteSafe (2005).

Table 3 Starting point of the strategy to develop counter measures for sustainable management

Components	Aspects	
	Sources & Streams	Health & Environment
Contain & Collect	What can be done to encourage people to take/send waste only to designated places? What can be done to ensure safe storage and handling of hazardous clinical wastes?	How can local waste assembly points be located, designed, equipped and operated so as to encourage use and discourage misuse, including prevention of litter and disease?
Sort & Recover	What can be done to promote the separation of wastes suitable for value recovery?	How can health conditions be improved for waste recovery workers?
Transfer & Treat	What can be done to ensure transfer of higher proportion of unrecoverable waste to treatment and/or disposal? What can be done to increase number and/or capacity of composting schemes?	How can disruption to waste transfers be minimized in flood conditions? How can composting schemes be designed, located and operated to avoid odour etc impacts for local community?
Dispose & Make Safe	What can be done to provide adequate capacity for safe final disposal?	How can landfills be properly engineered and operated in flood-prone areas? How can hazardous clinical wastes be safely disposed of?

Awareness Development among the City Dwellers

Strong initiatives should be taken at the generation point for proper storage if a society dreams for environmental sustainability in the existing system, which will eventually prevent littering of wastes. It needs very strong motivation and commitment from the generators i.e. city dwellers since most of the MSW comes from domestic sources. In this context mass awareness campaign may bring fruitful results to raise people commitment and participation in the process. The education on storage should be the first lesson, which can be started from school level by incorporating it into the text books. As the majority of population will remain out of school education, other alternatives may take into account to materialize such initiatives in order raise awareness among the city dwellers. Since the society is lagging behind formal education and the literature rate is very low, initiatives should be taken considering the socio-economic settings of the Bangladesh. Such initiatives may be identified as: (a) Leaflets, Posters, Stickers, (b) House-to-house Motivation, (c) Group Monthly Meeting (ward level), (d) Group Monthly Meeting (central body), (e) Awareness Rally (ward wise), (f) Art Competition, (g) Street Drama, (h) Billboard Festoon, (i) Annual Fair, (j) Mass Media. The main theme for this awareness campaign is ***"Don't throw wastes out, but store them in a designated place, by any means",*** to target the first and foremost requirement step that must be accomplished by the society to develop a proper management of MSW.

It looks very simple to store all the generated wastes at source, but it is, indeed, one of the most difficult tasks in solid waste management tiers. People need to change their minds and habits. Continuous mass awareness campaign should run in this regard through a responsible and public representative body such as city authority (Municipality and City Corporation). Authority should involve the people from the relevant stakeholders in this process. Such initiatives have been and are being taken place in different cities of Bangladesh but do not continue due to lack of responsibility, target and planning and as well as financial constraints. Therefore, awareness campaign needs institutional shape to run regularly targeting people of different cross-section without any interruption till the designated goal has been accomplished. A pictorial views on the conducted awareness campaign such as mass rally in the cities leaded by the city Mayor is shown in shown in Figure 8.

Figure 8 Mass awareness rally through the city street lead by the Mayor of City Corporation

Commitment of the Authorities

Despite the inherent constraints to tackle the adverse environmental impact comes from the rapidly increasing amount of MSW, each city authority in Bangladesh practices a system in its own way. As there is no system to be designated as ‘The Best’, the adopted system should be respected and hence appropriate counter measure to be implemented in phases to improve the system ensuring environmental sustainability. However, experiences show that although the system is running in combination of formal and informal sectors, such as city authority, NGOs, CBOs, Private sectors, the whole responsibility should be taken by the city authority, which has the commitment to the city dwellers for ensuring a clean, hygiene and habitable city. As the waste management is a social and technical issue, without very high commitment from the public representative and the pressure from the people who voted them to power, the success of any adopted system is fade. They should give commitment to the voter to take high responsibility to ensuring proper functioning of the existing system and hence to improve it in phases. One of such written commitment given by the city mayor and the female ward councilor in Khulna city is shown in Figure 9.

Figure 9 Written commitments given by city mayor and female ward councilor

Present experience shows that proper management of MSW in urban areas is very much concerned issue to city dwellers rather than the authority. Therefore, it needs very strong commitment from the authority to run the system properly. The system can be designed based on the financial and technological capabilities as well as the social structures. Sophisticated system without proper implementation is worse than a simple version with proper implementation and sustainability. Therefore, despite the inherent limitations prevailing in the city councils, this is the commitment of the authority, which will guide to achieve environmental sustainability of the adopted system.

Environmental Watchdog

Proper monitoring of the achievement of the existing system is an important requirement to ensure environmental sustainability. In this context, an independent body other than the directly involved parties such as Waste Management Division and service provider (City Corporation/ Municipality/ NOGs/ CBOs/ Private Sectors) is needed to involve in the process. This body can be designated as 'Environmental Watchdog', which may form by the selected and the interested city dwellers from different corners having relevant expertise and/or experiences. The city corporation will provide all logistical supports. However, the chairman and the members will work voluntarily. As an alternative, the city corporation may select and involve a private enterprise such as an environmental company, who will act as the 'Environmental Watchdog" for certain period with clearly defined terms and conditions. This body only looks after the environmental assessment at every tier of the existing solid waste management adopted by the city authority. As the accountability and transparency are the two prime aspects to make success of any attempts including environmental sustainability check of the adopted system, this body will also watch whether the information regarding the ongoing activities conducted by the city authority make readily available to the concerned stakeholders. The necessity of such a body is realized in different stakeholders' dialogue conducted in the recent years in presence of the people from various cross-section of the society, one of such discussion organized by a city authority is shown in Figure 10. The entrusted body will prepare monthly or quarterly report, which will be an open and free accessible source to all concerned stakeholders including the city dwellers. The watchdog also will select the best ward, school, hospitals, office, kitchen market, shopping center, etc. for monthly awards and encouragement incentives provided by the city authority. This body should not have any decision making capacity and/or authority on the MSW management system; however, its work and voices cannot be undermined by the concerned authority. The reports and associated recommendations provided by the watchdog should be considered as mandatory to discuss in the elected public representatives' meetings of the city authority for necessary observation and considerations.

Figure 10 Stakeholders' dialogue on the various issues of MSW management

MAIN CHNALLEGES AND THE SOLUTION APPROACH

It is evident that to overcome the present unpleasant and unhygienic situations in the urban areas of Bangladesh, the existing system should be improved in phases to reach an environmental-friendly condition. The improvement should be done in such a way, that the sustainability must be ensured and the adopted system should be design considering the capability of the city authority in all the relevant aspects and in accordance the prevailing socio-economic conditions, city dwellers' perception and the technological capabilities. To ensure the sustainability of the issues to be addressed, performance monitoring and impact assessment are must. The assessment reports should include the suggestion of the approaches needed to implement and/or refine the existing one considering the operational and environmental aspects. However, it is difficult to see how the objectives of environmental sustainability are going to be achieved within the inherent constraints faced by the city authority to improve the existing system as targeted. The major environmental issues to be addressed can be short listed in a tabular in Table 3.

Table 3 Major environmental challenges to run management and operational issues

No.	Management and Operational Issues	Major Challenges for Environmental Sustainability
1	Source storage	- Stop throw away of wastes by any means. - Separate hazardous wastes. - Overcome NIMBY syndrome.
2	Primary transfer of wastes from source	- Proper collection and transfer of wastes from source. - Transfer of hazardous waste with care.
3	Situation of on-site storage i.e. SDS	- No scavenging and no littering at SDS. - Stop SDS at the illegal/undesignated places. - Time frame for waste disposal and storage at SDS. - Improvement of SDS & no storage on earthen floor. - Separate handling option for hazardous waste. - Conversion of SDS to Transfer station in phases. - Ensure proper management of SDS.
4	Collection & Transfer of wastes from SDS	- Ensure regular collection within the fixed time span. - Stop seepage of leachate during transportation. - Covering of transportation vehicles to stop littering. - Avoid waste transportation during rush hour.
5	Composting technology	- Ensure separate storage of bio-waste at the source. - Stop sorting of partially decomposed wastes. - Make mandatory use protective articles at the plant. - Ensure reasonable wage, job security & healthcare. - Stop direct screening of compost, modify the system. - Stop discharge of leachate without prior treatment. - Private sector should be encouraged. - Government support should be increased.
6	Recycling industries/ factories	- Stop child labour in the local recycling industry. - Provide health protection articles to the workers. - Install pollution/contamination control devices in phase. - Provide government support for sustainability.
7	Ultimate disposal	- Stop illegal dumping of the collected wastes. - Recyclables and Bio-wastes should not go to landfill. - Ensure waste deposition in the designated place only. - Stop scavenging and littering of wastes in the sites. - Develop existing sites to meet environmental provision. - Introduce Sanitary landfill in phases.
8	Waste management section	- Set-up of Independent waste management division. - Private sector involvements need to increase in phase. - Sustainable coordination with concerned stakeholders. - Updates on environmental sustainability of the system. - Regular updates of information and make it accessible.
9	Participation of the stakeholders	- Establishment of importance of public participation. - Formation of management committee by local people. - Development of social commitment to the individuals. - Development of environmental knowledge of people. - Formulation of regular basis awareness campaign. - Public voices should be respected by policy makers
10	Environmental watchdog	- Ensure Open and timely access to information - Regular meeting with the concerned authority - Select best wards, schools, hospitals, etc. for awards - Follow-up of the outcome of the recommendations

CONCLUSION

In solid waste management since there is no 'The Solution' or 'The Best Solution', the starting point to protect urban environment from MSW problems, is to consider the existing management system as the base for any further improvement. To bring the existing system into control, very close monitoring system should be adopted and fixed-up the target at an achievable level with the present capabilities of the city authority and the prevailing socio-economic setting of the community concerned. The functionality of all tiers should be considered based on the environmental sustainability. The present organizational set-up should be changed and an independent wing with proper authority having transparency and accountability to stakeholders should be set-up to materialize the target without any compromise. Commitment towards clean city through waste management should be developed within the community and the authority concerned and their participation and ownership to the system should be ensured at any cost. An environmental watchdog should be entrusted to monitor the performance regarding the achievement, improvement and the environmental sustainability of the adopted system. Finally, city authority must give actual attention for any positive changes of the existing MSW management.

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Do We Need to Recycle Organic Waste Materials?

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EXPOSITION

Biogenic waste materials produced in the EU, and therefore also in the FRG, show a considerable quantitative potential. According to conservative estimates this is approx. 1530 million tons of fresh matter. This would be equivalent to about 600 million tons of dry matter. An energy potential of about 180 billion m^3 methane gas i.e. 200 GW_{th} has been calculated from this.

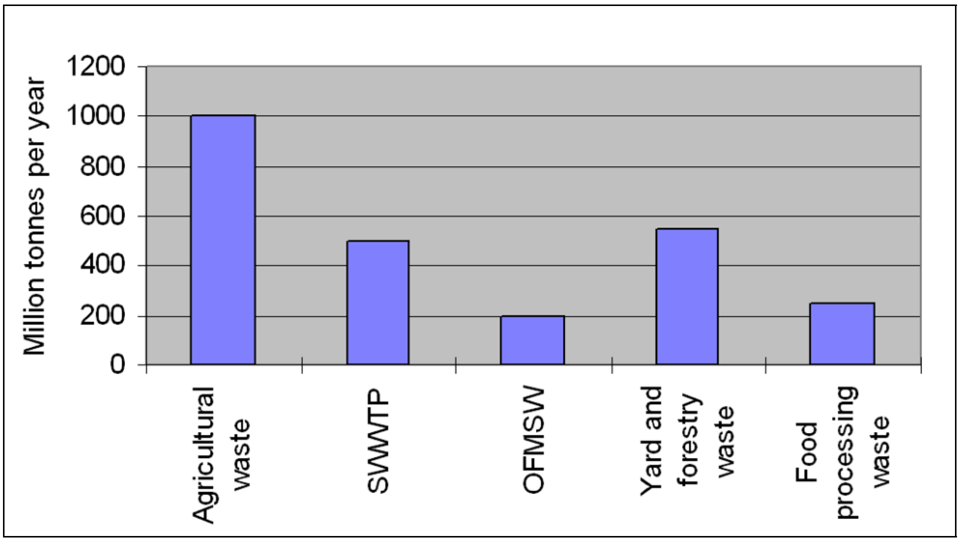

Figure 1 Annual production of biogenic waste in the EU

Organic waste not only has a considerable potential in renewable energy but is also a substitute for mineral and organic fertilisers or soil conditioners such as turf and therefore also a substitute for the energy used for recovering them as well as representing a substitution share for virtual water and in the reduction of desertification. Then again energy is also necessary to manufacture usable products from biogenic waste.

On the occasion of a trip to East Asia in 1909 Professor F. H. King wrote

Whilst the people of America and Europe each clear out about 5000 tons of Nitrogen, 2000 tons of potash and 1500 tons of phosphate per year into the seas, lakes, rivers or into the groundwater and consider it one of the greatest accomplishments of civilisation even today, the people of Asia far away to the East have avoided this enormous extravagance and since centuries, reverently taken care of the 1,158,000 tons of Nitrogen, 376,000 tons of potash and 150,000 tons of phosphate in the form of 182 million tons of excrement produced by 400 million people, by adding it to the soil.“

This statement was still true when I visited Shanghai in 1976. Faeces of 95% of the population in the city was collected in stone vessels or terracota urns and used as fertilisers for agriculture. 40,000 people were employed only for collecting faeces. When I last visited Shanghai in November 2002, I noticed that only 35% of the faeces was disposed in this manner. Human excrement had been substituted by mineral fertilisers.

So much to Prof. King. An outstanding feature of Asian plant cultivation, however, has always been an intensive compost management for sustaining soil structure and humus content.

Why do I quote this?

The present world population is about 6 billion. The distribution pattern and above all their provisions as well as the possible living standards however can vary considerably and are influenced by many different factors. Accessibility, relief, soil fertility, climate and weather conditions, availability and quality of water, the type and occurrence of natural material and energy resources and fertile soil determine the life of these people and what is more important - how they treat the fertile soil.

Fertile soil is a basic requirement if human beings are to produce enough food for themselves. This is mostly taken for granted by those that have no lack of food, which is of course a huge mistake. Land use for agriculture is jeopardised by different factors today. [5]

In order to answer the question in the title, it is important to reveal that the fertility of the soil is jeopardised, the factors that are affecting it and establish whether re-feeding the soil with organic materials is going to be a help.

Important factors that influence the fertility of the soil are:

- soil degradation and soil erosion
- wrong cultivation
- forest clearance
- acid rain and
- consequences of irrigation

The most serious problem, with which the farmers are confronted these days, is probably soil degradation and soil erosion which has increased by a factor of 1000. The effects of agriculture on the soil has reached a dramatic extent world-wide as is clearly shown in the table. It shows that about one third is lost due to wrong cultivation and overgrazing.

This is a succinct problem even in Europe. In fact 23% degradation places Europe right at the top of the list.

Unfortunately almost all forms of agriculture and increased soil degradation are connected. Even though soil erosion is a serious problem in the United States and many other industrialised countries, it is considerably more serious in the bordering countries.

The loss of soil material world wide is extremely critical as soil is a limited resource that cannot be substituted. The quantity and quality of the existing soil world wide, therefore, represents an important influencing factor for the quantity and quality of the food to be produced.

The spreading of arable land is one of the most important factors of global land use. Cultivated land has increased by 450% world wide in the past 300 years alone. A short term elution and degradation of the soil has often been the result of cut-and-burn. Likewise, extensive pasture farming can lead to desertification.

If such a loss of fertile soil is the case, the question is how food for a growing world population can be secured in the future and how the quality of our food can be guaranteed?

Table 1 Degraded soil surface world wide (in mio. hectares)

Region	**Overgrazing**	**deforestation**	**Wrong cultivation**	**other**	**total**	**Degraded percent of the whole area of vegetation (%)**
Asia	197	298	204	47	746	20 %
Africa	243	67	121	63	494	22 %
S. America	68	100	64	12	244	14 %
Europe	**50**	**84**	**64**	**22**	**220**	**23 %**
North and Central America	38	18	91	71	158	8 %
Australia, New Zealand, south Pacific	83	12	8	0	103	13 %
World wide	679	579	552	155	1965	17 %

NECESSITY OF ADDING ORGANIC MASS TO THE SOIL

Humus effect

Let us go back to the beginning. Re-feeding organic substances not needed by human beings, mostly in the form of compost, into the soil had guaranteed fertility for thousands of years in Asia.

When using organic fertilisers such as compost, a strict differentiation should be made between the direct effects of the nutrients contained in them and the indirect effects especially those of organic substances on plant growth. Ultimately, the soil improving effects make a considerable contribution to the success of compost fertilisation by improving the physical, chemical and biological soil properties of soil fertility.

Compared to other organic fertilisers (green manure, dung), compost is characterised by its content of easily degradable carbon compounds as these get mineralised to a large extent during composting. In addition to this the persistent components mostly get transformed to stable humic substance.

Tables 2 and 3 clearly show that the humus reproduction efficiency is significantly higher than that of other organic fertilisers.

In the course of time the structural and chemical properties of compost – humic substance and the original soil humus get aligned to a large extent.

The strongest limiting factor for plant growth is usually the water-air balance of the soil. This however does not hold for very mechanically contaminated soil in fields used for vegetable cultivation. High availability of nutrients and good root penetration, both pre-requirements for optimum nutrient utilisation by the plants is only possible in well aerated and well structured (relative density, pore volume, drainage capacity) soils that do not have the tendency to silt up. It was possible to record positive effects of compost fertilisation only after a few years with these soil characteristics (ref. table 4).

Table 2 Humus reproduction efficiency and quality of organic substance (C/N-ratio of different organic fertilisers)

Field crops/fertilisation	Effect of humus(t/ha)
Sugar beet (with leaves)	- 2.3
Sugar beet (without leaves)	- 1.9
potatoes	- 1.8
corn	- 1.4
cabbage	- 1.8
grain	- 0.7
mustard	+ 0.3
Ready made compost (20 t/ha)	+ 4.2

Table 3 Effects of bio-waste compost on humus content (4th test year; soil: loamy sand 17 % clay, 46 % silt; fertilisation: 2 x 510 kg N/ha in the form of bio-waste compost for each of 3 years)

Humus reproduction coefficient			
T Humus-C / t fertilisers-C		Relative (Kompost = 100)	C/N-ratio
Green manure	0,12 – 0,20	28 – 47	10 - 30
Straw	0,24	56	70 - 80
dung	0,35	81	12 - 15
compost	0,43	100	12 - 25
Fen peat	0,52	121	25

An important aspect of the fertility of soil is the capacity to store nutrients and make these available to the plants when required (sorption and cation exchange capacity). Besides clay minerals, organic substance is a significant sorption carrier and a increase in the cation exchange capacity can be noticed on increasing fertilisation with compost even in soils rich in clay. [3]

The soil improving effect of the organic substance in the compost is supplemented by the alkaline effect caused mostly by the high content of lime. The rise in the pH value which is often the case when fertilising with compost, effects both the nutrient and the pollutant availability.

Apart from natural and mineral substances, compost fertilizers also add humic substance to the soil which could create a favourable soil climate for plant growth.

Their main function is to raise the ion exchange capacity and with it the capacity to store nutrients as well as to stabilise the medium and coarse pores through which air and water are transported in addition to improving the water storage capacity.

The most important effects of humus on plant cultivation are:

- better workability
- less silting properties
- less susceptibility during longer periods of no precipitation or irrigation.

Table 4 application rates and soil properties

Soil properties	depth (cm)	Application rate (t compost fresh substance/year)			
		0	20	40	80
Organic substance in the soil (%)	0 – 150	4,95	5,69	6,02	7,60
Aggregate stability (%)	0 – 100	8,0	21,1	24,2	21,7
Seepage rate (mm/h)	-	89	255	296	219
Available soil moisture (Volume-%)	0 – 50	17,2	18,8	18,7	19,2

Content of plant nutrients

The future growth of food production depends on the availability of arable land. 4.9 billion hectares of land are at present being used for cultivation (approx. 37 % of total land on earth). Probably another 0.5 and 1.8 billion hectares of land could be made available for cultivation and agricultural purposes. Most of it is in Africa and South America. Most of this land is scraggy and more rain forests will have to be sacrificed. Through increased application of phosphate fertilisers, transforming more areas of land to cultivable land can be avoided.

About 3.3 Mio tons P_2O_5 in the form of phosphate fertilisers is being used by the EU countries at present in very competitive agriculture. More than half the food supply world wide depends on fertilisers including phosphate fertilisers. These are extracted from phosphate rock which is a finite naturally occurring raw material, extracted mainly in North America, North Africa, China and Russia.

Owing to the limited availability, phosphorous should be give special importance while considering a sustainable resource management. The availability of cadmium-poor phosphate is estimated at 100 to 150 years whereas the prognosis for the availability of cadmium-rich phosphate is another 400 years (DBU 1997, GOLDBACH & SCHERER 2000, BMU/BMVEL 2002). All life processes are essentially connected to phosphorous.

In the cultivation of plants too, the yield would be strongly limited without phosphate (WAGNER 1999). The scarcity of resources is a special point of focus because phosphate cannot be substituted. Municipal waste exhibit a substantial content of phosphorous and could therefore be categorised as a potential resource of phosphorous.

The composting and fermentation technology available in Germany covers a capacity of 12 million Mg/a. Of the 12.9 million potential bio-waste and green waste, 8,1 mg is collected and converted to compostthrough fermentation and composting. In the course of separating the pollutants, 8% of rotting feed of bio-waste and 5% of the green waste gets separated. Thus 3.7 million mg bio-waste and 3.8 mg green waste becomes available as compost raw material. The separated fraction which is rich in pollutants is dominated by woody components and the discharge of phosphorous is comparitively low.

Fig. 2 shows the areas in Germany where compost is applied. More than 95% of the compost products from bio-waste and other green waste (soft organics) are applied as fresh or ready made compost in horticulture and agriculture. Discharge of phosphate through seepage water, process water and condensate during the fermentation and composting process is negligibly low. All the phosphorous in the bio-waste and other green waste (soft organic) is therefore available through the recovery paths shown.

On the basis of the 5 million tons of fresh compost i.e. 3.2 million tons dry mass produced at present, the substitution potentials [1], which can be accomplished by the compost during fertilisation, are equivalent to the following quantities:

- Nitrogen (N) 39,520 t equivalent to 2.2 % of the requirement
- Phosphate (P_2O_5) 21,580 t equivalent to 7.7 % of the requirement
- Potassium (K_2O) 32,760 t equivalent to 6.7 % of the requirement
- Lime (CaO) 124,540 t equivalent to 5.9 % of the requirement

With that about 8% of basic fertilisation with P_2O_5 and K_2O as well as 6.5% of conservation liming can be substituted by the compost production (table). This is equivalent to the German performance balance of all regenerative energy (8%) with the generation of electricity (see Table 5).

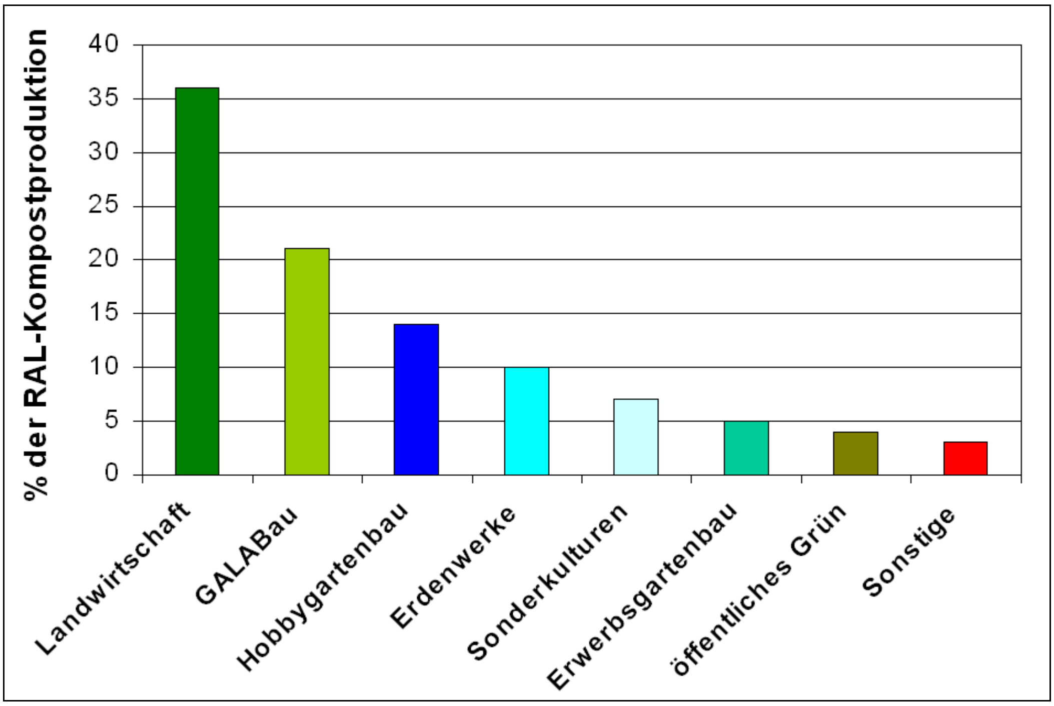

Figure 2 Compost application areas [2]

In addition to the bio-waste, other organic waste is also produced by agriculture and industry which could also be considered as substitute for phosphate. If all this is added together the picture depicted by table 6 is the result for FRG. The substitute amounts to about 110,000 Mg/a. 264,610 tons of P_2O_5 were used in the FRG in 2007. Organic waste therefore forms a substitution potential of about 42%. A consequent utilisation of organic waste in plant cultivation would place the performance balance of all renewable energy well above the aspired objectif of the EU of 20% for the year 2020.

Table 5 Consumption of mineral fertilisers in Germany und the substitution potential of compost

	Consumption of mineral fertilisers Nutrients in t/year	Production of compost Nutrients in t/year	Substitution performance of compost %
Nitrogen (N)	1,790,000	49,421	(2.8)
Phosphate (P_2O_5)	310,000	24,336	7.9
Potassium (K_2O)	510,000	40,435	7.9
Lime (CaO)	2.310,000	149,780	6.5

A development which can be continued world wide over many generations without impairing the ecological balance of the area and the society in their efficiency can be considered sustainable.

According to the Enquete Commission of the German Bundestag of 1994 „Protection of human beings and the environment“, following principles have been laid down:

- The utilisation of a resource should not exceed the rate of regeneration or the rate of substitution of its functions.
- The release of substances should not be larger than the capacity of the natural balance i.e. its assimilation capacity.
- Hazards and unjustifiable risks for humans and the environment through anthropogenic influences should be avoided.
- The measure of anthropogenic intervention in the environment should be in a balanced ratio to the time needed by the environment to react.

The demands on saving resources and the regeneration rate alone make the utilisation of material reasonable and necessary. With material utilisation a closed loop recycling management for plant nutrients can be built up.

Table 6 Available quantities of waste and the content of phosphorous in them in the FRG

Type of waste	Quantity of waste	Feeding and agricultural utilization		Quantity P	Quantity P_2O_5
	Mg FS	%	Mg	Mg	Mg
Bio-waste	8,872,600	42	3,735,365	6,425	14,649
Green waste (wood	1,600,000	80	1,280,000	717	1,634
Green waste (other)	2,400,000	95	2,280,000	3,466	7,902
Sewage sludge 2) 7)	10,800,000	55	5,940,000	31,185	71,102
food waste 3)	358,000	100	358,000	234	534
Animal meal 4)	422,361	0	0	0	0
Bone meal 4)	155,365	0	0	0	0
Animal fats 4)	306,781	0	0	0	0
Slaughterhouse waste	3,500,000	100	3,500,000	5,460	12,449
Wine pomace 1)	150,000	100	150,000	167	380
Yeast lees 1)	66,000	100	66,000	256	583
Apple pomace (wet) 5)	250,000	100	250,000	94	214
Malt residuum (hl) 6)	780,000	100	780,000	273	622
Bark 1)	3,750,000	70	2,625,000	945	2,155
Paper/cardboard 8)	18,000,000	1	127,800	96	219
Total	51,411,107		21,092,165	49,316	112,442

Of the total amount of energy consumed by the West German agricultural sector (412.3 PJ), 54.9% (228.8 PJ) can be allotted to direct energy input (electricity, fuel oil, power fuel, others) and 45.1% (159.7 PJ) to indirect input (fertilisers, other precursors). A long term comparison showed that the total energy consumption as well as the energy consumption per hectare in Germany has increased almost continuously.

It becomes obvious that 23% of the energy consumed by the German agricultural sector can be attributed to fertilisers alone. This is approximately equivalent to the use of fuel oil. The consumption of nitrogen itself is energetically equivalent to the consumption of power fuel in agriculture.

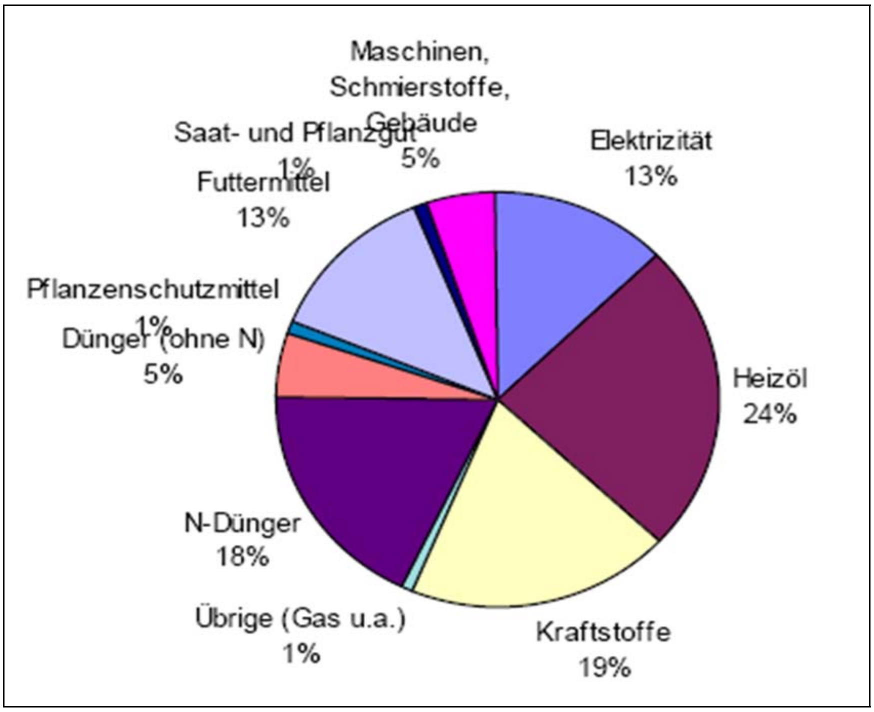

Figure 3 Total energy used by the German agricultural sector (ABL) 1990/91

CONCLUDING REMARKS

According to the survey of the expert advisory board, renewable energy sources contribute to about 8% of the energy supply in the FRG. 70% of this is covered by biomass in which 3.4% organic waste is also involved. Calculated on the basis of the total energy consumption this is only a marginal value of 0.27%. In spite of this the question of whether a energetic utilisation or a material utilisation of organic materials should be given preference is justified. If by referring to Germany, the energy equivalent of fertilisers is compared to the consumption of power fuel in agriculture, both can be put at the same level.

The question of whether material reclamation or energetic reclamation of organic waste should be preferred, can be answered very differently and depends on the regional conditions. Other aspects can be added to the energetic consideration such as:

- sustaining fertility and
- efficient utilisation of the resource water

Taking the whole world into consideration, the answer would be in favour of material reclamation in most cases!

Finally another aspect which supports a sustainable protection of agricultural soil and which appears to be urgently required needs mentioning – the aspect of applying organic waste as soil conditioners.

Two-thirds of the water lifted world wide is used for surface irrigation i.e. for producing bio-mass in the form of food, feed or wood.

One look at the food scene of the Swiss EWAG for 2025 shows that many regions will not be able to feed its people in a self-sustaining manner, owing to climatic reasons, scarcity of fertile soil or scarcity of water. Since approx. 1000 kg water is needed to produce one kilogramme of wheat but 4000 to 5000 kg of water is needed to produce 1 kg of meat, the direct production of vegetable food can be rated as more eco-efficient based on the water requirement. Apart from North America and Australia, even Germany and Central Europe will have to export substantial quantities of food to feed the increasing world population in the future.

Israel is already showing us how water scarcity can be balanced by importing water intensive goods (vegetable food, meat, milk etc.). An Israeli is already consuming more virtual water by importing these goods than the physical water that is being lifted for him in Israel.

Creating and participating in a world-wide water solidarity means e.g. for us in Germany, not so much as to save water but rather to ensure that fertile soil is sustained in order to increase food and feed production in the future.
Or expressing it differently: in regions rich in water a stop on sealing areas would contribute more to solving the world wide water problem than by saving drinking water. This would however mean that everything in one's power should be done to keep the soil fertile and organic fertilisers are necessary for this.

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The Mass Balance: A Support Tool for a Sustainable Landfill Management

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ABSTRACT

New concepts for the design and management of municipal solid waste landfills have recently been developed by the scientific community. Numerous options are now available for the reduction of long-term emissions of leachate and biogas into the environment, thus reducing the duration of the aftercare phase of landfills. The mass balance of pollutants in the landfill body is considered and the influence of different alternatives for the management of waste and landfill towards sustainability are discussed.

INTRODUCTION

Current regulations in Europe set in 30 years the duration of the aftercare phase of a municipal solid waste (MSW) landfill, after the end of the operations. However, the emissions after this period hardly meet the standards of acceptable quality for the environment. There is increasing recognition that time alone is an inadequate indicator of whether or not a landfill may be regarded as adequately stabilized (Fourie, 2003).

The need to reduce emissions below a certain limit within an established period of time is an ethical problem related to the concept of sustainability. It is not morally acceptable to leave to the following generation an inferior environmental state than the one left to us by our predecessors. Such a behaviour could cause unacceptable life conditions in a short time.

In this context, in the mid-eighties the term “final storage” was coined by Baccini, Henseler and other people from the Swiss working group about landfills (Eka, 1986). This term has step by step evolved until assuming in our days the meaning of a state of the waste in which the emissions are acceptable for the environment in the short term (1-10 years), in the medium term (10-100 years) and in the long term (100-10.000 years) (T. Sabbas et al., 1999). Acceptable impact means that the emissions from the landfill do not considerably affect the air, soil and groundwater quality. In other words, the emissions do not produce significant effect in the surrounding environment and the related risk can be considered negligible. Once this value of acceptable risk is set, the objective of the “Final Storage” can be defined. The legislator, assisted by the technician, will have the task of quantifying this acceptability threshold, in order to define the duration of the aftercare period.

The distinction of this new approach from the current one in the European Regulation is clear. In the decree, in order to determine the duration of the aftercare phase, a time-frame is defined, without taking into account the risk that will still be present after that time. On the contrary, in the sustainable management, acceptable emission limits for deciding the attainment of the conclusion of the aftercare phase has to be set (Figure 1).

A useful tool to study the emissions from a landfill in the long period is the mass balance. With this model it is possible to determine the effects of different alternatives for waste and landfill management, on the reductions of the emissions.

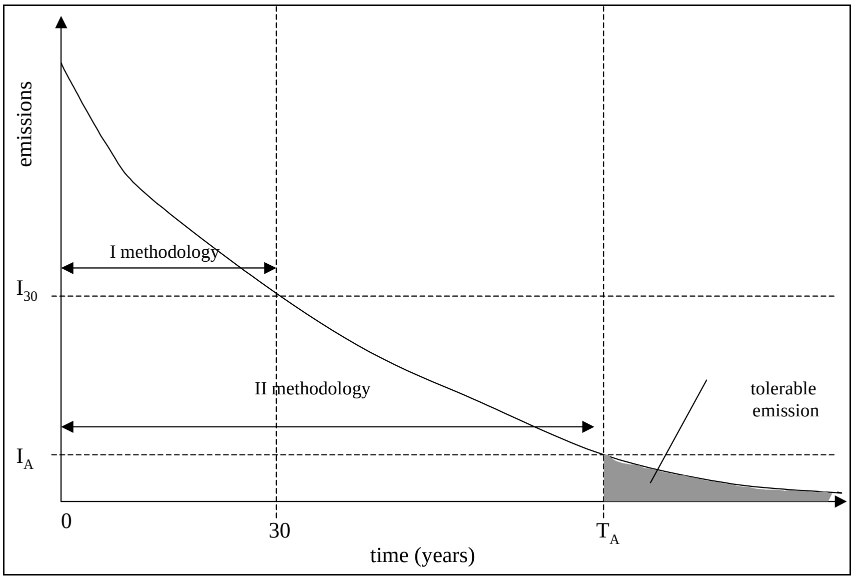

Figure 1 Comparison between the first methodology expressed by the European Regulation and the second methodology taken from the “Final Storage” concept. In the graph zero represents the end of landfill operations and the start of the aftercare phase

PRINCIPLE OF MASS BALANCE

The mass balance usually considers the fate of substances entering and leaving a system in various ways. The modelling approach to the mass balance tries to simplify the system with a Continuous Stirred Tank Reactor CSTR). CSTRs are also useful to describe more complex systems for which the assumption of a single CSTR is not acceptable. Such a system can be described by a distributed parameters model using a network of CSTRs with possible feedback. This is the case of a landfill with some sectors managed in different ways.

The basic assumption is that the concentration of a given substance in the volume V of the landfill is always uniformly distributed in the space. If a change in time of the concentration occurs instantaneously the new concentration is distributed all over the system. For this kind of system a parameter model of mass balance can be summarized as follows:

$$accumulation = input - output \pm reaction \tag{1}$$

Table 1 Average composition of the organic fraction in European MSW. (Stegmann, Ritzkowski,2008).

Lignin	6
Hemicellulose	7
Proteins	3
Paper additives	8
Cellulose	16
Hydrocarbons	9
Lipids, resins, waxes	2
Plastics	18

Varying quantities of organic compounds are present in waste, according to the different socio-economic and geographic contexts. For instance, in developing countries putrescibile organic compounds may represent up to 80% the total weight of waste, with a negligible presence of paper and plastic, whilst in European cities the rate of putrescibile organic compounds may be less than 20% with a high paper and plastic content. As a general rule the average quantity of carbon present in European wastes ranges from 20-25%, composed as illustrated in Table 1.

With regard to the mobility, two different types of organic fraction can be identified:
x_S = non-mobilisable solid fraction (non-soluble, non-degradable)
s_S = mobilisable solid fraction
During leaching and/or biodegradation or other reaction, the mobilisable solid fraction of carbon is transferred from the solid to the liquid (s_L = leachable fraction) or to the gas phase (s_G = gasified

fraction) or is transformed into non-mobilisable solid forms that contribute towards increasing the $x_{S.}$ fraction. The latter could apply to any other element, such as nitrogen or heavy metals.

Input in equation (1) represents the mass entering the volume from a variety of sources and different ways. If "*n*" streams of "*i*" waste components are considered with mass Q_i (t/year), each one with a different concentration in the solid phase, differentiated among the different forms (mobile s_{Si} and not mobile x_{Si} , expressed as mg/kg waste), the mathematical expression is:

$$Ingresso = \sum_{i=1}^{n} Q_i \cdot (x_{Si} + s_{Si})$$

Output in equation (1) is the mass leaving the landfill through biogas (q_G, m^3/y) and leachate (q_L, l/y) flows. If the concentrations of the contaminant in the biogas and in the leachate are respectively s_G (mg/l) and s_L (mg/m^3), the expression is:

$$Output = s_L \cdot q_L + s_G \cdot q_G$$

In order to distinguish between the fraction of leachate and biogas that are collected (q_{Lc} and q_{Gc}) and the fraction that migrates in a uncontrolled way through the barrier of the system (q_{Ld} and q_{Gd}) the following ca be written:

$$q_L = q_{Lc} + q_{Ld} \text{ and } q_G = q_{Gc} + q_{Gd}$$

The accumulation term, representing a mass increase (*m*) in the landfill over time (*t*), expressed as *dm/dt,* features a positive increasing during the landfilling of waste and is subsequently reduced to zero once the landfill has become exhausted.
Reaction term in equation (1) represents the mass of organic compounds that is mineralised or otherwise stabilised following the reactions of biological degradation or chemical-physical removal (precipitation, absorption, complexation, etc.) and can be expressed by means of a zero order or first order kinetic (r in mg/$m^3 \cdot$y):

$$Reaction = r \cdot V$$

Reactions may take place in an anaerobic environment (generally with formation of biogas) or under aerobic conditions with air influx and formation of oxidised gas. In an aerobic environment rates are indicatively one order higher than those detected in an anaerobic environment.
An description of the different input and output terms is given in Figure 2.
As a concept, a landfill reactor may be divided into three cascade reactors, one for each phase of life of the landfill. The reactor should be viewed as being constituted by a reactive part in which wastes are degraded and stabilised, and another in which the solid non-mobilisable fraction accumulates, as illustrated in Figure 3.

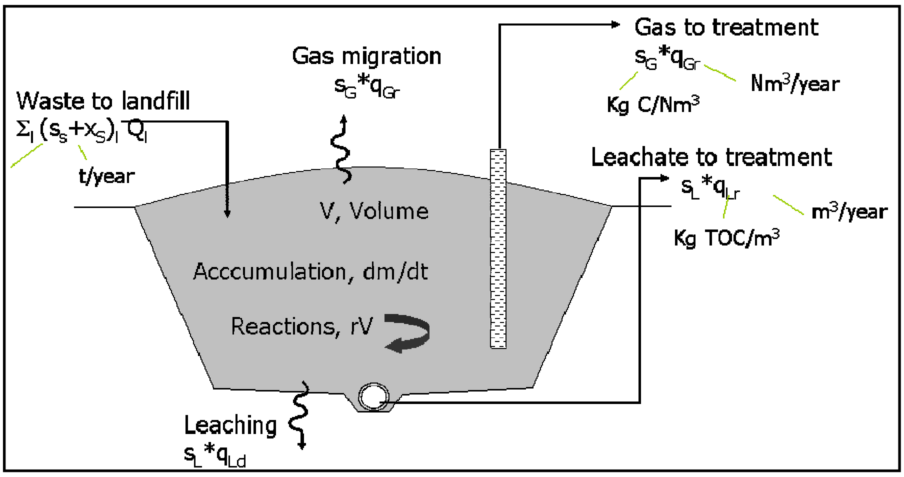

Figure 2 Schematic representation of the mass balance model in a landfill

Taking into account the reactive part of the reactor as described above, the balance may be expressed as follows:

$$\frac{dm}{dt} = \sum_{i=1}^{n} Q_i \cdot (x_{Si} + s_{Si}) - s_L \cdot q_L - s_G q_G - rV - s_S Q_S - \sum_{i=1}^{n} Q_i \cdot x_{Si} \qquad (2)$$

The term ($s_S\, Q_S$), where s_S is the residual concentration of mobilisable carbon in waste and Q_S is the residual quantity of waste, represents the residual amount of mobilisable carbon present in the waste and the carbon emission potential. Thus, as long as the emission potential remains high the landfill reactor should be protected by activating the physical barrier system represented by liners and drainage.

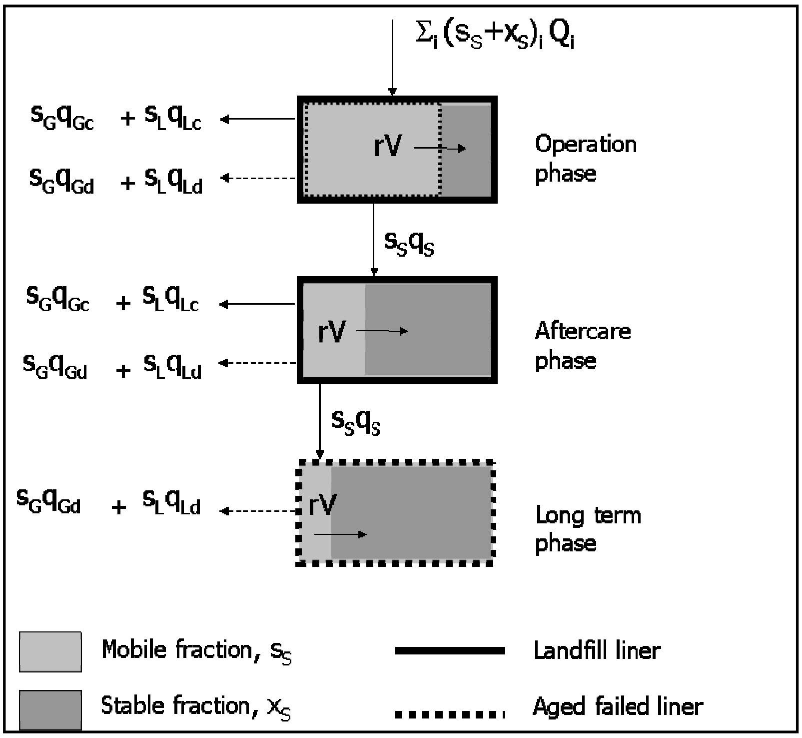

Figure 3 Diagram illustrating a landfill reactor in a series of cascade reactors corresponding to the various life phases of a landfill

More simply, by hypothesizing the achievement of stationary conditions, and taking into account the fact that the non-mobilisable of waste influx is not implicated in the reaction and by subdividing the emissions from the two fluxes mentioned previously (controlled emissions collected and emissions released in a controlled manner) the following may be stated:

$$0 = \sum_{i=1}^{n} Q_i \cdot s_{Si} - (s_{Lc} \cdot q_{Lc} + s_{Ld} \cdot q_{Ld}) - (s_{Gc}\, q_{Gc} + s_{Gd}\, q_{Gd}) - rV - s_S Q_S$$

Moving to the left the terms expressing an uncontrolled emission of leachate and biogas and the quantity of residual non-mobilisable compounds, i.e. terms that an environmental engineer should seek to minimise during the planning stage of a landfill, the following is obtained:

$$s_{Ld} \cdot q_{Ld} + s_{Gd} q_{Gd} + s_S Q_S = \sum_{i=1}^{n} Q_i \cdot s_{Si} - s_{Lc} \cdot q_{Lc} - s_{Gc} q_{Gc} - rV \qquad (3)$$

Assuming that in a sustainable landfill the residual degradable fraction ($s_S Q_S$) should be controlled and minimized and uncontrolled emissions should be avoided ($x_L \cdot q_{Ld}$ and $x_G \cdot q_{Gd}$), according to equation (3), this task can be achieved by means of :

- minimization of the amount of considered element introduced in the landfill ($\sum x_{Si} \cdot Q_i$);
- maximization of:

- biogas and leachate extraction ($x_L \cdot q_{Lr}$ and $x_G \cdot q_{Gr}$),
- mobilization of the extractable compounds and elements and fixation of what is not extracted;
- the reaction rate of degradable compounds.

Contrary to the general trend observed emphasising the need to minimise leachate production, the significance of water influx into the waste body, both as a reagent for biological degradation and flushing, on the equation for mass balance, should be underlined.

Minimisation of leachate production, at times resulting in the virtual suppression of the process by means of landfill surface capping may lead to a sort of mummification of waste, thus prolonging the potential emission of contaminants infinitely, in clear contrast with all criteria for a sustainable environment.

ACHIEVING SUSTAINABILITY BY MASS BALANCE CONTROL

The traditional technology for landfilling of raw waste causes anaerobic degradation processes to develop and persist in the waste mass, producing polluted leachate and biogas for a very long time. According to some Authors, the long-term environmental impact caused by MSW landfills may last for centuries (Kruempelbeck and Ehrig, 1999).

Liners might leak and drainage systems may clog and this in addition to the traditional impacts, such as the occurrence of odours, which invariably render landfill siting and public acceptance a problem. Accordingly, the sustainability of a landfill, whereby no environmental problems should be left to future generations, represents the main goal to be achieved by modern landfill strategies.

Many different options are available for reaching the target of the sustainable landfill. In Table 2 the influence of different alternatives for waste and landfill management on the main parameters in the mass balance is considered. The main options considered are waste minimization and pretreatment, leachate management (recirculation, flushing) and alternative landfill management as the in situ aeration. There is still much discussion concerning the extension of the pretreatment step which may involve mechanical, biological, thermal and physical-chemical (inertization) processes.

Mechanical pre-treatment such as shredding result in a positive influence on size reduction and on the acceleration of biochemical processes occurring in the landfill body and in the enhancement of the transfer of the biodegradables into the gas and liquid phase.

Biological treatment reduces the amount of readily available organics, enhances the waste degradation processes, moreover it increases the permeability of the waste mass and reduces (by giving rise to a methanogenic leachate) the clogging effect in the granular bed of the drainage system. However, in order to obtain a very well stabilized waste with very low emission potential, the biological pretreatment should last at least four months and this might be costlier than acceptable. A shorter biological treatment step might be coupled to the deposit into an aerated landfill, in order to have the stabilization process completed in situ.

Table 2 Influence of different options on the main parameters in the mass balance (**+** indicate a positive effect)

Option	X_{Si}	Q_i	x_L	q_{Lr}	x_G	q_{Gr}	dm/dt fix	dm/dt mob	rV
Mechanical pretreatment			+		+		+		+
Biological pretreatment	+								
Thermal pretreatment	++	++							
Waste minimization		+							
Leachate recirculation			+						+
Open landfill/flushing				++					+
In situ aeration						+	++		++
Anaerobic landfill			+		+		+		+

Thermal treatment dramatically reduces the amount of available organics as well as the amount of waste to be deposited; the leaching potential of incineration residues still has to be assessed, especially when deposited in combination with other waste; the real environmental significance of this kind of combined disposal should be further evaluated.

Leachate recirculation has a positive effect on the transfer of the contaminants into the liquid phase, moreover it provides an increase of moisture content and a better diffusion of substrate and nutrients in the whole landfill body and the degradation processes are thus enhanced. Flushing provides an enhancement of the degradation processes for the same reasons; moreover the mass of pollutants extracted with the liquid phase increases dramatically.

Aerobic conditions in the landfill body provide the acceleration of biological degradation processes in comparison to the traditional anaerobic landfill; the formation of non mobile compounds (humic substances) is enhanced as well. The maximization of carbon transfer into the gas phase is obtained by means of forced aeration and collection of exhaust gas.

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Impact of Climate Change on Indian Energy Sector and Clean Development Mechanism to Counter

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ABSTRACT

Economic development and poverty alleviation depend on securing affordable energy sources and Indian coal mining industry offers a bright future for the country's energy security. It examines the energy requirement perspective for India and demand of coal as the prime energy source. It is an irony that in-spite of having a plentiful reserve, India is not able to jack up coal production to meet its current and future demand. It discusses the strategies to be adopted for growth and meeting the coal demand. But such energy is very much concerned with environmental degradation. The paper highlights the emissions of greenhouse gases due to burning of fossil fuels. There is urgent need to adopt clean development mechanism of coal for meeting the energy security of India. It focuses the prospects of coal bed methane, underground coal gasification and coal liquidation to meet the energy demand in the foreseeable future. This paper highlights the Kyoto Protocol in limiting the emission of green house gases. It discusses on the formation of coal-bed methane and identifies CBM as a clean burning fuel. Its extraction not only reduces explosion hazards in underground mines but also reduces global warming. Underground coal gasification is a neglected option. There is urgent need to explore alternative methods for commercial extraction of those coal resources, which are currently not being mined through conventional mining. One solution is underground coal gasification (UCG). It discusses the benefits from UCG and Indian efforts in this regard. This paper emphasizes the need to develop clean coal technologies where coal can be refined in coal refineries to obtain different fractionated products having different quality –grade –class (QGC) of fuels. Liquefaction of coal affords liquid fuels from coal for further refining. The use of ultra clean coal in gas turbines directly will enhance the efficiency of power generation to 52-55% from the existing efficiency of pulverized coal power generation of 33 - 38%. Brute force high-pressure coal conversion processes will have to be replaced by the convenient and cost effective low atmospheric pressure processes through further research and development work.

INTRODUCTION

Clean development mechanism is the sustainable production and the creation of energy using processes and systems that are none polluting. Conservation of energy and natural resources is essential, which is economically efficient and safe for the workers, general communities and consumers. Sustainable consumption is the selection, use and disposal of products and services in a way that conserves energy and materials, minimizes the depletion of natural resources, avoids toxic and hazardous substances, and optimizes the quality of life of consumers throughout the life cycle of the products and services. Like sustainable production, sustainable consumption involves meeting present needs without compromising the capacity of future generations to do the same. As the economy grows, demand for the earth's natural resources accelerates drastically resulting in its depletion. Climate change and water stress are having a direct impact on business operations. Similarly issues around energy security and access to raw materials are affecting the competitiveness, as are the rising cost of waste disposal and pollution abatement. A paradigm shift is essential to deliver new products and services with lower environmental impacts across their life cycle. By 2015, China and India will account for 25% of world economy. The question is what sort of development is to be ensured?. Challenge for the present generation lies in de-linking economic growth and environmental degradation.

The requirement of primary energy sources is growing exponentially allover the world (Ghose 2002a). The global primary energy requirement has grown from 6700 MTOE (Million tonne oil equivalent) to 10200 MTOE over the last 25 years. There has been a very high positive growth in consumption of all kinds of primary energy sources e.g. oil, natural gas, nuclear energy, hydro electricity and coal (Anon 1988). Coal enjoys the main primary energy source status in Asia Pacific, which comprises the largest population, (Ghose 2004). The reserve-to-production (R/P) ratio in respect of major regions of the globe describes the life of different fossil fuels on earth on the basis of current level of production (Barney 1980). The fact remains that oil and gas have limited reserves to last 41 and 67 years respectively at current production level. In contrast, world has a coal reserve to last 190 years at the current production level. It follows that due to limited oil and gas resources, countries allover the world will have to depend on coal in foreseeable future for their primary energy requirement. Coal is widely available allover the world and is affordable. Its abundance, ease of storage and transportation and wide distribution over the globe determines a competitive international price.

The abundant reserves of coal spread almost allover the globe provides an energy security. Due to its low prices availability and transport ease, coal has become a popular choice as primary energy source in Asia-Pacific region that account for highest coal production and consumption in world. The industry has witnessed a comprehensive growth in production of coal in the last decade from the level of 257.8 Mt in 1994-95 to around 380 Mt in 2004-05 It is an irony that in-spite of having a plentiful reserves, India is not able to jack up coal production to meet its current and future demand. .A percentage of domestic coal demand is met by imports than for the other major fuels. The projected gap between demand and foreseeable domestic production capacities is on a rise. Such energy from coal is not environmentally friendly. The objective of this paper is to adopt clean development mechanisms of coal for meeting the energy security of India. It discusses cleaner energy production from coal. This paper discusses the production of coal with the use of most updated mine technology, recovery of coal bed methane, adaptation underground coal gasification process, clean coal technology.

INDIAN ENERGY PERSPECTIVE

India ranks sixth in the world in terms of energy demand accounting for 3.5 per cent of world commercial energy demand (Ghose 2003a). With a gross domestic product (GDP) growth of 8 percent set for the tenth five-year plan (2002-07), the energy demand is expected to grow at 5.2 percent. Although, the commercial energy consumption has grown rapidly over the last two decades, a large part of India's population does not have access to it (Ghose 2002b). . At 479 kg of oil equivalent (kg OE), the per capita energy consumption is also low when compared to some of the other developing countries, like Thailand (1,319 kg OE), Brazil (1,051 kg OE) and China (907 kg OE). Primary commercial energy demand grew almost three-fold at an annual rate of 6 per cent between 1981 and 2001, to reach 314.7 million tones of oil equivalent (MTOE). India's incremental energy demand for the next decade is projected to be among the highest in the world. India's commercial energy demand is expected to grow even more rapidly than in the past as it goes down the reform path in order to raise standards of living.

The all-India installed capacity of electric power generation under utilities was 115544.81 MW as on 31st January 2005 consisting of 80,201.45 MW of thermal, 30,135.23 MW of hydro, 2720 MW of nuclear, and 2488.13 of wind power. A capacity addition of 41,110 MW has been, targeted for the tenth plan. The projected requirement of commercial energy is estimated at about 412 MTOE and 554 MTOE respectively in 2007 and 2012 respectively. The commercial energy demand is estimated to grow at an average rate of 6.6 per cent and 6.1 per cent respectively during the period 2002-07 and 2007-12.

Coal as the Prime Energy Source for India

In India, an area of about 22400 square km is estimated to cover coal deposits below the earth's surface out of which 11000 square km has been regionally explored so far for mining. Out of this, an area of 5500 square km has been explored in detail for actual mining operations. The geological coal reserves of the country are estimated at 245.7 billion tones (Bt) as on January 2004. Out of this, proven reserves are 91.631 Bt while 116.174 Bt are indicated reserves and 37.9 Bt are inferred reserves (Anon 2003-2004). Globally, the coal accounts for 26% of the primary energy consumption, whereas in India, it has a share of 46%. In respect of generation of power, the share of coal on global basis is 36% and in Indian context it is 65% (Anon 2003-2004). Growth of Indian economy would lead automatically to growth in energy consumption. The dominant position of coal in energy consumption and electricity generation in Indian context is, thus, likely to continue for decades together because of a very comfortable proven reserves position of coal vis-a-vis the increasingly depleting reserves of oil and natural gas. The World Energy Outlook forecasts that India would face high demand of energy in future and coal alone can meet its needs. The industry has witnessed a comprehensive growth in production of coal in the last decade from the level of 257.8 Mt in 1994-95 to around 380 Mt in 2004-05. A far smaller percentage of domestic coal demand is met by imports than for the other major fuels.

Domestic Coal Demand and Supply

The projected demand for terminal year of the current year (2006-07) has been assessed at 460.50 Mt. This means a growth of about 109 Mt during current plan period as against around 60 Mt achieved during the previous two plan periods. The estimated capacity addition of coal based power generation during current plan period is 18300 MW as against actual capacity addition of about 7000 MW during ninth plan. Tentative projections for coal demands for the terminal years of eleventh plan (2011-12) and twelfth plan (2016-17) are 668 Mt and 816 Mt respectively. The projected gap between demand and foreseeable domestic production capacities is on a rise. It is an irony that in-spite of having a plentiful reserve, India is not able to jack up coal production to meet its current and future demand. Some of the reasons for this gap are:

- Gradual improvement in PLF of coal based power plants. Average PLF has increased from 70% (2001 -02) to 74% (2004-05) and every 1 % increment in PLF accounts for rise in domestic demand by 3.5 Mt per annum.
- Hardening up of international coal price and reduced global availability of coal resulting in lower imports.
- Over riding priority to power sector, thus reduced supply to other sectors.
- Captive blocks did not produce as planned.
- Coal Mine Nationalization Amendment Bill remains pending for parliamentary approval.
- Inspite of achieving the production target, domestic coal companies could achieve a growth of 5.4% and 6.5 % during last two years.

Coal India Ltd is the flagship state owned company that accounts for 86% of domestic coal production. It has been making sincere efforts to augment coal production by expanding its existing projects and opening up new projects in its command. But it is facing a lot of impediments, some of which are described here:

- delay in project approval because of multiplicity of approval points in the government.
- delay in handing over clear possession of land.
- law & order problems in coal belts, e.g. militancy, theft, illegal mining, extortion, cartel formation etc.
- resistance to out-sourcing
- issues related with Rehabilitation & Resettlement.
- fund constraints & industrial sickness of ECL & BCCL.
- transport bottlenecks -wagon availability & placement.
- impediments in procurement of HEMM spares due to purchase preference, litigations etc.

Strategies for Growth and Meeting the Coal Demand

Coal India has drawn up the long term vision and production plans to meet a major portion of growing demand for coal considering available geological reserves vis-a-vis technical feasibility of excavation / extraction based on available global technology, coal production programme in different 'Plan Periods' has been worked out . Besides mining coal through conventional technology, avenues of harnessing CBM and in-situ gasification of coal from inaccessible deposits have been considered. Further, alternative of augmenting coking coal either through acquiring overseas equity in coking coal property abroad or direct import has been considered to bridge the gap of domestic demand on coking coal.

Of the total energy consumption of approx 360 million tonnes of oil equivalent (MTOE) in the country, an estimated 35 percent is obtained from traditional sources (fuel wood, agricultural waste, animal dung etc.) and other 65 percent, termed as commercial energy, is obtained from coal, oil, gas hydel, nuclear and renewable sources (Abbasi and Ramesh 2002). The share of various energy sources in the primary commercial energy consumption of the country in 1997-98 was as follows:

Coal and lignite 56%; Petroleum 32%; Natural gas, 8%; Hydel 3% and Nuclear and renewable 1%. Coal and lignite are mostly used in power stations (75%), steel plants (6.2%), cement plants (3.6%), and other industries and brick making plants (15.2%). Petroleum and natural gas are mostly used for the transportation sector although significant amounts are used in oil and gas fired power stations, fertilizer plants, other industries and in the domestic sector for cooking and lighting.

Electricity is the preferred form of energy for use by the industry and is a crucial requirement for the expansion of the industrial and agricultural sectors. Of the installed generating capacity of 105000 MW in the 2001-02, major share was thermal (71%), followed by hydel (25%) and the remaining 4% on nuclear and renewable. The bulk of the power generated comes from coal and lignite fired power stations. The demand for the coal by the power sector has been estimated as 317 million ton in 2006-07 and 469 million ton in 2011-12.

The bulk of Indian coal reserves are of inferior grade (E and F grade) and the power stations are designed to burn such high ash coals. Currently some 60 percent of Coal India Limited (CIL) production is of inferior grade and by 2011-12 this figure is expected to go up (69%). As per a 1997 amendment of the Environment Protection Rules 1986, power stations located over 1000km away from the pits heads or in urban areas with critical air pollution concerns have to use beneficiated coal having an ash content not exceeding 34 percent.

Since coal will continue to remain the principal source of commercial energy in the country for the foreseeable future, all out efforts are needed for rapid development of coal sector. A substantial expansion in domestic coal production will be needed if the power sector is to expand to support the targeted 8 per cent GDP growth. Since the gestation period of a coalmine is considerably longer than that of power plants, planning for coal production should be done with a long vision. The existing coal distribution within the country may remain to be plagued with coal mafia as long as shortage of coal vis-a-vis demand exists. Therefore, there is need to bring about quantum jump in domestic coal production so that plenty of coal is available for domestic consumption. Following strategies will have to be worked out to boost up domestic production at competitive cost and quality with due regard to social issues.

GREENHOUSE GASES AND CONCERN OVER GLOBAL WARMING

The atmosphere is stratified on the basis of the temperature/density relationship resulting from interactions between physical and photochemical processes in air (Manahan 1999)..The average surface temperature is maintained relatively comfortable 15^0C because of an atmospheric greenhouse effect in which water vapor, CO_2 reabsorb much of the outgoing radiation and reradiate about half of it back to the surface. Were this not the case, the surface temperature would be around -18^0C Most models predict global warming at least $3\text{-}5.5^0$C occurring over a period of just few decades (Baurn1999). Such warming have profound effects on rainfall, plant growth, and sea levels, which might rise as much as much as 0.5-1.5 meters Severe draught conditions resulting from climatic warming could cut down substantially on CO_2 uptake by plants. Warmer conditions would accelerate release of both CO_2 and CH_4 by microbiological biodegradation of organic matter (Anon 1976). The plant and animal pests-insects, and rodents would thrive much better in warmer conditions. Interestingly, acid-rain forming SO_2 may have a counteracting effect on greenhouse gases (Zeller et.al 1999).

It has become quite concerned about the possibility of significant changes in global climate, especially because of potential effects on the frequency of the damaging storms (Hileman1997). International concern over global warming led to a meeting of 160 nations in Kyoto in December 1997. It has been proposed by US stabilizing emissions of greenhouse gases to 1990 levels during the period 2008-2012.

GOVERNMENT AND CORPORATE STRATEGIC ACTIONS

The government has already initiated a number of strategic actions to bring in institutional reforms and private participation in coal sector. However, following strategic actions can further be mooted to provide fillip for development of coal sector:

- Government to pursue amendment of Coal Mines Nationalization Act
- Government to allow captive mine owners to sell excess coal production through CIL.
- Coal India to facilitate transfer of surplus coal from captive mines to the coal companies at a price to be decided by a committee.
- Government should prioritize allocation of blocks, sector-wise.
- Sub-leasing some of the CIL blocks to private parties for coal production and overburden removal
- Exemptions from the provisions u/s 10 of Contract Labour (Regulation & Abolition) Act 1970 to ease out outsourcing.

- Towards new projects. the government will have to develop mechanism for single window approval of projects and fast track clearances of EMPs & forestry. The government will also have to bring enactment of legislation for land acquisition rights and uniform R&R policy for coal sector. Forest Conservation Act and other outdated acts also need to be reviewed in the light of need for rapid expansion of coal sector.
- Government to facilitate group captive mining joint venture consortium for promoting captive mining
- CMPDIL should expedite exploration of more blocks.
- For timely project approval coal companies should advance the initial actions for sanction of project through different stages.
- Wage board job definitions need to be changed to allow and foster multi-skilling.
- Powers of the boards & CEOs of the coal companies need to be enhanced to speed up decisions.

Mine Technology

Since bulk of coal production at lower cost will come from opencast mines, the opencast technology has to be consolidated.(Ghose and Majee 2000) Higher size coal projects employing high capacity equipment will need to be opened up for higher productivity (Ghose 1986; Srivastava 1987). The obsolete equipment working In existing mines could be replaced by higher capacity state- of- the art technology equipment to reduce operating costs. Full Maintenance contracts with OEMs will prove to be a prudent proposition to ensure higher availability and low downtime of equipment. In large mines employing large fleet of equipment, the operations must be directed and controlled by the G PS based networked software system. All such actions for improving effectiveness of opencast technology need to be guided by the international benchmarks.

The present mix of manual, semi-mechanized and mechanized u/g mines yielding low productivity needs to change in favor of 100% mechanized mines (Kundu and Ghose 1998a). Options for higher rate production technologies such as powered support long wall; continuous miners must be explored where geo- technical characteristics permit so. Where possible, special methods like blasting gallery, sublevel caving and short wall mining with powered support for extracting developed pillars should be introduced. As mechanization in u/g mines is brought in place, the u/g transport systems would also have to be rationalized to keep pace with - enhanced production (Kundu and Ghose 1994; 1998b). One of the major drawbacks in u/g equipment is that there is r dearth of indigenous manufacturers of u/g equipment. The indigenous mining equipment manufacturers could be encouraged to manufacture such equipment if u/g mechanization increases at a steady rate. The u/g coal mines also need to employ coal preparation machines at face and phasing out of blasting off the solids.

As the domestic coal production will increase in future by leaps and bounds, proliferating opencast mining activities will require a number of social issues to be addressed systematically with a sincere. Approach to be adopted by the coal companies (Banerjee 2004)

Impact of Greenhouse Gas Emission

Greenhouse gas emission and climate change is perhaps the most important environmental challenge facing by mankind today. A 2001 report by the Intergovernmental Panel on Climate Change (IPCC) shows that world temperature has been increased by 0.6°C during the last century (IPCC, 2001) . Computer model studies with business as usual scenarios indicate an estimated temperature increase varying from 2 to 3.5°C during the 21st century (Baurn, 1999). The consequences of such an increase in average global temperatures within 100 years would be disastrous. The IPCC estimates a sea level rise of 65 cm by the year 2100 putting millions of people and million square kilometers of land at risk of submergence. (WECED,1987). Stretches of low lying areas will submerge and about sixty odd island countries shall face deep encroachment by sea water and some may disappear (Doyle, 2007).

Changes in surface temperatures have profound effects on the water cycle and regional precipitation, evaporation and storm patterns. However, the subject is extremely complicated and the various remedies are being suggested. As the increase in temperature will not be uniform all over the surface of world, because the polar regions will undergo ten to twelve times more increase than the tropics, this will bring various changes in wind pattern, precipitation pattern within a country. So some fertile region may change into desert. Higher temperature will cause rise in evapotranspiration, which in turn affect the ground water table. As the climatic belts shift from equator towards pole, it is the general trend that the vegetation also should shift to stay in a favorable condition. In this phenomenon many plant species would die and these will be losses of genetic resources. Insects and pests will increase as warmer conditions could be more favorable to their growth, thus pathogenic disease will multiply. Kyoto Protocol of 1997 has brought to the surface sharp differences in approach to the problem amongst major industrialized countries (Anon, 1997).

The main environmental problems of developing countries stem from poverty and hunger and the solution is more development and not less. With this philosophy, the rich countries were asked to take time bound steps to curb the GHG emissions but no quantitative limits were put on the developing countries. However, some of the developing countries have large populations and are progressing fast on the path of industrial development. China and India accounted for only 7.6 per cent of the world primary energy consumption in 1980 but their share has gone up to 14.1per cent by the year 2003. The per capita CO_2 emissions from fossil fuel use in China and India, even after the rapid growth of their energy sector during the previous decade, much lower at 2.76 and 1.16 tonnes respectively in 2002 compared to the world average per capita v are alue of 3.9 tonnes .USA, the top emitter of GHGs in the world, has been reluctant to use strong measures to curb GHG emissions as it thinks the resultant increase in energy cost would make its economy less competitive. USA has refused to ratify the Kyoto Protocol (although it took active part in its formulation) citing that important developing countries such as China and India, have been left out of the requirement of time bound reduction commitments.

Kyoto Protocol for Control of Greenhouse Gases

At the 1992 Rio Climate Change Convention as well as at the subsequent Conference of Parties (CoP) meetings, the developing countries took the stand that their per capita GHG emission was much lower than that of the developed countries and they need energy at a reasonable cost for quick economic development and hence cannot afford measures for control of GHG emission. However, there is a tendency to s global tretch this argument of equitable emission rights too far. The share of the developing countries in CO_2 emission is increasing fast and some estimates put that by the year 2030, the emission from the developing countries may equal that of the developed world. Already China is the second largest primary energy consumer of the world with 11% of world energy consumption (Inman, 2008)

The Kyoto Protocol was negotiated at the 3rd COP meeting in 1997and has come into force on 16th February, 2005. The Protocol sets binding obligations on the industrialized developed countries to reduce their GHG emissions by at least 5 per cent below 1990 levels by the year 2012. No such binding quantitative restrictions were put on the developing countries. The emission of CO_2, the principal GHG, is strongly related to the use of fossil fuels, especially coal, for energy production. The projections of global primary energy supply with assumption of a modest economic and population growth rate show that carbon emission is likely to increase by 67 per cent by the year 2050 (IPCC,1990). A long term projection for the Indian energy sector up to the year 2031-32 show that CO_2 emission from India is likely to increase much faster to 3.5 times the present value in the next 25 years.

Article 25(1) of Kyoto Protocol states that the "Protocol shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Parties , which accounted in total for at least 55 per cent of the total carbon dioxide emissions for 1990 of the Parties The two largest emitting countries, Russia and USA, accounted for 53 per cent of the global emissions in 1990, and hence unless both these countries, and at least one of them ratified, the Protocol could not come into force. After many years of negotiation, Russia informed the U.N. about its ratification of the treaty on November 18, 2004 and thus the Kyoto Protocol has come into force with effect from February 16, 2005, i.e. after nearly seven and half years of its adoption. The largest GHG emitting country of the world, namely USA accounting for 24 per cent of the global emissions from fossil fuel use and with a per capita value of 20.1 tonnes in 2002 has not yet ratified the Kyoto Protocol (EIA, 2007). According to a recent US EPA report "Inventory of US GHG Emissions and Sinks:1990-2004" the GHG emissions in the US grew by 15.8 per cent from 1990 to 2004(USEPA, 2008). Under US leadership, an Asia-Pacific.Partnership on Clean Development and Climate has been set up with China, India, Japan, South Korea and Australia as the other members with the aim of creating a "voluntary non-legally binding framework" for international cooperation on the transfer of technologies that help to reduce GRG emissions. The first ministerial meeting of the Partnership was held in Sydney on January 11-12, 2006. The European Community has taken the leadership in implementation of Kyoto Protocol and a 2005 UNFCCC report of GHG emissions from countries show that whereas emissions from USA, Canada, Australia and Japan have increased in the period 1990-2003, in case of the European Community, the GHG emissions have come down slightly from that of the 1990 level. The CO_2 emission in Mt from fossil fuel use and estimate of per capita emission in tones for the year 2002 for 51 selected countries representing 93 per cent of global emissions and 78 per cent of population are given in Table 2.

The Kyoto Protocol (Anon, 1997) signatories agreed to reduce GHG focusing on expect its emissions by enhancement of efficiency in production, distribution and consumption of energy. U.N. Framework Convention on Climate Change (UNFCCC) was adopted in New York in May 1992 and signed at the Rio Summit in June 1992(UNFCC, 1992). India ratified the UNFCCC in November 1993, and after ratification by sufficient number of countries, the convention came into force from 21st March 1994 The main objective of UNFCCC is stabilization of greenhouse gas (GHG) concentrations UNFCCC established a Conference of Parties (COP) as the supreme body of the convention At the first CoP meeting, the developed country parties agreed to start negotiations to arrive at quantitative CO_2 emission ceilings within specified time frames of 10-15 or 20 years (IPCC, 2007).

Coal Bed Methane (CBM)

The CBM industry is basically an outgrowth of petroleum industry. Methane is a powerful greenhouse gas, as its adverse impacts are felt more intensely due to its shorter residence and higher potency in the atmosphere than carbon dioxide. Methane is associated with coal as a byproduct of the coal formation process. It is trapped in coal beds and released during and after mining. This methane does cause disasters in underground coalmines. If effectively recovered, coal bed methane associated with coal reserves and emitted during coal mining could be a significant potential source of energy. It is well known that coal is framed due to bio conversion of fossilized organic matter, In the process of coal formation, anaerobic conditions led to generation and trapping of methane in this coal seams. The pressure exerted by naturally formed water keeps the methane" absorbed" on internal surfaces of coal. Thus, coal bed gas is in monomolecular state and not as free gas, as in natural oil/gas fields. Therefore, all coalfields of the world have coal bed methane, the only difference being the quantity of gas in individual coal seams. Porosity plays an important role in building up methane gas reserves in the coal bed. Unlike the conventional reservoirs, in coal the methane is not compressed in the pore space (porosity) but physically attached to the coal at molecular level (micro porosity). Micro porosity makes up about 70 percent of the total porosity in coal bed and is equivalent to a conventional reservoir having 20 percent porosity, saturated with 100 percent gas. On account of this difference, coal has higher gas storage capacity than sands containing petroleum gas.

Generally well-practiced CBM technology involves drilling of wells down to target seam/zone. Desorption, diffusion and production of methane are accomplished with the reduction in reservoir pressure by dewatering of coal seam. Generally a CBM well yields high water and low gas in the early stages. Within 2-3 years water flow decreases and gas flow increases substantially. In general producibility of CBM prospects is largely dependant on gas content and saturation and permeability of coal. Other factors related to production include coal thickness, rank, pattern of cleat, fracture density, depth of coal seam and hydrostatic pressure. Further to ensure effective communication between coal fractures and well bore the coal seams are usually hydraulically fractured. The fractured coal provides a flow path into the well bore for water and gas. This broad framework of CBM exploration technology however needs to be fine tuned in different CBM prospects as Gondwana coal seam reservoirs exhibit significant heterogeneity of character and do not conform to any simple model of CBM play (Mitra, 2005).

Thus in early exploration stage the operators are confronted with the problems related to inadequacy of knowledge on reservoir parameters, lack of appreciation of hydrogeological behaviour of coal basin and erratic pattern of under saturation of gas in coal seams etc. Remedial measures are being taken but operators confronted with technological problems look for solutions elsewhere which sometimes are not forthcoming. As a result the speed of CBM operation suffers and proper message on CBM development does not pass to energy planners

To delineate potential CBM prospects in coal and lignite basins of the country emphasis was primarily laid on coal basins which are historically well known for the occurrence of high rank, gassy coal seams, generally a CBM well yields high water and low gas in the early stages. Within 2-3 years water flow decreases and gas flow increases substantially. In general producibility of CBM prospects is largely dependant on gas content and saturation and permeability of coal. Other factors related to production include coal thickness, rank, pattern of cleat, fracture density, depth of coal seam and hydrostatic pressure. Further to ensure effective communication between coal fractures and well bore the coal seams are usually hydraulically fractured. The fractured coal provides a flow path into the well bore for water and gas. This broad framework of CBM exploration technology however needs to be fine tuned in different CBM prospects as Gondwana coal seam reservoirs exhibit significant heterogeneity of character and do not conform to any simple model of CBM play (Mitra, 2005). Thus in early exploration stage the operators are confronted with the problems related to inadequacy of knowledge on reservoir parameters, lack of appreciation of hydrogeological behaviour of coal basin and erratic pattern of under saturation of gas in coal seams etc.

The generation of methane gas results from high temperature and pressure due to continuous burial. During the transformation process, coal becomes rich in carbon and large amount of fluid matter is released like methane, carbon dioxide and water. Such generation of fluid is significant in bituminous and higher rank coal with maximum yield of 150-200 cm^3per gram of coal. Indian's coals have gas content values ranging from 1 to 23m3/tonne. The existence of gas in coal has been known for many decades. It is only in the last decade and a half that this gas has emerged as a viable energy source with coal as both source and reservoir rocks. In USA, the CBM exploration was first initiated and an energy resource has also been recognized. By 1995, USA has produced about2.5 Bcfd (billion cubic feet per day) of CBM from 9000 wells, which is about 5 percent of the total gas consumption of USA. In CBM exploration, China is emerging as a major player and Australia is on the threshold of commercial production (http://www.cpcb.nic.in).

Prospects of CBM

Coal-bed methane (CBM) is a clean burning fuel for domestic and industrial uses, and its extraction reduces explosion hazards in underground coal mines. India is endowed with huge reserves of bituminous coal of Paleozoic and Tertiary ages within the CBM window at depths of nearly 250-1200 meters Lack of data on producible reserves of CBM, gas content, reservoir saturation and permeability has prevented full exploitation of the resource. India wants foreign and domestic private companies for the exploration and commercial exploitation of CBM resources at some of the underground coal mines. Contracts that will be awarded will be similar to the "concession" concept in oil and gas exploration. Coal-bearing areas will be leased to the successful bidders and they will have to explore and test-drill. If recovery and commercial exploitation of the CBM gas in these areas ultimately prove viable, the exploring firms will be free to construct pipelines and sell the gas to consumers or they may set up gas-based power plants.

UNITED States and Canada have been exploring methane obtained from coal beds (‘coal bed methane’) since the early 1970s and 1980s, respectively. Production of coal bed methane for domestic energy needs has grown significantly only in USA. Other coal-producing countries like Australia, China, Russia, Germany, Great Britain, Poland, etc. including India too have paid attention to the exploration of this new resource (now being considered as an economically viable unconventional source of energy) and have initiated several research programmes on different aspects of coal bed methane. In fact, irrespective of their maturity (rank), organic composition, or nature of occurrence, all coals contain gases, with methane usually as the main constituent (90–97%). However, deep-seated seams (depth around 1000 m or more) containing coal of higher rank (carbon content > 83.5%, R_0 max 0.7% and above) are considered most suitable for commercial extraction of methane. The global coal bed methane reserves are presumed to be several times greater than the total reserves of all the known conventional gas fields.

Around 1969, gas hydrate deposits were first discovered in Russia (Siberian gas fields). As a result, interest in methane from sea floor (‘hydrate’) began. Natural occurrence of methane hydrate was noticed in other regions of oceanic and terrestrial environments by the 1970s. The encouraging results from discoveries at Blake Ridge (USA) opened up new vistas to consider gas hydrates as a potential source of energy for the future. Currently, countries like Mexico, Japan and India have launched national projects for the exploration of methane hydrate, the most abundant carbon fuel resource. Conditions of extreme high pressures and cold temperatures favour accumulation of methane hydrates in deep ocean floor sediments, especially along continental margins. It is believed that methane hydrate reserves could possibly hold more fossil fuel energy than is present in conventional oil, gas and coal deposits.

To increase the safety and productivity of coal mines by capture and recovery of methane from being present in mine environment and to prevent the release of methane from coal mines to atmosphere thereby controlling release of a potential green house gas and checking global warming and to provide increased employment opportunities, direct and indirect in the area where such an exploitation and utilization of methane takes place.

Exploration and Recovery Status of CBM in India

For identification of potential coal-bed methane area studies for delineation of blocks for prospecting / exploitation of Coal bed Methane (CBM) have been carried out for Jharia, Raniganj, East Bokaro, West Bokaro, North Karanpura and Sohagpur coalfields by Central Mine Planning & Design Institute Ltd.(CMPDI) at the instance of Ministry of Coal and Directorate General of Hydrocarbons (Ministry of Petroleum & Natural Gas). Each of the above coalfields has been divided into two categories in regards to prospecting / exploitation of CBM as given below:

A. For "YES AREA "

Coalfield	Area (Sq.km)	Coal Reserves (in Billion tonnes)
Jharia	65.31	6.06
Raniganj	232.40	4.31
East Bokaro	62.50	2.62
West Bokaro	35.67	1.07
North Karanpura	340.54	8.52
Sohagpur	1188.00	10.69
Total	1924.42	33.27

(Reserves considered are in coal seams having thickness more than three meters)

B. For "MAY BE AREA"

Coalfield	Area (Sq.km)	Coal Reserves (in Billion tonnes)
Jharia	21.55	1.24
Raniganj	4.1	
East Bokaro	22.63	1.64
West Bokaro	18.20	0.52
Sohagpur	27.90	0.43
Total	94.38	3.83

(Reserves considered are in coal seams having thickness more than three meters)

C. Total Area (Yes & May be Area)

Coalfield	Area (Sq.km)	Coal Reserves (in Billion tonnes)
Jharia	86.86	7.3
Raniganj	236.50	4.31
East Bokaro	85.13	4.26
West Bokaro	53.87	1.59
North Karanpura	340.54	8.52
Sohagpur	1,215.9	11.12
Total	2,018.8	37.31

(Reserves considered are in coal seams having thickness more than three meters)

II. Coal bed Methane Recovery & Commercial Utilization Project

In order to control methane emission related to coal mining activity, Department of Coal, Ministry of Mines and Minerals, Govt. of India, in collaboration with Global Environment Facility (GEF) / United Nations Development Programme (UNDP) have taken up Demonstration Project to recover Methane during mining and use recovered methane for

- Power Generation
- As fuel (CNG) for Dump Trucks

CMPDI on behalf of Govt. of India is the main local implementing agency.

Objective of the Project

- to harness methane which poses safety problems in mines and if released in normal way during mining, is loss of energy resource and also causes damage to atmosphere.
- to bring to the country through technology transfer state-of art methodology for resource assessment and recovery techniques with due regard to the Indian conditions.
- to demonstrate utilisation of the recovered methane.

Project Sites

- Moonidih Mine and Sudamdih Mine of Bharat Coking Coal Limited (BCCL) in Jharia Coalfield, Bihar, India

III. **Exploration / Development of CBM by CMPDI**

CMPDI on behalf of CIL proposes to explore/develop coalbed methane resources. For this purpose, North Raniganj Block in the Raniganj coalfield is proposed to be taken up with ONGC as Joint Venture partner. CIL has also taken up with Dept. of Coal, Ministry of Mines and Minerals, Govt. of India, for release of Bokaro Block on nomination basis for exploration and development of Coal bed Methane. The general characteristics of coal deposits in the above named two blocks are tabulated below:

Coalfield	State	Name of the delineated block for CBM	Area of block (Sq.Km.)	Coal Charecteristics				Available coal resource (B.tonne)	Depth range (m)
				Vitrinite%	Ro%	UVM% (dmf)	Carbon % (dmf)		
Raniganj	West Bengal	North Raniganj	232.00	40-60	0.85-1.15	25-36	86-89	4.31	300-1000
East Bokaro	Bihar	Bokaro	62.50	45-65	0.80-1.24	21-37	85-90	3.15	300-1200
West Bokaro	Bihar		35.67	35-60	0.80-1.20	21-37	84-90	1.3	Upto 1000

Request for Expressions of Interest for Consulting Services for Development of Coalbed Methane in Permian coal deposits of Eastern India (Raniganj, East and West Bokaro Coalfields) in the states of West Bengal / Bihar.

Coal India Limited (CIL), a Government of India enterprise, contributing 88% of the country's annual hard coal production, wishes to take up development of coalbed methane in the Permian bituminous coal deposits of Eastern India in the states of Bihar / West Bengal.

Central Mine Planning & Design Institute (CMPDI) a subsidiary of Coal India Ltd (CIL) requests for expression of interest from qualified consultants/consultancy firms of international repute for assisting CIL in development of coalbed methane prospects in the Permian bituminous coal deposits of Eastern India in the states of Bihar / West Bengal.

Scope of Services

The scope of services being requested through this expression of interest from experienced Consultants / Consultancy Firms are to assist in :

- evaluation of available data.
- formulation of the Work plan up to Pilot Scale Assessment to estimate likely quantity & quality of gas-in-place.
- implementation of the agreed work plan.
- evaluation of data generated through pilot scale assessment including reservoir characteristics and resource modelling.
- preparation of a report based on the above, clearly bringing out the prospects of exploitation of coalbed methane on commercial scale.

Interested consultants must provide information along with appropriate documentary evidences indicating that they are qualified to perform above services (details about the organisation, financial details including turn over for the last three years, details of similar assignment successfully executed during the last five years, experience in similar condition, availability of appropriate skilled resources, brochures, etc). Consultants may associate with other Consultants with well defined scope of services to enhance their qualifications.

Expressions of interest must be delivered to the address below by 31st May '2000

Coal mining accounts for an estimated 10 percent of all human-related methane emissions. Methane, a potent greenhouse gas, is released to the atmosphere during and after the mining of coal, contributing to climate change. Technologies are now available to recover methane trapped in coal resources by drilling prior to and after mining. Recovery and use of this otherwise wasted source of energy both reduces methane emissions to the atmosphere and increases coal mine safety by eliminating this flammable gas from work areas. India is one of the largest coal producers in the world and has substantial coal reserves. Coal remains and will remain India's primary commercial energy source. This, however, brings associated negative environmental impacts from continued high emissions of methane and carbon dioxide. In this context, it is important to exploit and utilize available resources of coal-bed methane both to prevent its release to the atmosphere from coal beds as well as supplement natural gas resources and reduce consumption of coal and petroleum—both of which when burned contribute more carbon dioxide than methane. Development of India's energy sector has been a priority area of government policy in view of its need to sustain the growth of its economy and meet the basic needs of its people. Efficient use of energy resources and the long-term sustainability of its energy supply are two important objectives in India's energy planning.

The Project

This project, which is being implemented by India's Ministry of Coal, addresses two major issues that have prevented adoption of measures to drain, recover, and use methane effectively during mining: *(a)* methane released during mining is often viewed as a security hazard and low-valued resource, not harnessed, and *(b)* lack of technical know-how in harnessing coal mine gas during and after underground mining. The project is using advanced drainage technology from strata that release methane to optimize methods of locating and designing underground methane drainage potential. This will be explored through boreholes and surface wells in areas of virgin coal and gob areas. The project is also working to demonstrate the feasibility of using methane near sources of coal-bed methane, in this case, installation of gas-fired power generation facilities and a methane vehicle refueling station.

Activities

Strengthening and increasing capacity of relevant government ministries, rganizations, and research institutes to develop and support coal-bed methane projects. This involves training and experience in designing and implementing projects that are safe, cost-effective, and environmentally acceptable. Preparing and executing demonstration projects at the Moonidih and Sudamdih coal mines located in the Jharia coalfield for recovery and use of coal-bed methane, using three different drilling technologies.

- using gas recovered from the above activities for vehicle refueling and electric power generation.
- developing and adopting an action plan to replicate successful aspects of the demonstration projects.
- disseminating information and educating, promoting, and facilitating interaction with potential foreign
- investors through a coal-bed methane information clearinghouse.

Benefits

Reduce greenhouse gas emissions both from coal mining and consumption of coal and diesel fuel

- encourage widespread replication of methane recovery techniques in gassy mines
- build in-country capacity to expand methane recovery and use
- increase coal mining production and safety
- reduce electricity shortages in local mining communities and improve local air quality

The Global Environment Facility (GEF) is a financial mechanism that provides grants and concessional funds to developing countries for projects and activities designed to protect the global environment. GEF resources address climate change, biological diversity, international waters, and depletion of the ozone layer. Activities concerning land degradation, primarily desertification and deforestation as they relate to the four focal areas, are also eligible for funding.

GEF is a joint venture of the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank. These three agencies implement GEF projects.

Underground Coal Gasification a Neglected Option

India has large reserves of coal compared to crude oil and natural gas. There is urgent need to explore alternative methods for commercial extraction of those coal resources, which are currently not being mined through conventional mining. One solution is underground coal gasification (UCG). This is a viable means to exploit the deep seated, remotely located and uneconomical coal resources with lower cost. UCG also has the potential to work offshore coal reserves where traditional mining methods are inapplicable.

UCG employs a series of wells to convert in situ coal into product gas (syn gas), thus eliminating the expense of mining and reclamation. The technology is based on the management of underground gasifiers without making mines. The product gas composition is a mixture of H_2, CH_4, CO, CO_2 etc. with a calorific value of *850* to 1200 kcallNm^3. UCG differs from conventional surface gasification in a number of ways:

- Coal is not mined and chemical processes are arranged to occur in the virgin coal seam in situ**.**
- The process wells (the collective terms for the injection and production wells in a UCG project) must be connected within the coal seam by the links of low hydraulic resistance to allow production of commercial quantities of gas.
- Process water for gasification usually comes from the coal itself and surrounding rocks, and its influx must be carefully regulated.
- No ash or slag removal and handling are necessary since they predominantly stay behind in the underground cavities.
- The process must be confined within a hydraulic system created in the coal seam so that no leakage of the product is possible and no contamination of the underground environment can occur. Such a hydraulic system is called an underground gasifies, and its design is the most crucial part of a UCG operation.

UCG uses adjacent boreholes drilled into a coal seam (typically > 100 m depth). The injection wells are used to feed a pressurized oxidant such as air or oxygen/steam into the coal seam and for down the whole ignition of coal seams. The production wells recover the product gases. Conceptually UCG is very attractive but the application of the concept as a large scale method of coal conversion has proved to be more difficult. It is clear from the tests with UCG application in the past that the natural permeability of the coal seam to transmit the gases to and from the combustion zone can be unreliable. For gasification over long distances in the coal seam, a properly constructed in-seam channel is preferred, before the coal seam is ignited and the gasification cavity is developed. Various methods have been attempted by different countries to construct the in-seam channel including:

- drilling from an outcrop.
- slant drilling from the surface
- constructing man-made in-seam galleries
- directional drilling

The technology of directional underground drilling advanced considerably in the 1990's as a result of developments in the oil, gas and coal industries. The same technology is used regularly for the gass of coal seams in Australia, South Africa and the United States. This has increased the reliability and accuracy in construction of in-seam coal wells.

- Depth: Ideally between 100-600m. In case of coal seams at shallow depth (less than 100m), there is the possibility of leakage of gas to the surface, whereas at greater depth (more than 600m), the cost of drilling goes up and also making the links becomes difficult.
- Seam Thickness: The desirable thickness is 3-10m.
- Seam Gradient: Steeply dipping coal seams are most suitable for sustaining better ignition.
- Roof Characteristics: Strong and dry roof rocks are desirable to minimize heat loses and coal recovery
- Rank of Coal: Lignite and sub bituminous coal are desirable because they shrink and crack upon heating thus helping the product gas to flow. Bituminous coal on the other hand tends to swell on heating and become tarry. This closes up the channels, restricting the gas flow.
- Permeability / Cleat: High permeability and a well-developed cleat system is preferable.
- The coal should not have a major aquifer nor should one be found above the coal seam.

Benefits from UGC

The benefits of UCG are -

- Extraction of Energy from deep-seated coal deposits which are uneconomic at present. Remotely located deposits are not being considered for mining through lack of infrastructure and adverse economics. Further, offshore deposits cannot be mined with existing conventional mining methods.

- Minimum surface disturbances, minimizing land acquisition and rehabilitation requirements.
- Safety from conventional mining risks
- No surface disposal of ash.
- Initial capital investment is very much less in comparison to conventional mining.
- A practically unlimited supply of coal is available for gasification; no external supply is required to sustain the reaction.
- The product can be transported to meet the needs of power generation, heat supply and feed stock for fertilizers and petrochemicals.
- Reduced CO_2 emission.

The combination of UCG and CO_2 sequestration is an area of growing research interest. The gas can be processed to remove the CO_2 before it is passed on to end users, thereby providing a source of clean energy with minimal greenhouse gas emissions. CO_2 capture from Syngas using amine solutions is a well proven technology and the captured CO_2 can be used for CO_2 sequestration

Potential Risks with UCG

There is a risk of groundwater contamination because of

- escape of product gases during gasification.
- escape of pyrolysis products (aqueous and gaseous phase) during gasification.
- leaching and transport of aqueous phase contaminants post gasification.

There is a risk of surface contamination through drilling operations because of spoil and wastewater.

There are risks during gasification through

- waste water from groundwater infiltration
- waste water from product gas treatment facilities
- gaseous emission from product gas combustion unit/plant

Underground coal gasification (UCG) is a viable option. The Integrated Gasification Combined Cycle (IGCC) is an alternative to pulverized coal combustion for power generation. In pulverized fuel (PF) combustion, coal is milled to powder and blown into the boiler with air. The powdered coal having a large surface area gets easily combusted in burners. This provides the heat that is used to produce superheated steam to drive turbines and hence generate electricity. In power plant cycles like IGCC, coal is brought into contact with steam and oxygen and thermo chemical reactions produce a fuel gas of largely hydrogen and carbon monoxide, which when combusted can be used to power gas turbines. IGCC systems give increased efficiencies by using waste heat from the product gas. There are 209 *Underground* Coal Gasification-Applications in India. IGCC systems also produce less solid waste and lower emissions of SOx, NOx and CO_2. A combination of UCG and IGCC is technically feasible.

Indian Effort for UCG Development

A protocol for UCG development was signed between India the USSR in 1981. A core group consisting of the Central Mining Research Institute (CMRS), the Central Fuel Research Institute (CFRI), the Indian Institute of Technology (IIT) Kharagpur, Coal India Limited (CIL), the Central Mine Planning and Design Institute Ltd. (CMPDI) and the Oil and Natural Gas Commission (ONGC) was formed. It was also decided that UCG prospect evaluation for coal seams less than 300 m depth would be handled by CIL/CMPDI and that those more than 300 m depth would be handled by ONGC. In 1983, CMPDI began an S&T scheme to evaluate UCG prospects in regard to shallow lignite deposits of Paina-Merta Road with Soviet collaboration after consultation with CMRS, CFRI and ONGC. Soviet experts visited India in 1986 and examined the available geological reports of 13 coal/lignite blocks. They selected South Sayal and Madni Rai block CCL **[What is CCL????]** in Thakhandb, and the Palna-Merta Road lignite block of Rajasthan for exploration. The Soviet experts concluded that UCG technology was technologically feasible at Merta Road. But a pilot plant study at Merta Road lignite block was not recommended because of pollution of existing limited ground water resources in the area. During the same period (1984-86), ONGC drilled 2 pilot boreholes UCG-l & UCG-3, 10km. north of Mehsana city in Gujarat, to determine the nature of the rocks, sub-surface strata conditions and the nature, quality and properties of coal. Coal cores thus derived were subjected to various analyses in CSL Nagpur. No further studies on the subject have been made since then.

Clean Coal Technologies

Clean coal technologies have been put in four main categories i.e. pre-combustion clean coal technologies, during-combustion clean coal technologies, post-combustion clean coal technologies and advanced clean coal technologies. Pre-combustion clean coal technologies include beneficiation of coal, desulfurisation of coal, blending or homogenization of coal. During-combustion clean coal technologies are fluidized bed combustion, staged combustion, low NOx burners, boiler tuning for efficient and optimized combustion, super critical and ultra super critical boilers etc. These may include coal-water mixture combustion. Post-combustion clean coal technologies involve flue gas desulfurisation (FGD), flue gas denitrogenation, catalytic reduction of NOx, plasma reduction or selective catalytic reduction of NOx, electrostatic precipitators, bag houses, and cyclone and other scrubbers, etc. to arrest fly ash. Advanced clean coal technologies are Integrated Gasification Combined Cycle (IGCC) power generation, Pressurized Fluidized Bed Combustion (PFBC), IGCC – Fuel Cell power generation, ultra super critical boilers, etc. However, there is a need to make these clean coal technologies economical and if possible more efficient and free of major engineering problems where these exist. Several clean coal technology projects are being undertaken world wide.

Since coal contains mineral matter (ash) and other impurities, the atomic H/C ratio of coal is not high; its calorific value is lower than that of oil and natural gas. Therefore, concerns about the pollution caused by the use of coal fuels are increasing. This includes global warming, land degradation due to mining and fly ash disposal, water pollution due to coal washing (Giri and Sharma 2004). There is also a need to add value to coal and thus there is a need to develop clean coal technologies further. Physical coal beneficiation techniques using oil agglomeration, froth flotation, oleo flotation have to be integrated with chemical cleaning of coals (Sharma and Singh1995). Chemical cleaning of coal using alkali-acid leaching under milder conditions may produce cleaner coal. Some research in this direction has been reported, where coal may be cleaned by using HF-HNO_3 cleaning (Steel and Partic 2003) and by using alkali-acid leaching (Sharma 2005). The thrust is for producing ultra clean coal, a nearly zero ash coal, which may be used for the Integrated Gasification Combined Cycle and for PFBC power generation without any problems of resorting to hot gas clean up. IGCC power generation through hydrogen generation for zero emission has been reported (Zock et al.2003). Co-combustion of coal with plastics, biomass, oil, water, biogas, organic wastes, natural gas, etc. can be practiced for efficient power generation and for adding value to coal.

Coal Refineries

Since oil is refined to obtain different grades of fuels for use differently and efficiently in petroleum refineries, the coal can also be refined in coal refineries to obtain different quality – grade – class (QGC) of fuels. There is a need to develop further clean coal technologies for the stepwise refining of coal to obtain different QGC products as is practiced for crude oil in petroleum refineries. Organo-refining of coal i.e. stepwise solvent extraction of coal using different solvents such as N-methyl -2-pyrrolidone (NMP), anthracene oil (AO), morpholine (MO), ethylenediamine (EDA), quinoline (QN), liquid paraffin (LP), alkenes, phenols, dimethyl formamide (DMF), phenanthrene, carbazole, etc. can produce different QGC products from coal (Pandey and Sharma 2002). Several combinations of solvents can be used for the stepwise refining of coal and the process has been termed as Organo-refining of coals. This may lead to the production of two or three different QGC products from coal. Some of the premium QGC products such as super clean coal having ultra low ash can be used for the production of graphite, carbon-nanotubes, composites from coal. In fact, super clean coal or ultra clean coal can be used for more than 30 different uses including coking coal blends, carbon electrodes, reduction, nanocomposites, value added chemicals, specialty chemicals conducting polymers, engineering plastics, etc. The residual coal (RC) obtained after the stepwise organo-refining of coal may be used for power generation. This coal (RC) may be beneficiated or chemically cleaned to obtain cleaner coal. The washability characteristics of the RC can also improve after the removal of some of the organic matter from the coal by solvent extraction (organorefining). Liquefaction, gasification and carbonization of RC may also produce different QGC products for use differently and may be even efficiently.

Modification of Coal for Added Value

In fact, depolymerisation of coal through phenolation may enhance the yield of super clean coal (having ultra low ash) through organo-refining of coal. The use of coal derived and industrial solvent was made for these studies. In fact, coal can be chemically modified under ambient pressure and convenient conditions by reactions such as depolymerisation by phenolation, co-polymerization, alkylation, reductive alkylation, reduction, alkaline degradation, reductive depolymerisation, etc. Most of these processes involve atmospheric pressure operations, at low temperature as brute force high pressure coal conversion processes have to be replaced by the convenient and cost effective low to ambient pressure processes. Liquefaction of coal under mild atmospheric pressure conditions including solvent refined coal processes also affords different QGC products. The unit processes employed in oil refineries may include besides organo-refining, the processes such as carbonization, hydro carbonization, gasification, liquefaction (hydrogenation), cracking, co-cracking, chemical leaching, bio-refining, etc.

The RC can also be utilized through co-combustion with plastics, biomass, vacuum residue, organic wastes, biogas, etc. to generate power by using efficient ultra super critical boilers. Co-processing of RC or original (untreated) coal with waste plastics, biomass, petroleum coke, vacuum residue, etc. may also lead to cleaner and efficient utilization of coal (Ahmaruzzaman and Sharma 2005) by PFBC, IGCC or power generation techniques. Unit processes such as organo-refining, depolymerisation, reduction, reductive alkylation, carbonization, hydro carbonization, hydro cracking, cracking, catalytic cracking, gasification, etc. may form different reactor units in future coal refineries. The role of depolymerization and organorefining and carbonization or gasification of RC (Anon 2006a) may be worth studies further for their role in future Integrated Coal Refineries. Next generation coal refineries may include one or all of the 4 models described presently.

Most of the techniques of physical beneficiation of coals are already being commercially exploited. In future techniques such as oil agglomeration, froth flotation, etc. may be integrated with biodepyritisation by using patented processes. The flow schemes of beneficiation of coals may be developed further. The rejects may be fired in fluidized bed combustors (FBC). The success of coal blending or homogenization may be dictated by the developments in the technology of solid-solid mixing such as blending in beds, strata, skewed chevron, windrow, chevron-windrow, chevron, blending in silos, blending on moving belts etc.

The US DOE has recently reported (Anon 2006b) an updated status of the DOE commercial – scale demonstration of clean coal technologies (CCTs). These demonstrations involved billions of dollars not only USDOE funding but even the funding support from the participating commercial organizations on cost sharing basis (i.e. federal government, other public institutions, the technology suppliers and users). These were performed under Clean Coal Technology Demonstration Programme (CCTDP), Power Plant Improvement Initiative (PPII) and Clean Coal Power Initiative (CCPI). The CCT research development and demonstration programmes contribute to achieve the DOE strategic goal, including the President’s Coal Research Initiative, Future Gen Initiative, Global Climate Change Initiative, Hydrogen Fuel Initiative and Clear Skies Initiative (CSI). The programme further addresses the requirements of the Clean Air Interstate Rule (CAIR) and the Clean Air Mercury Rule (CAMR).

The CCTDP was focused on reducing SO_2 and NOx emissions and on advanced turbines, gas separation membranes, fuel cells, new gasification processes, carbon sequestration, hydrogen production and other advanced energy system technologies. These include low NOx burners staging combustion, oxygen-enhanced combustion, selective catalytic and non-catalytic NOx reduction etc (Anon 2006c). Mercury control technologies use sorbents and oxidizing agents and wet-FGD scrubbers ESP and fabric filter dust collectors were used to control even PM 2.5. Advanced power systems include IGCC – Fuel Cell power generation and circulating fluidized bed combustors (CFB) using low grade coals and waste materials. The new advanced systems being developed are hybrid systems integrating IGCC and CFB technologies and advanced combustion using O_2 instead of air or chemical looping to affect the equivalent of combustion. The other endeavor includes upgrading goal by removing ash to obtain clean fuels. The work on conversion of coal to liquid fuels, chemicals or hydrogen is also being undertaken. Under industrial applications, direct coal use for substitution of coal in place of coke for coke making and for oil or natural gas in energy production are being undertaken. The work on the utilization of fly ash in cement and in abandoned coal waste piles is in progress. A large number of projects have been successfully completed.

CONCLUSIONS

The global energy demand is on the rise, more so in the case of developing countries like India. Though conventional fossil fuels that provide primary energy have limited resources, coal will maintain its dominance in international energy scenario because of its huge reserves that will last for two centuries. Due to environmental concerns, various other energy options including renewable are being tried globally but they have failed to provide bulk energy at competitive cost. Renewable sources alone do not offer us a path to sustained development within our present span of vision. Economic development and poverty alleviation depend on secure and affordable energy sources like coal. Indian coal mining industry offers a bright future for the country's energy security, provided the industry is allowed to develop by supportive government policies, adopts latest technologies driven by contemporary managerial acumen and addresses environmental and social challenges effectively. The demand for coal is increasing with each passing year surpassing the domestic supplies. Coal shortage not only fails to fulfill country's basic energy needs but also gives rise to social problems like illegal trade of coal. Import of coal will not be a viable and sustainable solution for bridging the demand-supply gap. Therefore, the domestic coal industry will have to pull up its socks to augment coal production and meet country's primary energy needs through adopting sustainable technologies to meet the environmental challenge.

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New Technical Strategies on Anaerobic Digestion in Europe

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ABSTRACT

Present, a new boom on anaerobic digestion is to be recognized. The renewable energy law of Germany enhanced the energetic use of biomass. Parallel prices of oel of near 100 US $ per barrel caused a new societal debate about a sensible mix of energy. The monetary stimuli of the renewable energy law increased the interest on anaerobic digestion within the agricultural sector. Newer deliberations are based on the idea to use larger amounts of energy crops for the production of energy by anaerobic digestion technologies. The potential in Europe is huge, but used until now only partly. The chances of economic growth for the future are immense. It is important to show the technical basics of the anaerobic technology and as well the potential for the society. That includes beside the willingness to establish innovative technology as well the growth of scientific based knowledge in parts of the anaerobic technology.

INTRODUCTION

Since the 18th century it is known that methane is a material that is constantly produced in nature. In the 19th century the microbial origin of methane was proven. In 1920, Imhoff (Imhoff, 1990) converted the knowledge available at that time in practical use (i. e., construction of the first sewage treatment plant). During World War II the biogas recovery from agricultural wastes (i. e., semi-liquid manure) has been researched in and also used for energy production. During the seventies the technology of biogas production experienced innovative development, mainly as a result of the energy crisis (Kraft and Bidlingmaier 1999)

Anaerobic Digestion as a method for waste management with special consideration to the circle of carbon and nutrients as a part of sustainable development has been used in Europe the last 50 years. But sustainable farming is not an European or American idea, it has its longest roots in 4000 years of sustainable farming in Asia. Over centuries one farmer could support 8 persons, 2 cows, 2 donkeys and 8 – 10 pigs by farming approximately one hectare land (King 1970). That could only happen with a strict return of any organic material or waste back to the farm land.

Present a new boom on anaerobic digestion is to be recognized. The renewable energy law of Germany enhanced the energetic use of biomass. Parallel prices of oil of near 100 US $ per barrel caused a new societal debate about a sensible mix of energy. The monetary stimuli of the renewable energy law increased the interest on anaerobic digestion within the agricultural sector. Newer deliberations are based on the idea to use larger amounts of energy crops for the production of energy by anaerobic digestion technologies. The potential in Europe is huge, but used until now only partly. The chances of economic growth for the future are immense.

Substantial impulses for the technology of anaerobic digestion came by the introduction of the separate collection of organic waste. Present the potential of organic waste can be estimated to 10 – 12 million tons per year. In 2001, about 700-900 biological treatment plants were in operation in Germany. The cumulative capacity of these plants has been about 6-8 million tons. In March 2000, 403 biological treatment plants with an input of 4.5 million tons were able to meet the RAL-quality standard (Kehres 2001). Graph 1 shows the useable energy capability for Germany in 2004.

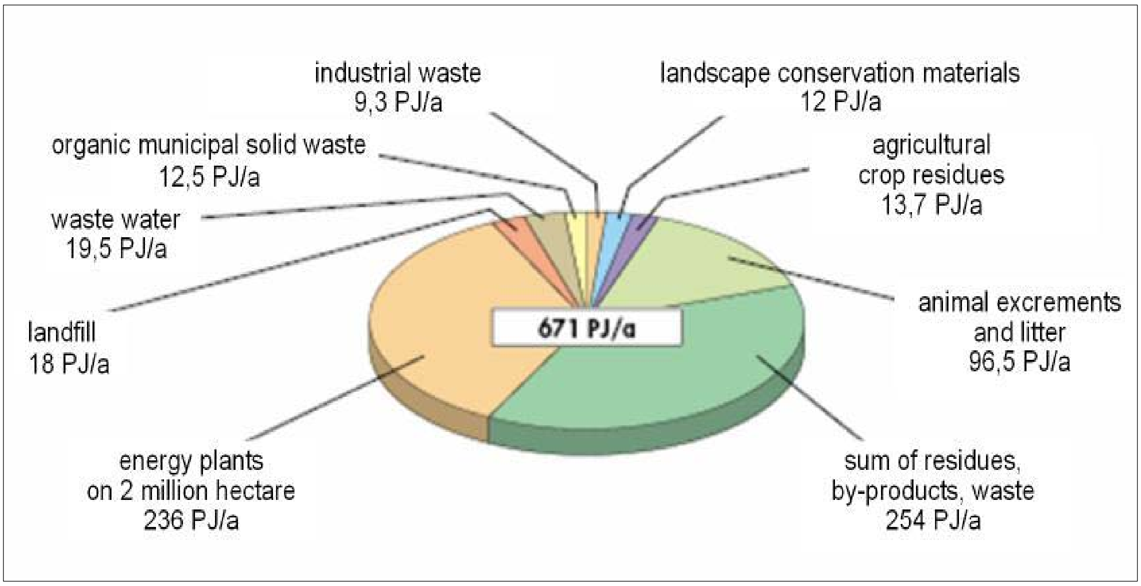

Figure 1 Useable energy capability for Germany in 2004 (FNR, 2005)

The biological treatment of organic material needs a separate collection of those materials. The European Union focuses all European Nations on the reuse of organic materials. But the situation is not uniform. The German speaking countries plus Denmark, the Netherlands and parts of Belgium do have an installed and working separate collection for organic waste. Approximately 75% of all households are connected to the system in these countries. A group of countries containing of Italy, France, the United Kingdom, Sweden and Finland is planning or starts implementing the separate collection of organic waste. Spain, Greece, Ireland or Portugal do not have any activity in this field.

In order to estimate the potential of organic substances for the production of biogas in Europe the substrates manure, energy crops (energy plants), agricultural residues, sewage sludge, organic waste and grey waste have to take into special account. Originated in a data base from 2004 about inhabitants, areas under cultivation and the amount of domestic animals in Europe, the potential of biogas can be calculated. The calculation is divided into the old EU 15 countries and the rest of Europe. That is substantiated with the present different technical level of standards. Russia is not taken into account.

Table 1 Potential of biogas in the EU 15 (selected substrates) 2004

Energy plants (1/3 of the areas under cultivation)	189	billion m³/a
manure	56	billion m³/a
agricultural residues	56	billion m³/a
organic waste	4,2	billion m³/a
grey waste	2,5	billion m³/a
sum	**306,7**	**billion m³/a**

Table 2 Potential of biogas in Europe without the EU 15 (selected substrates) 2004

Energy plants (1/3 of the areas under cultivation)	189	billion m³/a
manure	23	billion m³/a
agricultural residues	23	billion m³/a
organic waste	2,1	billion m³/a
grey waste	1,3	billion m³/a
sum	**238,4**	**billion m³/a**

Sewage sludge and industrial organic waste have not been taken into account. Realistic, an average content of methane of about 55 Vol. % with in biogas can be used for calculation. The energy content for the EU 15 countries is 1687 billion kWh/a and for the whole Europe without the EU 15 it is 1311 billion kWh/a. That corresponds with an electrical power of about 562 billion kWh/a for the EU 15 countries and 437 billion kWh/a for the whole Europe without the EU 15. Germany consumed about 507 billion kWh/a of electrical power in 2004.

Influenced by the renewable energy law a boom of small and medium plants for biogas happen in Germany. Figure 2 is showing it.

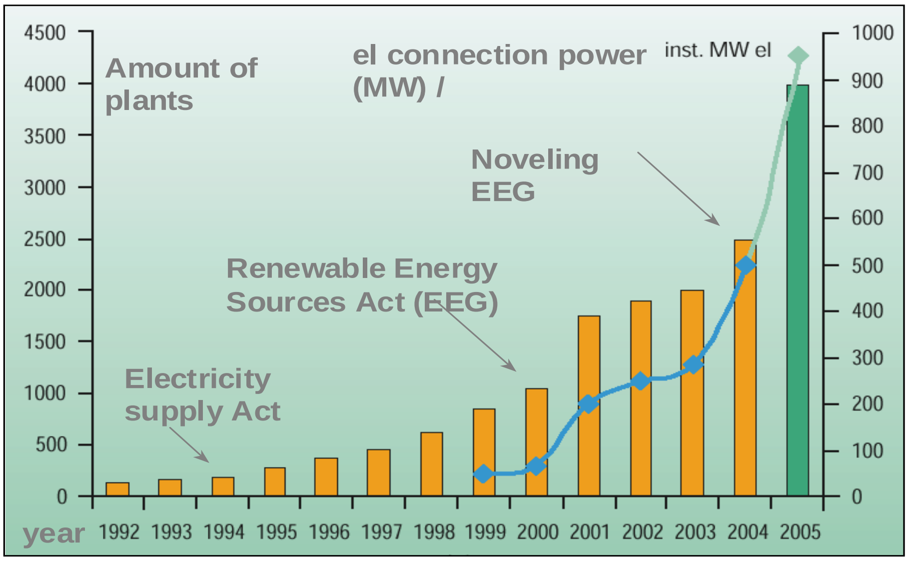

Figure 2 Development of biogas plants in Germany (FNR 2005)

Anaerobic technology is particularly well suited for the utilisation of organic industrial refuse with high water content as well as for the organic part of bio-waste. A crucial factor for the increasing acceptance of anaerobic waste treatment is the fact that - in contrast to composting – the energy (digested gas) which is released during anaerobic digestion can be collected and used and enables economy in fossil energy carriers. On the pre-condition of best power benefits (electricity and warmth) an anaerobic digestion contributes to the reduction of global CO_2-emissions. Compared to composting, especially with problematic wet refuse, which is poor in structure, e.g. bio-waste from the town centre area, an anaerobic digestion shows advantages in the treatment as well as with emission-limitation because of the closed reactors and less exhaust air volume flow. This development is taken into account by more and more installation by farmers who have taken the opportunities of anaerobic treatment systems these days.

GENERAL TECHNICAL POSSIBILITIES

The state of the art of use of technical solutions in Europe has been shown by de Baere (2001). Table 3 summarises the results.

Table 3 Overview of the technical state of the art on anaerobic digestion in Europe (Baere 2001)

		1991	2000
Wet digestion	Capacity [Mg/year]	~ 80.000	~ 480.000
Dry digestion	Capacity [Mg/year]	~ 50.000	~ 560.000
Mesophil	Capacity [Mg/year]	~ 3.000	~ 120.000
Thermopile	Capacity [Mg/year]	0	~ 52.000
One stage	Capacity [Mg/year]	~ 90.000	~ 920.000
Two stage	Capacity [Mg/year]	~ 50.000	~ 110.000
Co-digestion	Capacity [Mg/year]	~10.000	~ 50.000

Dry or Wet Anaerobic Digestion

The dry digestion procedure uses organic waste corresponding to his water content of 30 to 35 mass % dry substances. Dry digestion is often designed as single stage procedure. Within an amount of dry substance over 40 mass % the danger of inhibition and obstruction of transport inside of the reactor increases. The retention time in a single stage version is 3 – 4 weeks for a mesophilic process and 2-3 weeks for a thermophilic process. The less mass transport- caused by the low water content- is to be seen as a benefit. It allows a smaller dimension of the reactor system.

The wet digestion uses pre-treated organic waste with an amount of dry substance from about 10 mass %. That property of the organic material opens the optimised possibility of mixing and transporting the material inside of the reactor. The conditions for heat- and material transport and exchange as well as the exit of the bio-gas are very good. That indicates as a benefit a high variability of figuration regarding the process procedure.

Mesophilic or Thermophilic Digestion

The different described groups of responsible bacteria for biodegradation demand different temperature optima. The methanogenic bacteria can be divided into two groups of micro-organisms demanding two temperature ranges. Methanogenic reach a maximum gas production rate at temperatures in a mesophilic range of 35°C to 37 °C and a thermophilic range at 50°C to 55°C. The gas production is about 10 % higher in the thermophilic range. The group of mesophilic bacteria contains a higher number of different tribes, compared to the thermophilic bacteria.

Because of the low release of energy within the process of anaerobic digestion of organic matter, the needed temperature for the reaction has to be guaranteed by using external energy. The positive aspects of the thermophilic digestion are:

- higher degree of sanitation,
- about 10 % higher gas production and
- about 10 % higher biodegradation of the organic matter.

But the net energy yield is less, because of the higher energy consumption for heating the process, using the produced bio-gas. Another disadvantage is to be seen in the production of higher ammonia rates, which can inhibit the anaerobic digestion. The balance of ammonia and ammonia depends on the temperature. Even a toxicological effect on the bacteria could be the result. That is, why a lower stability of the process can be postulated for the thermophilic digestion. Because of those reasons most procedures of digestion are run by a mesophilic range.

Single or Two Stage Anaerobic Digestion

The single stage digestion allows the parallel running of all Steps of the anaerobic bacterial metabolism in one reactor. Each condition regarding moisture and or temperature can be chosen. But an optimisation of a single step of biodegradation is impossible, without changing the conditions of all other steps as well.

Using a two stage digestion a separation of fluid and solid material before or after the production of methane is possible. The separation before the production of methane start has the advantage, that the fluid phase can be degraded within short retention times in reactor with a very high efficiency. This technology is based on an excellent experience by waste water treatment plants. The two stage digestion separates on one side the processes of hydrolysis and acidification and on the other side production of acetat and methane.

Table 4 Comparison between Single or two stage anaerobic digestion (Widmann 1999)

Single stage	Two stage
<u>benefit:</u> - low costs of invest - simple control engineering	<u>benefit:</u> - higher stability of the process - individual solutions - higher efficiency reg. time and volume - better sanitation(lower pH-in hydrolysis)
<u>disadvantage:</u> - no optimisation possible - pH -problem (instability) - general lower stability	<u>disadvantage:</u> - higher costs of invest - more difficult control engineering

Concentration of ammonia higher than 1.000 mg/l or higher than 1 Vol.-% can inhibit the hole process. As well a low pH can course a lower production of methane. Table 5 shows a summary of optimal living conditions of methanogenic bacteria.

Table 5 Optimal living conditions of methanogenic bacteria (Kraft 1993)

Parameter	unit	value
temperature	[°C]	30-35 und 50-55
pH	[-]	6,6-8
water content	mass.-% w.b.	> 50
redox potential	[mV]	<-330
alkalinity	[mg $CaCO_3$/l]	>2000
salt	[g/kg d.b.]	<20
ammonium	[g/l]	<1-2,5
hydrogene sulphide	[mmmolar, Vol.-%]	<3, <1
sulphide	[mg/l]	<100-400
organic acids	[mg/l]	<15000

TECHNICAL SOLUTIONS

The classical concept of anaerobic digestion plants contents of

- management building
- tanks and reactors
- delivery
- processing
- biological treatment
- conditioning of products
- emission-limiting.

Standard Continuous Dry Fermentation

One of the classical continuous operated dry fermentation plants in Europe is the DRANCO system. Planned and developed by the company Organic Waste Systems (OWS) in Belgium. The plant, situated in Brecht (Belgium) treats 50.000 ton of organic waste a year. Figure 3 shows the procedure of that system.

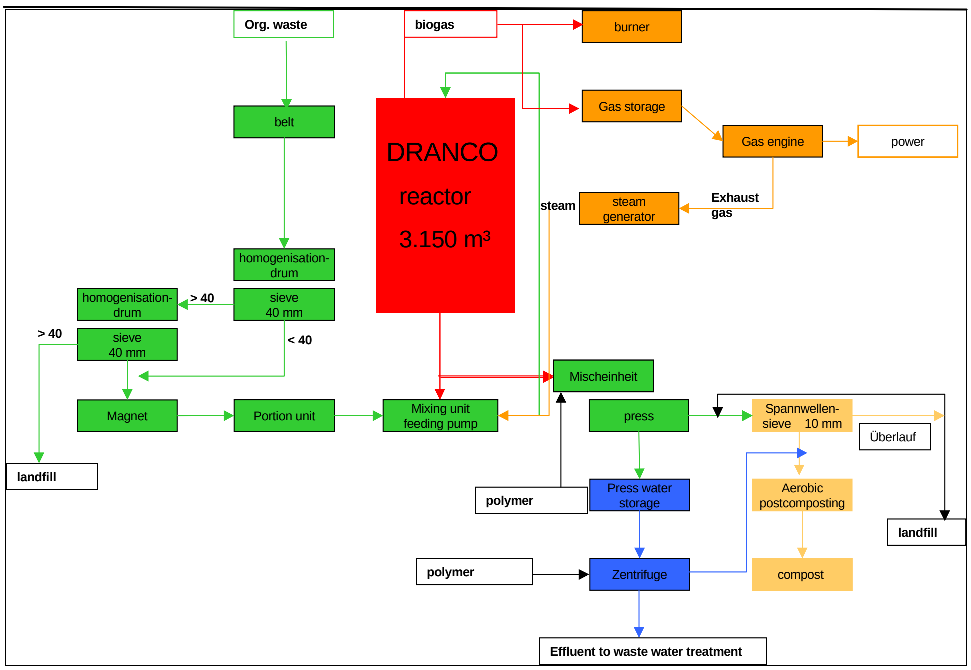

Figure 3 Procedure of the DRANCO system, dry continuous fermentation

The incoming separate collected organic waste consists of (%w.b):

garden waste	75,
kitchen waste	10,
wet paper	10,
industrial waste	3,5 and
disturbing material	1,5.

The material is characterized in the average by a dry substance content of 40 mass -% and a content of 55 mass.-% of organic dry substance. Table 6 shows the process parameter of the DRANCO plant in Brecht (II).

Table 6 process parameter of the DRANCO plant in Brecht (II).

parameter	unit	
load	kg org. dry sub./m³ d	7 - 14
biogas	Nm³/Mg Input	90 - 120
biogas	Nm³/m³ d	4 - 8
methane	Vol.-%	50 - 60
retention time	d	15 - 25
dry substance	mass.-%	28 - 40

The material is homogenized, sieved and mixed for about 5 hours in two drums. Approximately 10 mass % of the input has to be sorted out and stored at the landfill. The fresh substrate is mixed with fermentation residues at a ratio of 1:5. The complete mixing is ensured by a loading pump. The reactor (3.150 m) itself contains no mixing equipment. The production of electricity is realized by two combined heat and power stations (each 650 kWh). The own consumption of the plant is 450 kWh, that includes 250 kWh for the loading pump.

The fermentation residues are dewatered with screw-press. A polymer, to dewater the material easier, is added (3,5kg/Mg of fermentation residue). After that, the process water will contain about 5 mass% of dry substance. The dewatered fermentation residues are composted for about 2-3 weeks. The heaps are active ventilated. As a result a high qualified final product (compost) is produced. The plant is operated by three workers in two shifts. The earnings are 83 €/Mg input material. For the separate collected material, that price is fixed. It ensures an operational safety for the plant. Figure 4 shows a picture of that plant.

Figure 4 DRANCO dry continuous fermentation, Brecht II

New Developments on Dry Fermentation

Fundamental changes in the field of waste management, especially anaerobic digestion are definitely connected with a splitting up from the philosophy of “end of the pipe“. The future belongs to material flow management in connection with product oriented waste treatment. A result could be the development of treatment plants which are adopted for specific material flow. Those plant can act dynamic regarding changing input materials, but the can react to changes of the demanded product quality as well. To achieve that aim, the conservative structure of anaerobic digestion plant needs fundamental changes. The advanced items regarding that topic are integrated, fractal and dynamic (Grooterhorst, 2000). The realisation of those innovative concepts needs an interdisciplinary work. Additional to the classical subjects like civil engineering and agricultural engineering, a co-work with subjects like natural science, bionic, robotic, informatics and measurement has to be organised.

The needs for the next 10 years can be summarised:

- research regarding the kinetics of methaneogenesis,
- research for speeding up the process of anaerobic digestion whit an variation of the process controlling,
- development of small, moveable and flexible reactors,
- development of a new design for the reactors,
- test of different organic materials(waste, faces, etc.) regarding there influence on the dynamic of the population or the effectiveness of degradation.

The advance of small reactors for example could be seen in:

- small and repetitive segments grant the possibilities of a more specific and flexible treatment of changing substrates,
- they can be controlled more flexible,
- they grant a higher yield of methane,
- they allow shorter retention times,
- they can be easier transported,
- they allow the possibility for a dynamical increase or decrease of the capacity and
- they could be used as well aerobic as anaerobic.

A representative of that new trend in anaerobic digestion is BEKON. It provides plants with single-stage dry anaerobic fermentation operation. Using the conditions of packed beds. The material is not moved or mixed after storing at the reaktor again. The dynamic element is taken by water, which is percolated through the organic material. The benefit of those systems can be summarized:

- biomass with high dry solid matter (DS) contents; no disturbances by woody or fibrous constituents,
- dilution, stirrer, pumps are not needed; less accident-sensitive equipment, less maintenance effort modular design feasible; lower investment costs,
- lower process energy demand and
- storage of fermentation residues not necessary

Figure 5 shows a schematic view and Figure 6 a photo of the BEKON system, as one example for batch dry fermentation. It handles 20.000 Mg of organic waste a year.

In practice in Germany decentralised small plants are strongly demanded by medium and large size farmers as well as by machinery rings of farmers. There demand includes the remote control of the anaerobic digesters in contradiction to there former experienced based control.

The combination of small reactors and information technology will open the possibility of long distance controlling of anaerobic digestion plants even in foreign countries. Certain knowledge about the controlling of the biological process is still to search.

The main challenges are:

- controlling and prediction of the biological process,
- shorting of the start up procedure (lag stage),
- short time characterisation of substrates and
- prediction of the gas production of mixtures of substrates.

Small and mobile reactors for anaerobic digestion will be part of new answers for mega cities. Those systems open the chance for partly closed waste management loops.

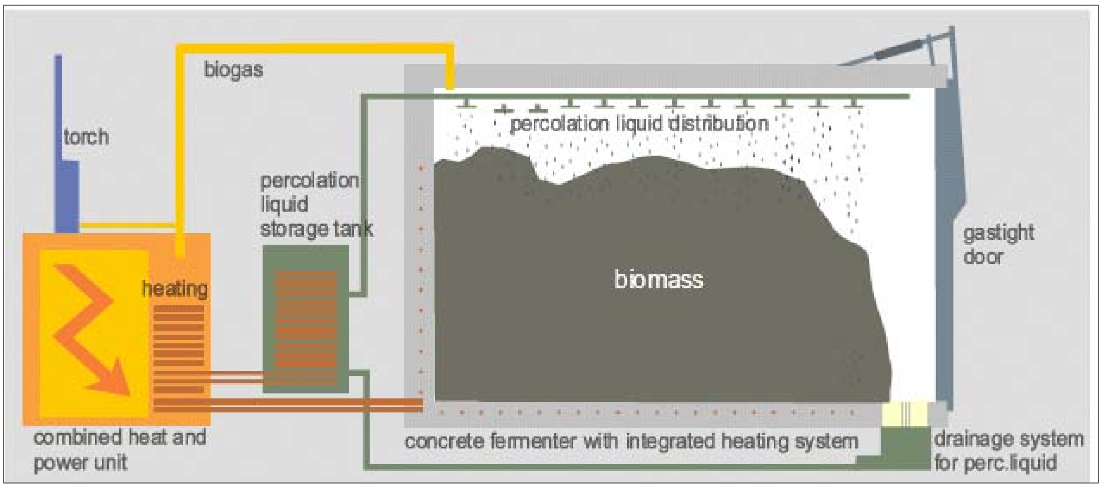

Figure 5 Schematic view of BEKON

Figure 6 BEKON system, batch dry fermentation (Germany)

At the moment the Bauhaus-University of Weimar is developing transportable reactors for anaerobic digestion with remote control for refugee camps to improve the horrible hygienic situation there.

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Microbial Oxidation of Methane in a Mineral-Based Aerated Biofilter – Model Studies

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ABSTRACT

Biofiltration of landfill gas is a cheap, easy and efficient way of landfill impact minimization on the environment. A number of gaseous components of biogas, such as CH_4, NMOC, H_2S, and NH_3 could be oxidized by specialized groups of microorganism, to the substances much less dangerous for environment. Efficiency of gas removal is determined by different factors connected with climate, gas properties and type of biofilter filling bed. The bed material influences the gas and water permeability, gas diffusion coefficient, water holding capacity, specific surface area, and substrate availability for bacteria. The paper presents results of laboratory study carried out in columns filled by mixture of expanded perlite and compost with zeolite and bentonite additions. Examined materials were flushed with mixture of CH_4, CO_2 and air. The methane oxidation capacity of the materials, profiles of gas concentration, water content, organic matter, and temperature were measured in the course of the experiment.

INTRODUCTION

Decomposition of the biodegradable fraction of wastes deposited in a landfill makes a significant source of methane emission to the atmosphere. Mitigation of methane emission from landfills comprises mainly extraction and utilization of the landfill biogas as a source of energy. When this is not applicable (for example, when the stable methanogenic phase is over) remains its biochemical oxidation in the landfill soil cover as a natural bioremediation mechanism. The latter possibility has been suggested and documented in the pertinent literature [Aitchison, 1993; Kightley et. al., 1995, Stepniewski and Pawłowska, 1996; Stępniewski and Rożej, 2000]. It should be mentioned that sometimes landfill methane is flared (what is possible when its concentration exceeds 30%) but in such cases the diffusion through the soil also takes place, so the methanotrophic activity is also useful. The same is valid in the situation of the pumped gas recovery system providing extraction of only a part of the biogas generated.

There are several forms of biotechnological usage of methanotrophic activity in landfill conditions. The shape of the biological filter bed and its volume can be selected depending on kind of landfill (organized with the insulated bottom and top cap, organized with the top layer unpacked, unorganized), predicted volume of the biogas production (of various methane concentration). It could be a simple landfill cover, modified landfill cover, bio-window or biofilter, but the mechnisms of the process is the same in every solution. During the movement through the filter layer, CH_4 is oxidised by methanotrophic microorganisms to CO_2.

Microorganisms responsible for methane oxidation, so-called methanotrophs, are common bacteria that can use methane as the sole carbon and energy source. They were isolated from soil derived from different environments, exposed to low (atmospheric) CH_4 concentration (Boeckx et al. 1998; Suwanwaree and Robertson, 2005; Jang et al., 2006), as well as exposed to high CH_4 concentrations, e.g. rice fields (Watanabe et al., 1997), places near the natural gas leakage (Hoeks, 1972), landfills (Kightley et al., 1995; Kalistova et al., 2005; Abichou et al., 2006). Methanotrophic bacteria that can oxidize CH_4 under oxic conditions were isolated for the first time from soil close to a leakage of natural gas by Söngen in 1906 *(Mancinelli et al., 1981)*.

Methanotrophs contribute to the reduction of atmospheric methane concentration by preventing methane emission from various environments and by capturing it from the atmosphere (acting as a sink). The second type of the methanotrophic activity seems to be the more important. According to estimates by Reeburgh et al. (1993) soils exposed to high methane concentrations (landfill cover soils, surface layer of bog soils) prevent the emission of about 700 Tg of CH_4 annually. When methane migrates from its source to the atmosphere it passes through an aerated layer, where the oxidation process takes place. With respect to the oxygen demand, methanotrophic bacteria are classified into two functional groups: obligatory aerobic bacteria that cannot live in anaerobic conditions and bacteria that can survive an anaerobic period and reactivate in aerobic conditions. Most of methanotrophs belong to obligatory microaerophiles. They prefer oxygen concentrations below atmospheric *(Mancinelli, 1995)*.

It was found that growth of methanotrophs and their methane oxidation capacity in the soil depend on many factors such as: temperature, pH, moisture content, size of particles, air-filled pore volume, and the content of nutrients, of organic matter, and of inhibitors. The factors could be classified as internal (resulting from the type of material) and external (resulting from climate). Some of the factors could be easily-controlled, creating conditions for effective biotechnological usage. The methane oxidation capacity depends primarily on the material in which the process occurs. The size and shapes of the structural elements of the material influence the methanotrophic properties of the material by determining its porosity and the surface area accessible for microorganisms. Soil porosity determines the gas diffusion rate and consequently the availability of substrates (CH_4 and O_2) for methanotrophs and the removal of gases resulting from the metabolism (CO_2). Diffusion also determines the depth of the oxidation zone in soil. Bender and Conrad (1995) found that, when the grain diameter decreases from above 2 mm to below 0.05 mm, the maximal methanotrophic activity is reduced and the time for soil to reach it lengthens, although the number of methanotrophs remains basically unchanged. The content of mineral salts and the pH value depending on chemical composition of the porous material also determined the methanotrophic activity and could be controlled.

The aim of the study was to examine the capacity for methane oxidation in two kinds of composite materials (perlite inoculated by loess soil mixed with compost and secondary minerals, such as zeolite and bentonite) subjected to continuous flow of methane for several months. We examined the changes in CH_4, CO_2, and O_2 concentrations, in organic carbon concentration, water content and temperature profiles in particular materials. Perlite was selected as a basic material of filter filling bed because of its porous structure (ensuring gas diffusion) and mechanical and chemical stability. The secondary minerals were added in order to increase of specific surface of the material, and the compost was the source of nutrients for bacteria. The process was not limited by lack of oxygen as atmospheric air was supplied together with the filtered gas stream from the bottom of the column.

MATERIALS AND METHODS

The experiment was carried out in PVC columns filled by two mixed materials based on perlite (each material in three repetitions):
-composite **A**: perlite +1% w/w $CaCO_3$+2% w/w loess soil taken from humus horizon+2% w/w. bentonite + 20% v/v compost (after 2.5 months of stabilization)
-composite **B:** perlite +1% w/w $CaCO_3$+2% w/w loess soil taken from humus horizon+2% w/w. slovakian zeolite (ground) + 20% v/v compost (after 2.5 months of stabilization)
The properties of the examined materials are shown in Table 1.

The mature municipal solid waste compost used in the experiment was taken from Municipal Solid Waste Treatment Plant in Warsaw. It was sieved by 1mm mesh before using. The perlite is a popular, commercially available mineral substrate used in plant cultivation.

The dynamic experiment was conducted in six PCV columns, 1 m of height and 5cm in diameter (see Figure 1). Each column was equipped with valves, which made it possible to flush it from the bottom with the mixture of methane, carbon dioxide and oxygen. The profiles of gases distribution were determined during the entire experiment. Gas samples and soil samples (when the steady state conditions were established) were taken by sampling ports distributed at 10 cm intervals along the columns. Each port was plugged with a septum in order to take the samples of the gas from particular depths. The bottom of the columns was shaped in the form of a funnel, which allowed free outflow of an excess of water. The lower parts of the columns were filled with gravel (4 – 8 mm) to ensure uniform access of methane to the filling material. A perforated plate was put on the gravel and 80 cm bed of the examined material was placed on it. The scheme of a single column is presented in Fig. 2.

The experiments were carried out under laboratory conditions, at a temperature of 22±2 ^{o}C. Each material was examined in three repetitions.

Table 1 Characteristics of the materials used in the experiment

Parameter *) (average values)	Composite A with zeolite	Composite B with bentonite
TOC [% s.m.]	4.3	4.2
Total Kjeldahl Nitrogen [% d.w.]	0.2	0.2
C:N ratio	21.5	21
Organic matter content [% d.w.]	9.5	9.5
Initial water content [% of dry weight]	65	96
Water holding capacity [% of dry weight]	159	168
Bulk density of wet material [g/cm^3]	0.438	0.485
$CaCO_3$ content [% d.w.]	5.6	5.8
pH in H_2O,	8.29	8.15

** Determination methods: Total organic carbon – Tiurin method; Organic matter content – loss of ignition (500^{o}C), Total nitrogen – Kjeldahl method, Water content – loss of drying (105^{o}), bulk density – cylinder method; carbonate content- Scheibler method, pH –potentiometer method.*

Single column imitates a biofilter likely to be used for oxidation of methane produced in landfill waste layer. Biofilter should work under open air conditions therefore the upper part of column was open in the course of the experiment. The columns were tightly closed only during the measurement of oxidation capacity.

Figure 1 Experimental setup

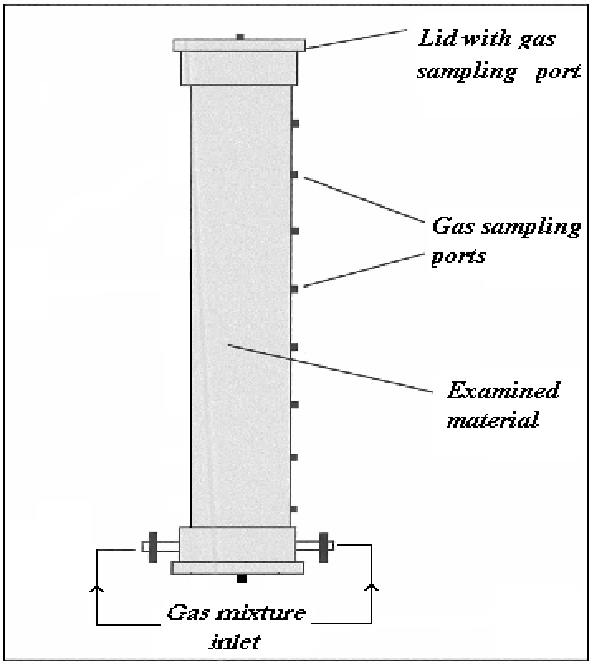

Figure 2 Scheme of the construction of single column used to assessment of CH_4 oxidation capacity in the dynamic system

The gas mixture (11.5% of CH_4 + 11.5% of CO_2 +15.5% of O_2 and 61% of N_2) was applied to the base of each column at a rate of 16 cm^3min^{-1} for six months. Daily load of methane for one column was ca. 1300 $dm^3m^{-2}d^{-1}$. Methane (99.95%) and CO_2 (99.95%) were supplied from gas tank. Oxygen was supplied together with nitrogen from atmospheric air by a compressor. Stability of gas mixture composition and gas stream flow rate were provided by 9 digital gas flow controllers (Brooks Instruments.

Quantitative composition of gas taken from the columns was determined by Gas Chromatograph (Shimadzu 14B). Gas samples were analysed with the use of a thermal conductivity detector (TCD) fitted with glass packed columns. The Porapak Q column (2 m x 3.2 mm I.D.) was used to determine CH_4 and CO_2 concentrations. The oxygen concentrations were measured by the column (3 m x 3.2 I.D.) packed with Molecular Sieve 5A. The parameters used for the analysis were as follows: injector 40^o C, column oven 60^o C, detector 60^o C and current bridge 150 mA. The carrier gas was helium with a flux rate of 40 cm^3 min^{-1}. Peak areas were determined by the computer integration program (CHROMAX 2007 version 1.0b). Detection Limit for CH_4 was 0.01%.

Profiles of CH_4, CO_2 and O_2 concentration in the column were determined on the basis of composition of gas samples (100 μl) taken by gas syringe from gas sampling ports placed along the column.

Water content was determined as a loss of mass after drying. The soil samples (1.5g) were taken up from different depths of the columns (at the end of the experiment) and dried at temp 105 ^{o}C during 24 hours. After this time the loss of weight was measured and the water content was calculated in relation to dry mass of the material.

Thermovisual camera Therma CAM^{TM} E45 (FLIR) was used for temperature measurements in the columns. The parameters used were as follows: background temperature 23 ^{o}C, emissivity 0.9.
Organic matter was determined by ignition loss method. The soil samples taken up from different depths of columns (at the end of the experiment) and dried out at a temperature of 105^{o}C, were calcinated in muffle at temp 500 ^{o}C by 24 hours. Loss of ignition was the basis for calculation the organic matter content in relation to dry weight.

In order to determine the methane oxidation capacity, the columns were closed tightly for 15 minutes by the upper lid equipped with rubber stoppers. A plastic tube was connected to each lid in order to prevent the headspace from the gas pressure increase (due to gas inflow) and thus from the effect on the gas flow rate. Then 0.05 cm^3 gas samples were taken from the headspace after 5, 10 and 15 minutes. Next, they were analysed for CH_4 and CO_2 concentrations by gas chromatography, as described above. The methane oxidation capacity (Q) was calculated on the base of methane concentration increase in the headspace measured in the determined time. This value was compared with the rate of methane supply to the base of the column. In this way, the methane oxidation capacity was obtained. Next, the per cent of CH_4 oxidation was calculated:

Per cent of CH_4 oxidation (Oxidation efficiency) = 100% - ($V_{out.}/V_{in.}$ x 100%)

Where, V_{out} - the rate of CH_4 emission from the column,

$V_{in.}$ - the rate of CH_4 supply to the base of the column.

In order to determine the number of bacteria the soil samples were taken from the depths: 10, 30 and 50 cm and were extracted by using 0.9% NaCl with detergent addition due to rinsing of bacteria cells from the surface of the solid phase. The plate method was use for determination of the number of methanotrophs. Volume of 0.2 cm^3 of proper dilution suspensions derived from soil were poured on Petri plates with NMS medium and were evenly distributed. Three different dilutions were cultured (each in three repetitions). The plates were incubated at 28°C with the mixture of CH_4 (5%) and atmospheric air.

RESULTS AND DISCUSSION

Methane Oxidation Capacity and Efficiency

Efficiency of methane oxidation in the examined filling bed at the end of the experiment was estimated at 89.4% ± 6.7 in composite with bentonite and 98.85% ± 0.75 in the composite with zeolote. The capacity of methane oxidation was very high in comparison to literature data. De Visscher et al. (1999) found the value about 336 $dm^3m^{-2}d^{-1}$ in simulated landfill cover. Stein and Hettiaratchi (2001) reported the value of 270 $dm^3m^{-2}d^{-1}$ measured in column experiment filling by soil from landfill cover. Only the value reported by Streese and Stegmann (2003) in compost material was similar.

They found very high methane oxidation capacity measured over the first 100 days of the experiment (equal to 1314 $dm^3m^{-2}d^{-1}$) but after few months CH_4 oxidation capacity decrease to 320 $dm^3m^{-2}d^{-1}$.

Table 2 Parameters characterizing methane oxidation potential of the examined materials

	Composite with bentonite	Composite with zeolite

Methane oxidation capacity [$dm^3 m^{-2}d^{-1}$]	1250 ± 94.3	1383.9 ± 10.5
Methane oxidation efficiency [%] (CH_4 load = 1400 $dm^3m^{-2}d^{-1}$)	89.4 ± 6.7	98.9 ± 0.8

The capacity of methane oxidation measured by us was still showing the upward trend. Probably the values presented in Table 2 are not the maximum values possible to achieve in the examined materials. The capacity of methane oxidation in composite with bentonite was growing of about 4% while in the composite with zeolite of about 6% during one month time.

Profiles of CH_4, CO_2 and O_2 Concentration

Methane concentration in the gas mixture was ca. 11.5 (v/v). A decrease of CH_4 concentration towards upper parts of the columns (to the value ca. 7-8%) was observed during the experiment (Fig.2). The scheme of CH_4 distribution in the columns was similar in both materials. The differences are not statistically significant. Average value of methane concentration in composite with bentonite is 9.2%, and in the composite with zeolite is 9.9%.

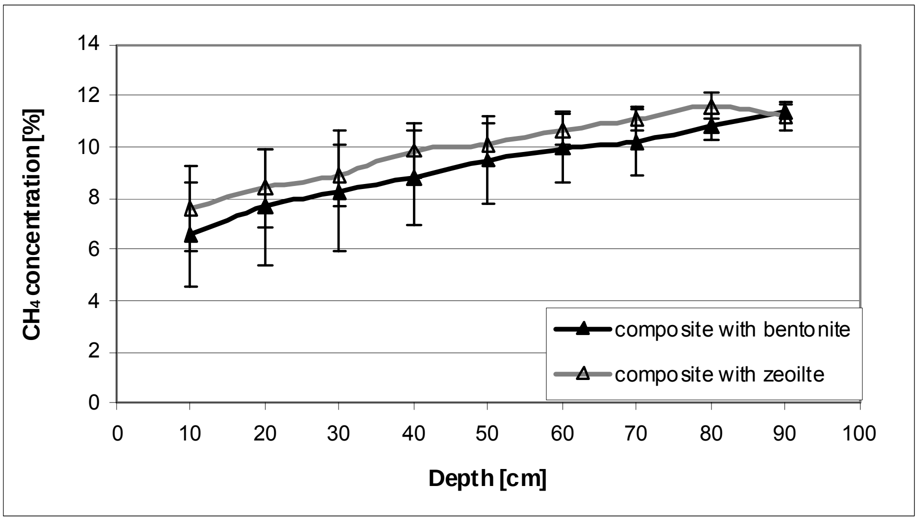

Figure 2 Profiles of CH_4 concentration in particular filling beds (average values and standard deviations) measured in the last months of the experiment

At the first stage of the experiment the filling beds did not contain compost. Perlite was inoculated only by soil taken out from A horizon of arable loess soil. But the efficiency of methane oxidation was very low in these materials and the municipal waste compost was added in the 3rd month of the experiment. The methane oxidation potential of the tested beds increased after that significantly, what suggests that the process was limited by the availability of nutrients. Compost addition caused changes in the methane concentration profiles in both the materials Methane concentration started to decrease significantly (Fig. 3).

The concentration of CO_2 in gas mixture supplied to the column was ca 11 b.5%. The increase of CO_2 concentration was observed during the methane oxidation in the columns. CO_2 is a product of CH_4 oxidation; additionally it is also the product of organic matter mineralization. The average values of CO_2 concentration were 12.8 in composite with zeolite and 13.3 in the other material.

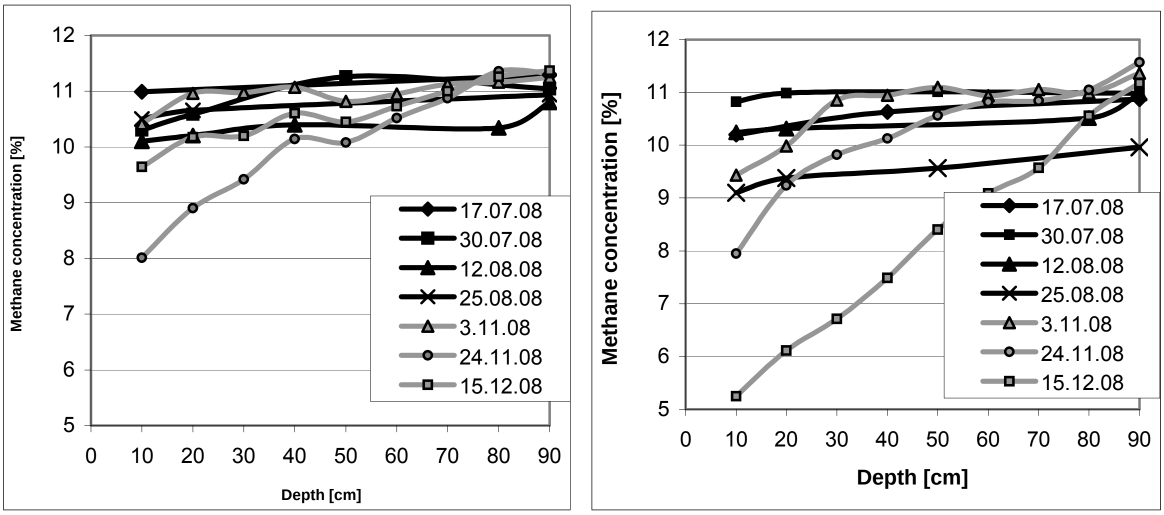

Figure 3 Profiles of CH_4 concentration in the composite with zeolite (a) and bentonite (b) before (black curves) and after (grey curves) compost addition

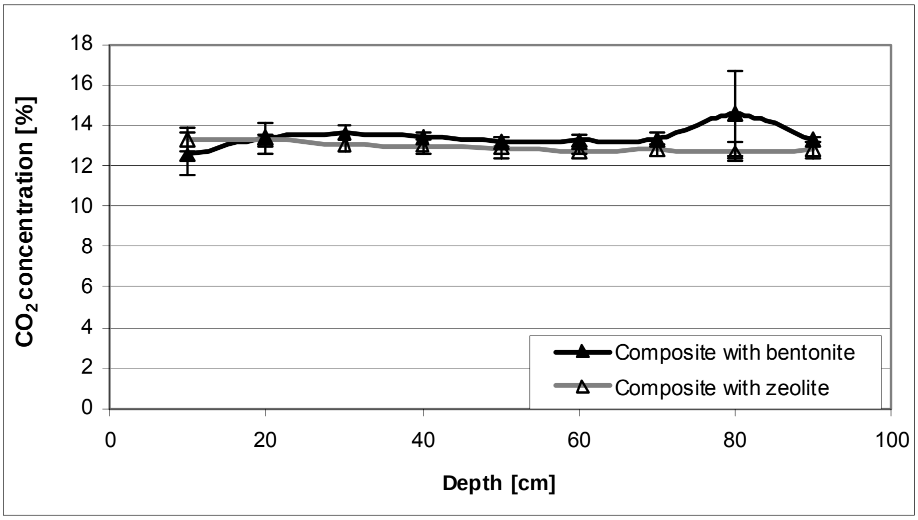

Figure 4 Profiles of CO_2 concentration in particular filling beds (average values and standard deviations) measured in the last months of the experiment

The columns were purged by the gas containing about 18% of oxygen. During biofiltration oxygen was consumed due to methane oxidation and organic matter mineralization. Concentration of O_2 decreased slightly towards column surface, reaching the value of 9.0% at a depth of 10 cm in the composite with bentonite and the value of 12.5% in composite with zeolite (Fig. 5). Lower O_2 concentrations were observed in the filling bed containing bentonite what could be connected with limitation of gas diffusion (higher water content).

Profiles of Water Content

Water is a product of methane oxidation therefore the water content in the biofilter bed should increase during the biofiltration. The properties of bed material influence the water holding properties. The water content profiles were changing in the course of the experiment. Initial water content of both the materials oscillated around the value of 70% in the composite with zeolite and around 90% in the composite with bentonite. Profiles of water content (average values and standard deviations) are presented in Fig 6. The changes of moisture content in profiles of the both tested materials were not important. Significant decrease caused by drying influence the gas stream flow was observed only at the depth 90 cm. Water content in composite with zeolite ranged from 83 to 102% w/w and from 97% to 126% in the composite with bentonite.

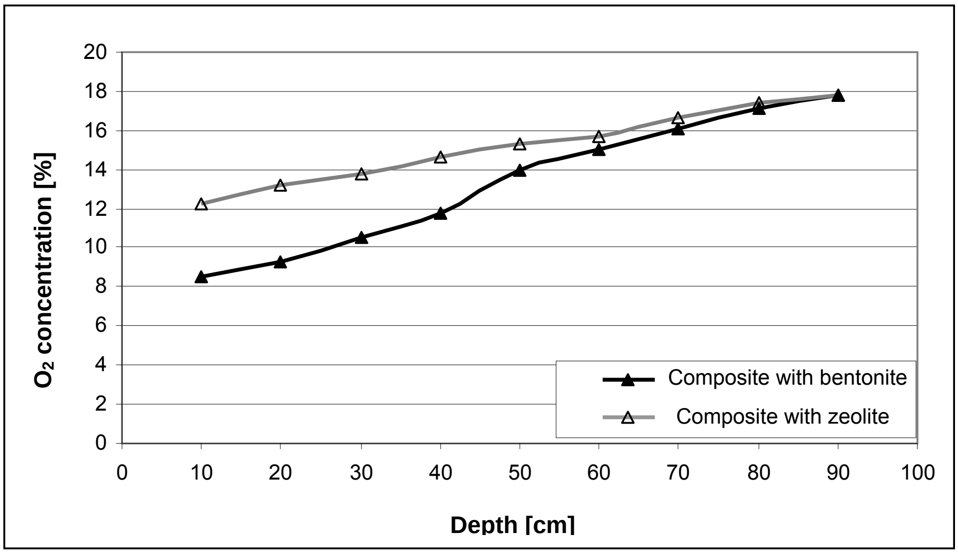

Figure 5 Profiles of O_2 concentration in particular filling beds (average values and standard deviations) measured in the last months of experiment

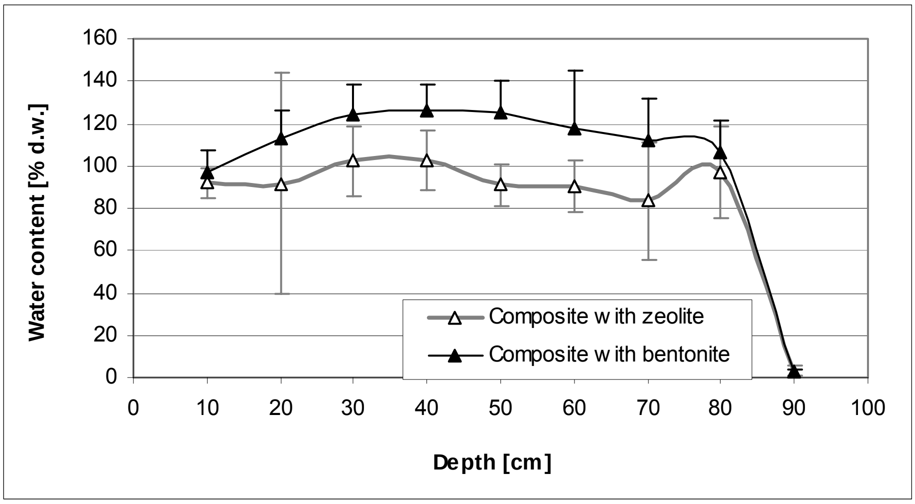

Figure 6 Profiles of water content in the composites at the end of the experiment

Profiles of the Temperature

Biochemical oxidation of methane is an exotermic process so the changes of temperature of the filling bed could be considered as an indicator of the reaction intensity. The profiles of temperature distribution in both the examined materials determined in the 6-th month of the experiment are presented in Fig. 7. Average temperatures in the profiles of both the composites were similar: 21.8^{o}C in the zeolite composite and 22.1^{o}C in the bentonite composite. The temperatures were semi-stabile up to the depth of 70cm. Significant decrease of temperature was observed below this depth.

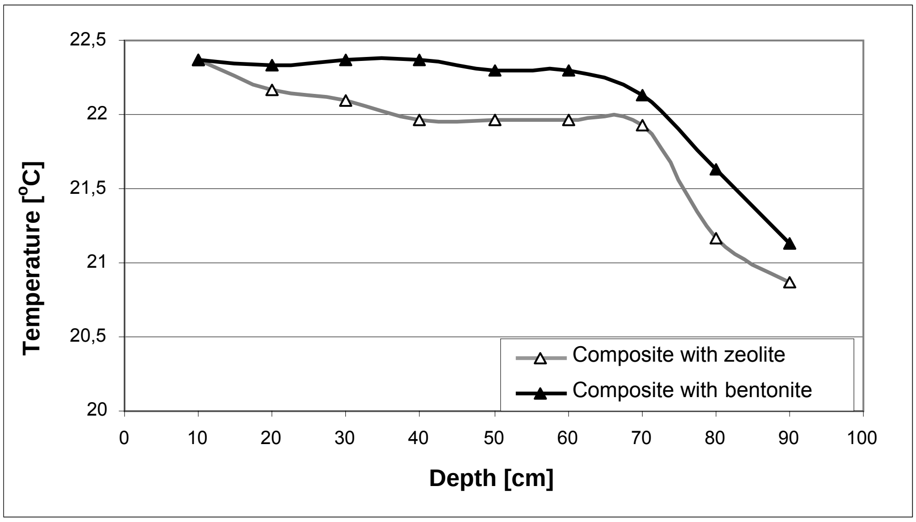

Figure 7 Profiles of temperature in the examined material at the end of the experiment

Profiles of Organic Matter Content

An increase of organic matter content (OMC) was observed in each column in the course of the experiment. Average value of OMC in composites was 9.5 ±1.15% d.w. while average value of OMC at the end of the experiment in the composite with zeolite was 15.85% d.w. and in the composite with bentonite was 16.86 % d.w. An increase of OMC in relation to the initial value was 67% in first material, and 77.5% in the second. The largest difference between the maximum and minimum values of OMC in the profile, observed at a depth of 90 cm and 10 cm was equal 9.76% in composite with zoelite, and 6.3% in composite with bentonite. It suggests that the biomass growth in the bentonite composite was smaller.

There are no statistically significant differences in organic content matter at particular depths of both the materials (Fig. 8). The organic carbon (OC) content decreased with depth from maximum values near the surface to the minimum value at the bottom.

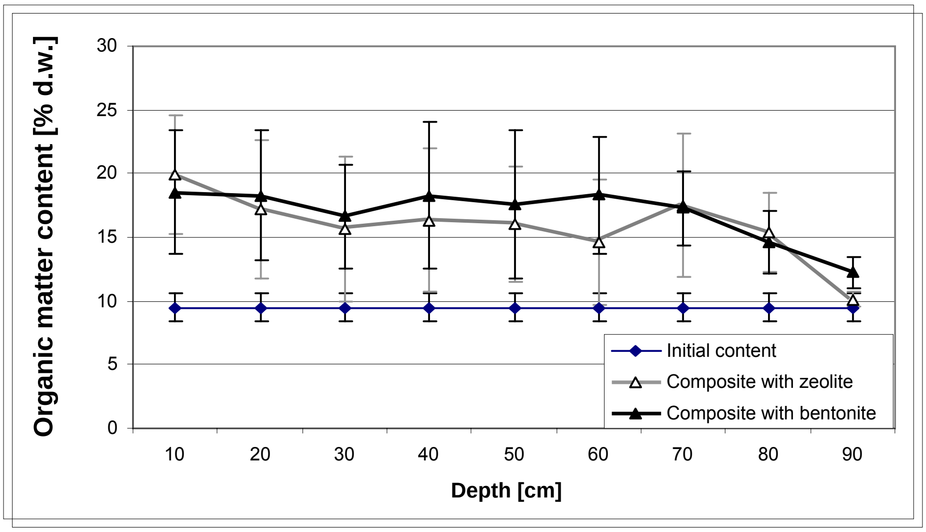

Figure 8 Profiles of organic matter content in the materials at the end of the experiment

Number of Methanotrophic Bacteria in the Column Profiles

Number of bacteria in examined part of the column was similar at every depth. It varied from $2.53 \cdot 10^6$ to $1.55 \cdot 10^7$ in the zeolite composite and from $5.53 \cdot 10^6$ to $1.81 \cdot 10^7$ in the bentonite composite. Significantly lower amount of bacteria cells was observed at a depth of 90 cm. It was connected with desiccation of the bed surface by gas stream flow (soil moisture was very low at this depth in every column). Lack of a significant differentiation of bacteria number results from good accessibility of substrates (methane and oxygen) at each depth of columns.

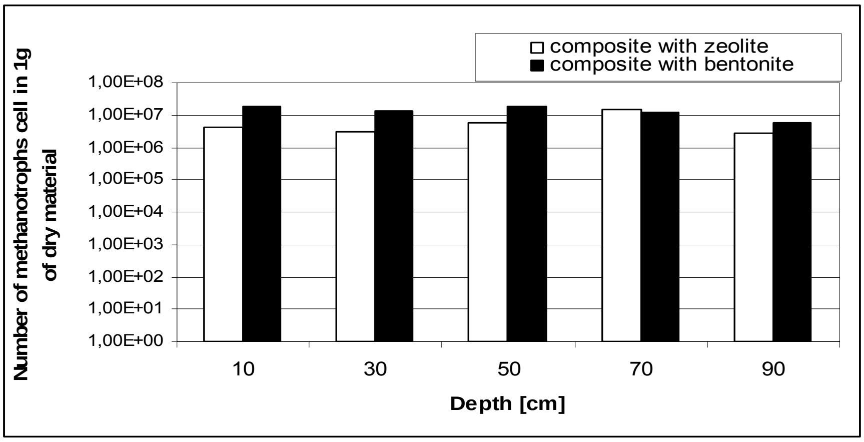

Figure 9 Number of methanotrophic bacteria (average values) in perlite filling beds at the end of the experiment

CONCLUSIONS

The results of the investigations carried out on two kinds of mineral-based filling bed of actively aerated biofilter suggest that:

- The methanotrophic capacity measured in the composite with zeolite was higher (1383.9 ± 10.5 $dm^3m^{-2}\ d^{-1}$) than that of the composite with bentonite (1250 ± 94.3 $dm^3\ m^{-2}\ d^{-1}$). The efficiency of the process was equal to 98.9% ± 0.8% and 89.4% ± 6.7%, respectively.
- Methane oxidation in perlite inoculated only by arable soil taken from organic horizon was negligible. The capacity of methane oxidation increased significantly after compost addition.
- The profiles of CH_4 and CO_2 concentrations in both materials were not significantly different
- Values of average temperature were similar in both the materials. They were: 21.8°C in the composite with zeolite and 22.1°C in the composite with bentonite.
- The profiles of organic matter content were not significantly different in the examined materials. Average value of organic matter content in the composite with zeolite was 15.85% and 16.86% in the case of bentonite addition.
- The number of bacteria responsible for methane oxidation was similar in both the filling beds. It varied from $2.53 \cdot 10^6$ to $1.55 \cdot 10^7$ in zeolite composite and from $5.53 \cdot 10^6$ to $1.81 \cdot 10^7$ in bentonite composite.

It can be summed up, that the mineral-based materials such as a mixture of perlite and compost could be an effective filling bed of biofilter for reduction of landfill methane emission. Type of secondary mineral used as a supplement increasing the specific surface area of the filling bed did not affect the methane oxidation capacity. It could be expected that mineral basis of the bed will ensure longer activity of the biofilter because of mechanical and chemical resistance of the material. High porosity of the materials can limit the consequences of pores clogging by exopolimeric substances produced by the methanotrophic bacteria.

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Solid Waste and Climate Change: Perceptions and Possibilities

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ABSTRACT

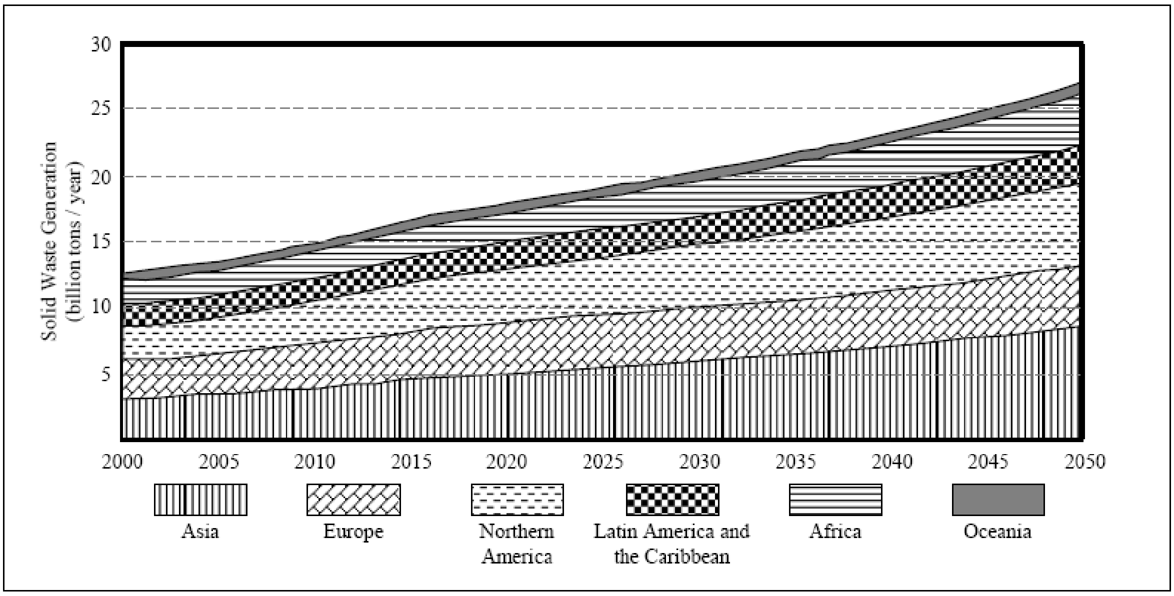
Climate change is a serious international environmental concern and the subject of much research and debate in recent years. It is estimated that 3.4 % of Green House Gases (GHGs) emit from waste sector and contributes to one fifth of global anthropogenic sources. Eventhougth the contribution is very small but still matters and it needs immediate actions to mitigate. Since, the world population is increasing day by day; the per capita waste generation also getting amplified consequently, lead to failure of proper waste disposal practices especially from developing countries. The unscientific method of waste disposal continuously emits GHGs, which is ultimately contributing to the global climate change. Hence, mitigating GHG emissions from proper waste management practices is to be given priority in developing countries. Compared with the other 15 sectors which are listed under Kyoto protocol, controlling and reducing GHG emissions from waste sector seems to be cost effective through Clean Development Mechanism (CDM). CDM is one of the flexible mechanisms, which acts as a mean and technology transfer from developed to developing countries. This could lead to sustainable development of the host countries as well as economically reduces GHG emissions. Hence, there is a great possibility in reducing GHG emissions and associated climate change impacts through appropriate waste management practices.

INTRODUCTION

The current generation encounters large number of problems which has multidimensional impact on all the life forms existing on the earth. One of the thriving problems is that of global warming and climate change mainly due to the anthropogenic release of GHGs i.e., mainly CO_2 and CH_4. The major consequences due to global warming were documented in recent days and they are:

- Rise in sea level due to melting of glaciers from Arctic and Antarctic regions;
- Frequently occurring natural disasters like, cyclones, earthquakes, heat waves, flood, high drought and spreading of epidemic diseases;
- Reduction in agricultural crop yield due to shifting of local climatic variables; and
- Loss in biodiversity and impacts on ecosystem is leading to change in entire food web.

As clearly declared in the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report on ‘‘Climate Change”, mitigation of GHG emissions is now required to tackle global warming and to reduce its associated environmental consequences. Various anthropogenic sources contribute to this problem and aggravate its effects including burning of fossil fuels for purposes like power generation, vehicular propulsion and industrial usage, deforestation, agriculture and waste sector. Among the number of anthropogenic sources, Municipal Solid Waste (MSW) and Wastewater (WW) are grouped under waste sector and which is considered as one of the significant sources for contributing global climate change. In most of the developed and developing countries with increasing population and urbanization, it remains a major challenge for municipal/local authorities to collect, recycle, treat and dispose of increasing quantities of MSW in a proper way. The amount of MSW generated and its physico-chemical characteristic varies with country, population, cultural habits and seasons. Figure 1 depicts the trend in MSW generation from developed and developing countries. It is observed that the solid waste generation ranged between 0.1 and 0.5 t/capita/year in low-income countries; whereas, between 0.2 and 0.6 t/capita/year in middle-income countries; 0.3 and 0.8 t/capita/year in high-income industrialized countries (Bogner et al. 2007).



Source: Yoshizawa (2007)

Figure 1 Prediction of global MSW generation rate

Further, the biodegradable food materials and yard wastes normally dominate in MSW of developing Asian countries while paper and hardboard dominate in developed countries (Visvanthan and Trankler 2004). It envisages that the appropriate treatment technology for organic waste is to be considered prior to final disposal to mitigate GHG emissions from these countries.

WASTE MANAGEMENT IN DEVELOPING ASIAN COUNTRIES

Due to increasing economic growth rate and population the per capita MSW generations in Asian countries were expected to increase and far exceed than the developed countries. Generally, MSW collection and segregation is managed by the respective municipal and local bodies in the country. The predominant waste collection system in most of the Asian cities is through communal bins and door to door collection system. High fractions of organics (more than 60 %) lead to a dense and humid waste that affects the collection and transport system. Hence, the percentage of collected MSW to the amount of disposed MSW varies between 22 and 80%.

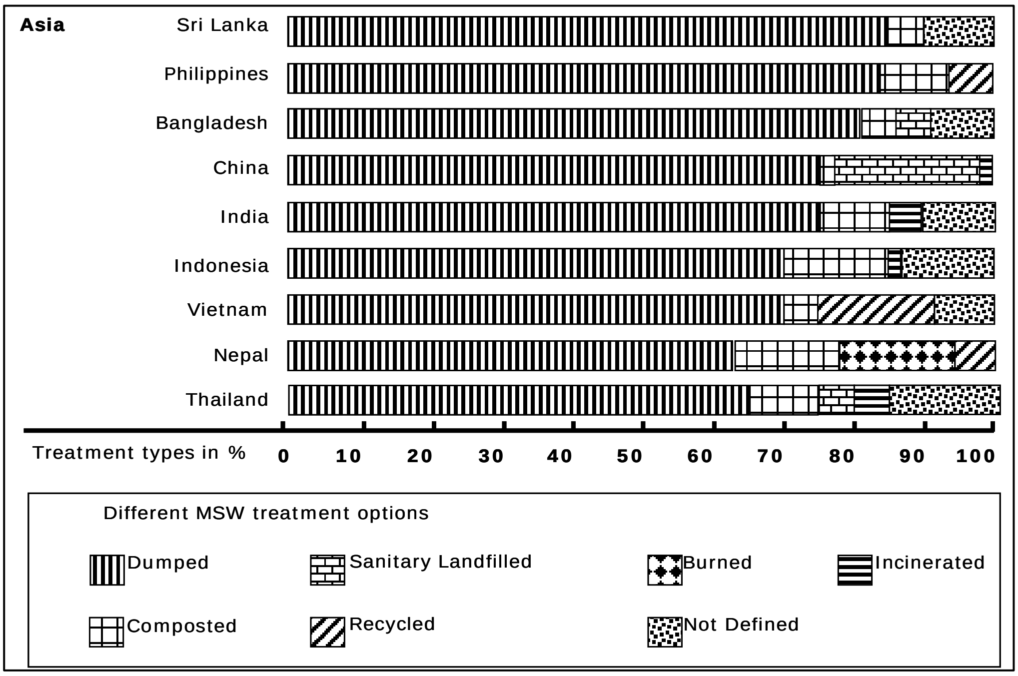
Table 1 depicts the percentage distribution of individual components in MSW from major Asian countries. The low proportion of recyclables in MSW can be attributed to the market value of recyclables. In developing economies, recycling occurs at every stage of the system, leaving only a small portion that ultimately reaches the open dumps/landfills for final disposal. However, income level, economic growth, lifestyle, and location strongly influence MSW composition and also collection/recycling efficiency.

Table 1 MSW composition from developing countries

Host Country	Physical composition of MSW (all values are given in %)					
	Organic components	Paper	Plastic	Glass	Metal	Others
India	41.8	5.7	3.9	2.1	1.9	44.6
Nepal	80.0	7.0	2.5	3.0	0.5	7.0
Bangladesh	84.4	5.7	1.7	3.2	3.2	1.8
Thailand	48.6	14.6	13.9	5.1	3.6	14.2
Myanmar	80.0	4.0	2.0	0.0	0.0	14.0
Indonesia	70.2	10.6	8.7	1.7	1.8	7
Philippines	41.6	19.5	13.8	2.5	4.8	17.8
Malaysia	43.2	23.7	11.2	3.2	4.2	14.5
Japan	31.2	44.8	9	7	6	2

Source: World Bank, 1999

Figure 2 illustrate the various MSW disposal practices from developing Asian countries. Looking at the most common disposal methods, open dumping dominated than any other waste disposal method and an associated environmental problem such as GHG emissions, is also serious from these countries. Since the waste management decisions are often made locally, without direct consideration of GHG mitigation; it is likely that the importance of the waste sector for reducing emissions has been underestimated from developing countries. Therefore, good waste management practices are to be considered to promote GHG mitigations.



Source: Collaborative Working Group (CWG), 2009

Figure 2 Distribution of commonly used MSW disposal technologies from developing Countries

GHG EMISSIONS FROM WASTE DISPOSAL PRACTICES

The waste sector is accountable for approximately 5 % of the global green house; about 1,300 $MtCO_2$-eq in 2005 as reported by IPCC (4^{th} assessment report). This 5% consist of methane (CH_4) emission from anaerobic decomposition of solid waste and carbon dioxide (CO_2) from wastewater decomposition. Only CH_4 is accounted for the estimation of GHG emissions from solid waste management practices not CO_2 despite its Global Warming Potential (GWP) upon release. This is mainly due to the general consensus that CO_2 is of biogenic origin (IPCC, 2006).

Landfilling, composting and incineration are considered as the most common treatment technologies for MSW worldwide. Among them landfilling is expected to increase due to developing countries movement away from open dumping to landfilling. Various independent theoretical and experimental studies suggest a large variation of GHG generation from 1 tonnes of waste, ranging from 40 m^3 to 250 m^3 and reviewed by Lou and Nair (2009). This is understandable as Landfill Gas (LFG) generation is highly dependent on a variety of factors; for example waste composition is one crucial factor determining GHG emissions. However, the existence and continual usage of landfills now and in the future cannot be denied. Not all waste can be composted or recycled, and a certain portion of waste will inevitable is landfilled.

Composting of organic waste has been widely acknowledged as an alternative to landfills in order to reduce the GHG emissions. Aerobic decomposition from well managed composting results in the emission of CO_2 and H_2O. Due to the heterogeneous nature of a compost pile, some CH_4 may emit from anaerobic pockets formed within the piles (Bogner et al. 2007). The studies have shown that the majority of this CH_4 getting oxidized in to CO_2 in aerobic pockets and near the surface of the compost pile, making CH_4 emission negligible while composting. Hence, composting of organic fraction of MSW avoid the methane emissions directly as well indirectly by avoiding open dumping.

Technology applications for thermal recovery (direct combustion of waste to recover heat) and fuel recovery (Refuse Derived Fuel - RDF and Packaging Derived Fuel - PDF production from waste) are not observed in most of the developing Asian countries. These technologies are found to have been best applied only in the developed countries. Current estimate of GHG emissions from waste incinerators is about 40 $MtCO_2$-eq/yr, or less than one tenth of landfill CH_4 emissions worldwide. Although some pilot models have proved successful in developed countries, many details are yet to be determined in terms of implementation necessitating further research.

Waste recycling on the other hand reduces greenhouse gas emissions by preventing direct landfilling or open dumping of valuable and by preventing the consumption of energy for extracting and processing raw materials. The magnitude of avoided GHG-emissions benefits from recycling is highly dependent on the specific materials involved, the recovery rates for those materials, the local options for managing materials, and (for energy offsets) the specific fossil fuel avoided (Smith *et al.* 2001).

Life cycle activities associated with the different waste management strategies are not included in the IPCC emission calculations. However, for a more holistic approach, streamline life cycle activities should also be accounted when quantifying a waste management strategy impact on GHG emissions.

CDM AND GHG EMISSION MITIGATION IN WASTE SECTOR

At present, developing countries have no obligations to constrain their GHG emissions. But they are still able, on a voluntary basis, to contribute to global emission reductions by hosting projects under the Clean Development Mechanism (CDM). This could lead to sustainable development of the host countries as well as economically reduce greenhouse gas emissions globally. As of May 2009, the number of CDM projects in pipeline counted to be greater than 4,200 out of which 1,640 projects were registered with the annual average Carbon Emission Reduction (CER) of 301,268,738 CO_2-eq till the end of year 2012.

Around 17.4 % (≅349 projects) of the CER is distributed from Sector 13 i.e., waste handling and disposal as shown in Figure 3. It can be seen that the maximum number (around 60 %) of CDM projects are in the Energy sector and that many are small renewable projects occurring in more than 40 countries. The registered CDM projects under Sector 13 with individual breakup from developing Asian countries including India, Bhutan, Nepal, Bangladesh, Thailand, VietNam, Myanmar, Cambodia, Indonesia and Philippines were presented in Table 2. From these developing countries only 62 projects were registered for CDM under sectoral scope 13 which is equivalent to 39,98,759 CO_2-eq of CERs.

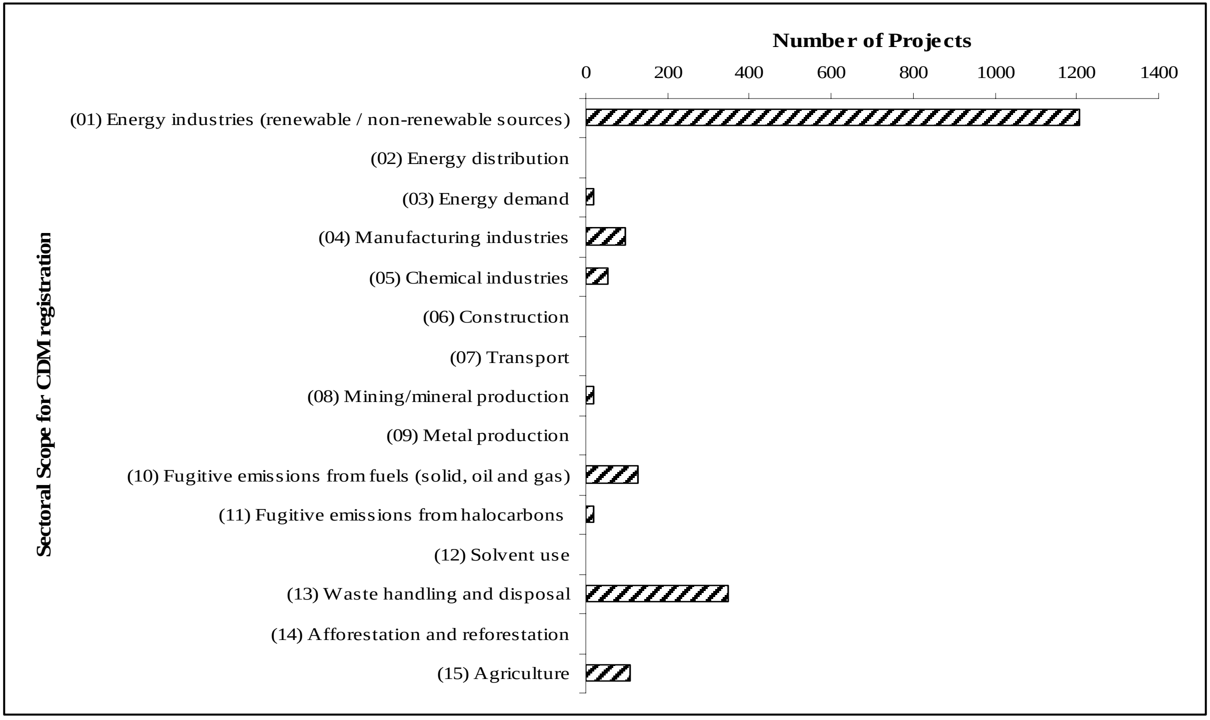


Figure 3 Distribution of CDM projects under different sectoral scope of UNFCCC

The projects are further inventorized under three main groups *viz.,* MSW, wastewater and others. The total number of projects registered under wastewater treatment appears to be maximum, where as CERs comparatively lesser (1,691,096 CO_2-eq) than the solid waste category (1,922,503 CO_2-eq). Out of 17 projects from developing countries in Solid waste category, composting of OF-MSW dominated than any other waste disposal practices. Whereas, the LFG recovery from landfills (account for 10.15% of emission reductions) dominated from developed countries viz., Latin America, Carribean Region and Brazil and around 95 % of the registered LFG projects are occur under CDM. Some projects are flaring gas, while others are using the gas for on-site electrical generation or direct project use. In general, costs and potential for reducing GHG emissions from waste sector are usually based on landfill CH4 as the baseline. When reporting to UNFCCC, most developed countries take the dynamics of landfill gas generation into account; however, most developing and non-reporting countries do not as said by Bogner et al. (2007).

Table 2 Registered CDM projects and GHG reduction from developing countries

Host Country	Solid Waste		Wastewater		Others*		Total	
	Number of Projects	MT CO_2 reduction / annum	Number of Projects	MT CO_2 reduction / annum	Number of Projects	MT CO_2 reduction / annum	Number of Projects	MT CO_2 reduction / annum
India	6	5,33,508	8	2,51,441	5	1,38,811	19	9,23,760
Bhutan	0	0	0	0	0	0	0	0
Nepal	0	0	0	0	0	0	0	0
Bangladesh	2	1,69,259	0	0	0	0	2	1,69,259
Thailand	1	47,185	11	8,05,866	0	0	12	8,53,051
VietNam	2	2,79,969	0	0	0	0	2	2,79,969
Myanmar	0	0	0	0	0	0	0	0
Cambodia	0	0	1	50,036	1	51,620	2	1,01,656
Indonesia	3	1,80,192	6	4,49,352	1	1,66,000	10	7,95,544
Philippines	3	7,12,390	11	1,34,401	1	28,729	15	8,75,520
Total	17	19,22,503	37	16,91,096	8	3,85,160	62	39,98,759

Source: Sectoral Scope 13-Waste handling and disposal, UNFCCC- http://cdm.unfccc.int/Projects/projsearch.html

Incinerations have been widely applied in many developing and developed countries, especially those with limited space for landfilling such as Japan and many European countries. Globally, about 130 million tones of waste are annually combusted in more than 600 plants in 35 countries. The UNFCCC has also approved three municipal waste incinerators with 450,813 MT CO_2-eq reductions by treating MSW from developing countries in recent years. According to the CDM project database, the first few registered incineration projects are listed below from developing Asian countries,

- In November 2007, the CDM approved a project with two new municipal waste incinerators near Delhi, India (TIMARPUR-OKHLA Waste Management Company Pvt Ltd's (TOWMCL) integrated waste to energy, Project 1254).
- In May 2007, the CDM funded a gasification incinerator project for municipal solid waste in Bali, Indonesia (PT Navigat Organic Energy Indonesia Integrated Solid Waste Management (GALFAD), Project 0938).
- In April 2007, the CDM funded a refuse derived fuel incinerator for municipal solid waste in India (Shriram Energy Systems Ltd (SESL) 6 MW Municipal Solid Waste Based Power Project at Vijayawada & Guntur, Andhra Pradesh, Project 0959).

Compared to waste incineration and composting processes, which only mitigate future emissions, landfill gas recovery and flaring reduces GHG emissions from waste landfilled in previous years. Most of the developing countries do not consider these temporal issues since the waste is dumped unscientifically in vacant lands.

INTEGRATED SOLID WASTE MANAGEMENT AND GHG MITIGATIONS

The mitigation of GHG emissions from waste must be addressed in the context of Integrated Solid Waste Management (ISWM). The major ISWM activities are waste prevention, recycling and composting, and combustion and disposal in properly designed, constructed, and managed landfills. Also pretreatment of waste by Mechanical-Biological Treatment (MBT) is another approach, which can reduce the significant volume of waste for further treatment. These different waste management activities have varying impacts on energy consumption, GHG emissions, and carbon storage as shown in Table 3. Therefore, the mitigation of GHG emissions from waste relies on multiple technologies, whose application depends on local, regional and national drivers for both waste management and GHG mitigations. For example, recycling of waste has its own carbon related benefits (direct and indirect) in terms of saved energy, conserved resources, avoided extraction of ores, transporation etc.

Table 3 Waste management strategy and GHG sinks

	GHG Sources and Sinks		
MSW Management Strategy	**Raw Materials Acquisition and Manufacturing**	**Changes in Forest or Soil Carbon Storage**	**Waste Management**
Source Reduction	Decrease in GHG emissions. Relative to the baseline of manufacturing	Increase in forest carbon sequestration (for organic materials)	No emissions/sinks
Recycling	Decrease in GHG emissions due to lower energy requirements (compared to manufacture from virgin inputs) and avoided process non-energy GHGs	Increase in forest carbon sequestration (for organic materials)	Process and transportation emissions associated with recycling are counted in the manufacturing stage
Composting (food discards, yard trimmings)	No emissions/sinks	Increase in soil carbon storage	Compost machinery emissions and transportation emissions
Combustion	No change	No change	Non-biogenic CO_2., N_20 emissions. Avoided utility emissions, and transportation emissions
Landfilling	No change	No change	CFL emissions, long-term carbon storage, avoided utility emissions. And transportation emissions
Anaerobic Digestion	Reduces the fuel energy consumption	Increase in soil carbon storage	Plant machinery emissions, Transportation emissions

Source: USEPA, 2002

A SCENARIO FOR MSW MANAGEMENT AND GHG MITIGATIONS

Considering typical Asian city as a case with a living and floating population of 1 million and percapita MSW generation of 1kg/day, the total waste being managed by the year is around 365,000 tons. It is assumed that the percentage distribution of individual components in the waste stream as given in the Table 4 for calculating GHG emission and mitigation. The organic fraction of 60 % (219,000 t/year) from the MSW can be source segregated either for composting or anaerobic degradation. The plastics (4%), paper (6%), glass (2%) and metal (1%) contents which are approximately contributing to that of 47,450 t/year can be collected separately for appropriate recycling to mitigate GHG emissions and the remaining 23 % (83,950 t/year) of inert can be landfilled. The chemical characteristics considered as Carbon (30 %), Nitrogen (1.1 %) and Moisture (55 %) in MSW. The three different scenarios were considered i.e., composting and anaerobic digestion for organic waste in the study based on the review of most common waste disposal method prevailed in the developing Asian countries and integrated with recycling of valuables for GHG emission calculation. Landfilling option is not considered since difficulties in getting lands for operation in the present scenario from developing countries.

Table 4 Typical waste composition considered for scenario development

Waste Components	Distribution (%)	Total Quantity (t/year)
Organic contents	60	219,000
Paper	6	21,900
Plastics	4	14,600
Glass	2	7,300
Metal	1	3,650
Wood	1	3,650
Green waste	3	10,950
Inert materials	23	83,950
Total	**100**	**365,000**

Scenario -1: Composting

In this scenario it is assumed that the biodegradable organic content from the MSW is completely stabilized by aerobic windrow composting method and used as manure. Biological conversion factor for composting is assumed i.e., 0.084 for the GHG emission calculation. It is estimated that around 18,396 t CO_2 will be emanate from the complete biological conversion of organic components from the MSW under aerobic conditions. But generally composting process will be extended between 30 and 45 days until getting C/N ratio of less than 20, since, the complete biological conversion of C content will take long time. Hence, the correction factor of 0.5 is applied in the GHG emission calculation assuming that only 50 % of organic content is processed/converted under composting technology in the field. Finally around 9,198 t CO_2 will be estimated to release from the composting process and remaining C content will be applied to the C sink soil. Since the CO_2 emission from the biodegradable organic is considered as biogenic, the emission of 9,198 t CO_2 will not be considered as mitigation of GHG. But the composting of biodegradable organics will avoid the uncontrolled dumping of waste in open dumps, which is considered to be the major setback for developing country and continuous source of methane emission.

Scenario -2: Anaerobic Digestion

In this scenario, the anaerobic treatment of organic fraction is considered for mitigating GHG emissions from MSW. The organic conversion factor of 0.029 along with the correction factor of 0.7 (70% of organic fraction converted into biogas) is considered to calculate equivalent CO_2 emission. It is estimated that 4,445 t CO_2 will be released at the end of anaerobic degradation and the digestate can be applied to C sink soil with proper pretreatment. Methane captured from the digestion process translates to 3,219 t CO_2 equivalent, which can be used as fuel for energy production that will intern reduce the consumption of fossil fuels. The digestate from the anaerobic reactor can be applied to C sink soils as manure after proper treatment.

Scenario -3: Reduce, Reuse and Recycling

In this scenario, it is considered that the valuable materials either reduced/reused or source segregated for recycling. Reduce, reuse and recycling of the waste mainly reduces the raw material consumption and associated GHG emissions. It is assumed that 50 % of the waste is reduced/reused or 100 % recycled from the waste stream. The conversion factors considered for paper, plastics, glass and metal were different for reduce/reuses and recycling as shown in Table 5. Cumulative of 15,768 and 47,012 t CO_2 emissions can be reduced respectively by reducing/reusing and recycling of materials from the waste stream. Reduce; reuse and recycling of waste further mitigate GHG emissions through lower energy demand for production (avoided fossil fuel) and by substitution of recycled feed stocks for virgin materials.

From the scenario developed, the recycling of waste materials from the urban waste will mitigate more than 85 - 90 % of CO_2 emission by the process of recycling whereas the management of organic waste only contributing to 10 – 15 %. Biological waste treatment projects have qualified for CDM projects, whereas, the recycling of waste is not under the scope of CDM. But still, considering the climate benefits and social development, waste recycling should be considered. As presented in Table 5, the anaerobic digestion for organic waste and recycling of valuables together will reduce the emission of 53,547 t CO_2 equivalent into the atmosphere. On the other hand composting along with proper recycling strategy will reduce the emission of 56,502 t CO_2 equivalent.

Table 5 Scenario development for waste disposal practices and GHG mitigation

Waste Management options	Waste Quantity (t)	Conversion Factor*	Correction factor	GHG emission (t CO_2)
Anaerobic Digestion (AD)	219,000 (Organic)	0.029	70 % (0.7)	4,445
Methane recovery				3,219
Aerobic Composting		0.084	50 % (0.5)	9,198
Waste Reduction and Reuse			50 % (0.5)	
Paper	21,900	0.8		8,760
Plastic	14,600	0.4		2,920
Glass	7,300	0.12		438
Metal	3,650	2		3,650
Waste Recycling			100 % (1)	
Paper	21,900	0.6		13,140
Plastic	14,600	0.3		4,380
Glass	7,300	4.0		29,200
Metal	3,650	0.08		292
AD + Waste Recycling	266,450 (Organic + Recyclables)	-	-	53,547
Aerobic Composting + Recycling		-	-	56,502

*Note: * the conversion factor from –USEPA,2002 and IPCC, 2006*

Further, the concept of 3R's (Reduce, Reuse and Recycle) can be used as a potential tool to avoid waste mismanagement and its associated GHG emissions. Also, it is essential for the private formal and informal sectors to capitalize on waste management and recycling issue to turn into opportunities. Therefore, it is very clear that that the integrated approach for managing organic and recyclables will mitigate GHG significantly from developing Asian countries.

CONCLUSIONS

In the race towards urbanization, many developing countries have witnessed the overflow of MSW and depletion of natural resources at an alarming rate. Unlike developed nations, final disposal of MSW in developing Asian countries is usually a matter of transporting the collected MSW to the nearest available space for disposal. Though the predicament of solid waste management is a regional one but it has its imprint on the global scenario. The main impact is that threat to global climate change through continuous emission of GHGs. An analysis of the various sectoral scopes under CDM registry, it is quite revealing that the municipal solid waste project has the largest potential GHG emission reduction more than the all the other projects put together from developed and developing countries. Often there is no single best option for MSW management; rather, there are multiple measures available to decisionmakers at the municipal level where several technologies may be collectively implemented to reduce GHG emissions and achieve public health, environmental protection and sustainable development objectives. Hence, the mitigation of GHG emissions from waste must be addressed in the context of integrated waste management. In recent years, 3R initiatives have been promoted as the part of integrated waste management and resource consumption to reduce the GHG emissions from MSW. Hence, the appropriate integrated practices and perceptions will mitigate possible GHG emissions from waste sector in the developing Asian countries.

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General Approach of Solid Waste Management

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Waste Management Alliance - Building Approach of Rural Municipalities of Southern Leyte, Philippines

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ABSTRACT

Like many municipalities in developing and decentralizing countries, local government units (LGUs) in the Philippines are striving to improve solid waste management (SWM) systems. In comparison to urbanized cities, many municipalities are too small to deliver basic services to the public. To enhance economies of scale and resource base, three adjacent rural towns formed the "Southern Leyte Pacific Municipal Environmental Alliance" (SoLePaMEA). The group adapted a broad clustering model that not only shares facilities but includes diffusion of experiences from agreed SWM pilot projects. With national-local knowledge transfer from the Department of Environment and Natural Resources, SoLePaMEA underwent a consensus-building process to arrive at job- and resource-sharing agreements while taking into account internal and inter-LGU socio-political and technical issues. This paper puts particular emphasis on the simplified tools used in stakeholder consultation and summarizes approaches and experiences made during alliance-building and phased implementation of joint SWM programs.

INTRODUCTION

The Philippines is presently undergoing democratic governance and decentralization processes. Under recent national policies, local government units (LGUs) are endowed with local autonomy and powers in recognition that LGUs are at the forefront of the delivery of basic services to the people and communities, including the field of solid waste management (SWM). But like in many other municipalities in the developing world, these local authorities are coping up to meet their "relatively new" and broader service obligations, defined in concert with their communities, in consideration of their limited technical expertise and financial resources. For the 120 cities in the Philippines today, this may be less of a problem but it is a major challenge for the majority of the 1,511 municipalities whose total annual income is less than PhP 100 Million (~USD 2 Mio).

The country's national policy on SWM was passed in 2000. Republic Act (RA) 9003 otherwise known as Philippine Ecological Solid Waste Management Act assigned cities and municipalities with greater SWM roles such as mobilizing the SWM Board, preparing the 10-Year SWM Plan, collection of residual wastes, disposal facility management (e.g., dumpsite closure/rehabilitation and sanitary landfill establishment), crafting SWM ordinances and ensuring financial sustainability. In addition, cities and municipalities are expected to support its component barangays [the smallest political subdivision in the Philippines and itself considered as LGUs] in achieving the mandatory 25% waste diversion through segregation, composting and recycling. Such tasks require high degrees of technical expertise, administrative specialization and financial resources. Considering that most municipalities in the Philippines can only tap a fraction of their annual budgets and have a limited number of capacitated personnel for SWM, alternative ways need to be explored by the LGUs to implement the legal prescriptions while contributing to the filling in of national policy gaps.

Since 2005, AHT GROUP AG (AHT) has been implementing the Solid Waste Management for Local Government Units (SWM4LGUs) Project on behalf of the German Technical Cooperation (GTZ) with funding support from the German Federal Ministry for Economic Cooperation and Development

(BMZ). The overall goal of the GTZ-AHT SWM4LGUs Project is to build the capability of Philippine LGUs in establishing integrated solid waste management systems and operate them in an economically and environmentally sustainable manner. Together with its partners from the government of the Philippines' Department of Environment and Natural Resources (DENR), GTZ-AHT assists a dozen LGUs, primarily the cities, in complying with RA 9003 while bridging local lessons with national-level policy actions.

To come up with an SWM model for rural municipalities, the project has also been supporting a number of towns in the province of Southern Leyte in building an alliance for municipal clustering on SWM projects. Unlike most cities, small municipalities have little choice but to pool resources and coordinate efforts to solve common SWM problems.

Local Situation

The province of Southern Leyte is bounded by bodies of water in three directions with its eastern part facing the Pacific Ocean, which is the one of the reasons for the area's high amount of rainfall. Economic activities are highly dependent on agriculture and fishing and its families have poverty incidence more or less similar to national average (NCSB, 2006). In terms of local government resources, most municipalities in the province belong to the lower income brackets based on their internal revenue allotment (IRA). IRAs are the annual budget received by the LGUs from the national government as its share in government revenues.

The delivery of municipal solid waste management services in Southern Leyte is relatively limited with coverage areas usually just concentrated in poblacion [town proper] areas. A handful of LGUs have come up with SWM Plans, pilot-tested partial waste segregation systems, and established composting and material recovery facilities (MRFs) albeit with limited tonnage capacities. There is presently no sanitary landfill in the province and each municipality still operates at least one dumpsite. Notably, the presence of a dumpsite in a municipality is the most prominent reason for municipal mayors to face administrative sanctions and/or citizen's suits as provided by RA 9003.

In recognition of the community's demand for better services and the discharge of their official duties, the LGUs of the towns Anahawan, Hinunangan, Liloan, San Juan and St. Bernard have embarked upon building an alliance in SWM municipal clustering. To avoid spreading themselves too thinly, the three (3) administratively adjacent municipalities of Anahawan, San Juan and St. Bernard spearheaded the consensus-building efforts in establishing the "Southern Leyte Pacific Municipal Environmental Alliance (SoLePaMEA)".

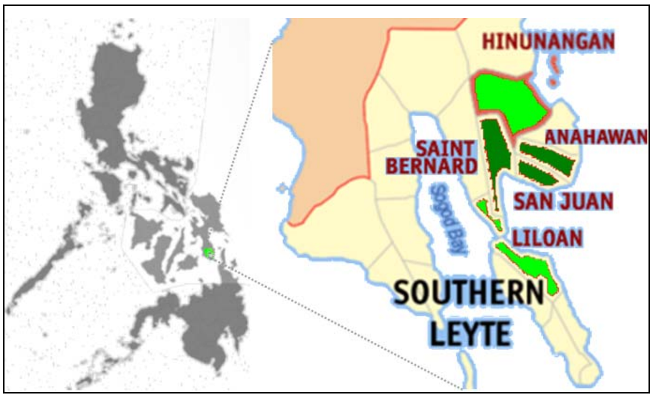

Figure 1 Location of SoLePaMEA municipalities

The concept of municipal clustering is not new to the Southern Leyte local authorities. In fact, the Inter Local Health Zone initiative of these Pacific towns was given a national award for successfully pooling their resources in establishing a common district hospital and rural health services, which each could not afford individually. Nevertheless, the concept of clustering in other sectors, or by other LGUs for that matter, remains a challenge unique to the local situation and common needs of the municipalities.

Legal Framework

There are national laws and policies in the Philippines that provide the legal basis to encourage municipal clustering depending on local needs. Foremost is the 1987 Constitution of the Republic of the Philippines, Article X Section 13, which states that "Local government units [LGUs] may group themselves, consolidate or coordinate their efforts, services, and resources for purposes commonly beneficial to them in accordance with law."

In 1991, Republic Act [RA] No. 7160 otherwise known as The Local Government Code of the Philippines was passed to confer upon LGUs, as the state's territorial and political subdivisions, a meaningful local autonomy while institutionalizing more responsive and accountable local government structure. Specifically, Section 33 of RA 7160 provides for cooperative undertakings among LGUs and specifies that the "LGUs may, through appropriate ordinances, group themselves ... [and] in support of such undertakings, the LGUs involved may, upon approval by the Sanggunian [municipal council] concerned after a public hearing conducted for the purpose, contribute funds, real estate, equipment, and other kinds of property and appoint or assign personnel under such terms and conditions as may be agreed upon by the participating local units through Memoranda of Agreement."

Furthermore, when waste management was identified as one of the functions that could be devolved chiefly to LGUs, RA 9003 otherwise known as Philippine Ecological Solid Waste Management Act of 2000 stipulated that cities and municipalities were mainly responsible for SWM planning, public information and residual waste collection and disposal while assisting their barangays in recyclables and biodegradable waste management. Acknowledging the resource constraints of most municipalities, Section 44 of RA 9003 mandates LGUs "to [cluster] ... for purposes of jointly addressing common solid waste management problems and/or establishing common waste disposal facilities".

Clustering Models

In general, clustering refers to the pooling of efforts and/or resources of neighboring cities and municipalities to address common local challenges. Among its inherent advantages are enhanced economies of scale, higher financial base and more flexibility, which all contribute to the overall improvement of locality's environmental situation.

Various strategic clustering models have been studied for possible benchmarking. A sourcebook published by the World Bank looks at 'regionalization' as a logical option for small municipalities in India wherein the operation and management of a common sanitary landfill is lead by a professional agency while the cost-sharing scheme is based on tipping fees proportional to the waste tonnage delivered (World Bank 2008). Similar initiatives are also present in the Philippines. The Metro Manila Development Authority serves as the regional council legally mandated specifically to manage or contract out disposal facilities for the national capital region. There are also the proposed clustering projects of Metro Bohol, Northern Metro Cebu, South Cotabato, Tacurong-Isulan, Malay-Buruanga, Albay District III, and Misamis Oriental clusters (Jardin 2007), which explore the scheme of managing a common landfill with support from the national government, the province and/or the private sector. It remains to be a challenge to develop a cluster involving rural municipalities with very small capital base to venture into inter-municipal cooperation or non-profit public corporation, which could be attractive enough for private sector participation later on. Based on the experiences of many developed countries, waste management started out as purely a local government undertaking but increasing demand for better service delivery attracted private agencies to take over with a more competitive asset management.

While many of the proposed clusters in the Philippines are primarily concentrated on the establishment of common waste disposal facilities, the municipalities of Southern Leyte also intend to define other sharing arrangements for other components of SWM. From the point of view of the LGUs involved, clustering does not exclusively mean sharing of physical infrastructure but can also take shape in the form of technical knowledge sharing through pilot projects. And more importantly, the cluster model to be developed should be demand-driven and based on local needs.

ALLIANCE BUILDING STRATEGIES

The full implementation of RA 9003 has been a continuous challenge to cities, specifically in putting up resource recovery programs and sanitary landfills (SLF). Lower-income municipalities are confronted with an even greater feat – implementing RA 9003 utilizing any available albeit limited resources that they have. Despite the logical advantages of clustering, many LGUs had to hurdle traditional constraints in inter-municipal cooperation, which include unclear roles of institutions, strong local politics and bureaucracy, and limitations in resources. Through a series of consensus-building strategies, the Southern Leyte LGUs have planned, held dialogues, compromised and agreed on a clustering model where workload and resources will be equitably shared by all LGUs right from the start (Honor-Do 2008).

Leveling-off Common SWM Concerns

The three municipalities commenced with an inventory of its available financial resources and evaluating each town's level of compliance with the mandates of RA 9003. As shown in Table 1, the municipalities have comparable demographics, area and budgets. St. Bernard has the relatively highest income but it also has the highest population. Anahawan has a larger administrative area than San Juan but the latter has relatively more economic activity.

Table 1 Municipal profile and status of RA 9003 implementation

	Anahawan	San Juan	St. Bernard
Municipal Profile			
Population, 2008	8,359	13,304	26,297
Area (hectares)	5,809	4,956	10,020
Income Class, 2008	5th Class	5th Class	4th Class
Annual Budget for SWM, 2008	PhP 300,000 (~USD 6,000)	PhP 500,000 (~USD 10,000)	PhP 287,000 (~USD 5,740)
Waste Characteristics			
Waste generation rate	0.32 kg/capita/day	0.40 kg/capita/day	0.22 kg/capita/day
Waste composition:	WACS, 10/2007	WACS, 04/2006	WACS, N/A
Food waste	21.08%	6.03%	-
Yard waste	48.08%	49.54%	-
Recyclables	27.91%	43.61%	-
Residuals	2.12%	0.82%	-
Special waste	0.79%	0.00%	-
Status of Municipal Compliance to RA 9003			
Resolution adopting RA 9003	Adopted	Adopted	Adopted
Municipal SWM Board	Created, Functional	Created, Functional	Created, Functional
Municipal ENR / SWM Office(r)	Designated an SWM focal person	Officially created an MENR office	Designated an SWM focal person
Municipal 10-Year SWM Plan	None	Prepared, Adopted	Drafted
Information, Education (IEC) Campaigns	Yes, RA 9003 orientation	Yes, Barangay assemblies	Yes, Incorporated in all BDPs
Enforcement	Not yet undertaken	Not yet undertaken	Not yet undertaken
Waste Segregation at Source	Not yet practiced	Yes, in pilot areas	Not yet practiced
Segregated Waste Collection	Not yet practiced	Yes, in pilot areas	Not yet practiced
Materials Recovery Facility	Constructed MRF	Constructed MRF	None
Closure of Existing Dumpsite	Not yet	Not yet	Not yet
Sanitary Landfill (SLF) Site	None, available site is quarry-type	None, soil type is not clayey	Yes, one site is suitable

The municipalities also share similar status as regards RA 9003 implementation. All LGUs have functional municipal SWM boards and local statutes but all the three still illegally operate dumpsites. Although the municipality of San Juan is ahead in terms of piloting its waste segregation and recovery system, it has limitations in putting up a landfill because the type of soil in the area does not pass the national SLF site identification guidelines. Only St. Bernard has potential site approved by the authorities but like Anahawan, its service area is primarily rural and agricultural.

SWOT Analysis

In an orientation workshop conducted by the GTZ-AHT SWM4LGUs Project and facilitated by DENR-CENRO's SWM coordinator, each municipality analyzed its strengths, weaknesses, opportunities and threats or SWOT (GTZ 2007) in the context of RA 9003. Table 2 synthesizes the gaps and possible options for improvement proposed by the LGUs.

Table 2 SWM gaps and potential solutions proposed by the municipalities

Gaps	Options for Improvement
Policy-making, Planning and Financing Systems	
• Outdated and unimplemented policies; Absence of municipal ordinance adopting RA 9003	• Review existing ordinances on SWM and localize RA 9003 into an omnibus comprehensive statute. Integrate provisions for stronger IEC and enforcement office/system
• Absence of 10-Year SWM Plan; Some SWM plans have unrealistic targets.	• Formulate 10-Year SWM Plan in a participatory manner with a more dynamic and responsive design to address current/future needs.
• Policies have no budget allotment, or have funds that are difficult to tap by implementers.	• Integrate SWM budget into annual funds. Create a separate SWM accounts within the municipality/barangay's general funds dedicated for SWM collection of fees, etc.
• Limited SWM budget; Unsustainable setup; Lack of policies in charging reasonable SWM fees; Low collection rates of SWM fees (usually only from business but not households.	• Various LGU levels to find alternative fund sources. • Prepare FS for loan applications if budget is insufficient. • To enhance cost-recovery conduct: (a) SWM full-cost accounting, (b) willingness-to-pay studies, (c) local policies, (d) auditing system in collecting/tapping funds for SWM and (e) higher fee schedules for un-segregated waste.
Political, Administrative, Organizational and Institutional Dynamics	
• Inactive municipal SWM Board; Members unfamiliar with exact roles or have limited knowledge.	• Re-activate local SWMBs especially during political transitions. Assign coordinator/secretariat to facilitate policy making and monitoring of activities. Capacitate members.
• Inactive barangay SWM Committees (BSWMC).	• Municipalities to assist component barangays in planning and capacity development, especially for focal persons.
• Absence of TWG to implement Board policies; Members often tasked with multiple functions.	• Local chief executives should issue a Special Order creating the SWM TWG responsible for implementing and enforcing the policies and plans crafted by the SWMB.
• Absence of dedicated Municipal ENRO or SWM focal person.	• Designate MENROs or SWM focal persons while paving the way for the creation of a dedicated/regular office.
• Political affiliations are major constraints in clustering.	• Pilot and establish institutional, operational and financial model, through a Memorandum of Agreement (MOA).
• Limited or unstructured external support assistance for LGUs	• DENR-EMB and the Regional Ecology Center to provide support and technical assistance to LGUs.
Waste Segregation, Segregated Collection, Recycling/Recovery, & Public/Private Participation	
• Limited awareness/participation of communities on segregation	• Conduct IEC and social marketing. Infuse values formation. Encompass all target groups. Work with various sectors.
• Lack or inconsistent public policies on segregation; Mixed collection of pre- segregated waste.	• Put up practical, sustainable and consistent segregation system. Empower and involve barangay officials and stakeholders. Establish incentive and penalty systems. Prohibit mixing of already segregated wastes.
• Lack or unconsolidated data on markets for recyclable materials	• Link up with buyers, junkshops and consolidators. Create markets for recyclables and compost products, if possible.
• Limited equipment and infrastructure for segregation	• Install segregated waste bins. Put up accessible MRFs preferably in each barangay. Select suitable technologies.
• Waste collection coverage is only limited to town centers.	• Leverage efforts with barangays and communities. Encourage composting in households and farmlands.
Disposal Facilities: Closure and Rehabilitation of Dumpsites & Establishment of Sanitary Landfills	
• Absence of dumpsite closure plan; Low priority vis-à-vis SLFs.	• Provide technical assistance to LGUs. Appropriate funds for closure of dumpsites.
• Proposed SLF sites are either geo-technically or socially un-acceptable	• Conduct proper SLF site identification. Cluster with other LGUs with available sites. LGUs to undertake social acceptability programs even if not mandatory.
• Initial investment for SLF is high; Operating expenses will be a regular burden to LGUs.	• Identify best financing schemes. Municipal council should source out funds for SLF operations. Design cost-recovery systems. Enter into SWM/SLF clustering if applicable.

Individual Municipal SWM Planning

In support of each municipality's relatively long-term 10-year SWM plan and with a fresh assessment of its level of compliance with RA 9003, the LGUs have undergone parallel workshops to craft its individual SWM plans. Prior to actual planning, the LGU representatives had been capacitated

on the regulatory, technical, financial and other cross-cutting concerns in implementing waste management programs.
The planning exercise was focused on identifying realistic targets and activities, which are doable within the next three years. These medium-term plans were later presented to, and adopted by, their respective municipal councils.

Joint Municipal SWM Planning

A succeeding participatory workshop was conducted for the municipalities to identify those activities in their work plans, which they were willing to implement independently or share with the others. Independent activities were only what each LGU can do based on local situation while shared activities were those that need more expertise and resources to implement. Shared activities were consolidated and formed the group's joint SWM work plan.

The joint work plan was not immediately passed by the respective municipal councils as a number of issues needed to be resolved. The facilitators recognized right from the start that this scheme of alliance-building has high sustainability potential in the long run but the process itself is more prone to intra- and inter-LGU dynamics. Whether administratively valid or politically driven, the need to respond to these concerns was fully acknowledged and addressed through a series of consensus-building sessions.

Joint Council Sessions

Under the Philippines' Local Government Code, no project can be implemented by any LGU without the due approval of its respective Sangguniang Pambayan (SB) [municipal council]. The council has the power to appropriate budgets and approve activities for funding. Upon the request of all municipalities, a special joint SB session was held to give opportunity to all SB members to clarify issues and understand the proposed clustering scheme. Concurrently, the local legislators were informed on the responsibilities of LGUs under RA 9003 and the technical, administrative and financial aspects of waste management.

Various clustering options were also presented to the LGUs for benchmarking. After being updated on the progress of alliance-building, a participatory workshop was held with the SB members along with the LGUs' technical working group representatives. Table 3 summarizes the main issues that the municipalities perceive as challenges in SWM clustering.

Table 3 Main issues and challenges in SWM clustering

Issues	Challenges
Community involvement and social acceptance	• Public acceptance (in all municipalities) re: concept of SWM clustering • Potential lack of cooperation from the general public • Negative impression from the community, especially for host LGU(s)
Technical and operational framework	• Sharing scheme on landfill maintenance (landfill cells and access road) • Sufficiency of shared disposal area (no. of years) • Exclusion of hospital and clinic waste
Organizational and employees' strength	• Lack of technical capability to establish and sustain the program • No specific employees to handle SWM / Lack of work force • Fear of overloads in office responsibilities among technical staff
Political dynamics (internal and external politics)	• Internal LGU politics (dynamics within a municipality) • Inter-LGU political dynamics (mistrust between municipalities) • Apprehensions of other LGUs violating policies laid down in the MOA
Financial resource availability	• Financial incentive or budget for the ESWM office / personnel not specified • Budgetary constraints (LGU's share in initial capital costs) • Sustainable source of annual operating budget for SWM facilities
Joint agreements and enforcement	• Strict implementation of household segregation in all municipalities • Ningas cogon (bush-fire type) implementation • Commitments of the clustered municipalities • Sustainability of the program amidst political transition

As a response to the recognized potential constraints in clustering, the LGUs agreed upon the creation of decision-making and technical bodies to oversee the shared SWM activities in all municipalities. Although RA 9003 has suggestions on the functions of a possible "local SWM cluster board", it does not define its membership. Furthermore, a "joint technical working group (TWG)" is not also mandatory under the law. Still, the participating LGUs found it essential that such bodies be created hence its composition and functions should then be defined and officially agreed upon.

Alliance SWM Board and Joint TWG

The functions of the Alliance SWM Board were deliberated. In the legal context, RA 9003 only stipulates that, "In the case of clustered LGUs, a governing memorandum of agreement of the cluster may be created in addition to ordinances, stipulating that the local SWM cluster board shall administer the fund." The said cluster board shall also be responsible to "develop schemes to sustain the fund", approve SWM fund requests, "establish appropriate [SWM] special accounts" and facilitate knowledge and skills exchange.

Based on this, a corresponding set of LGU representatives was suggested. The parties concerned emphasized the need for objectively nominating board delegates based on held positions and not based on personalities to minimize political interventions even in the future. In addition, another set of representatives for the joint TWG was also identified. The joint TWG was envisioned for each LGU's technical staff to coordinate with each other and collaborate on implementing the policies set forth by the Alliance Board. Table 4 shows the composition of each LGU's representatives to the municipal partnership.

Table 4 Composition of the SoLePaMEA SWM Board and Joint TWG

Members of the Alliance SWM Board	Members of the Joint SWM TWG
1. Mayor with Vice-Mayor as his/her alternate	1. Focal person for SWM *or* MENRO
2. Councilor, Environment Committee	2. Municipal Engineer *or* General Services Unit
3. Councilor, Finance Committee	3. Municipal Planning and Development Officer
4. Municipal Budget Officer	4. Municipal Agriculturist *or* Technician
5. Focal person for SWM *or* MENRO	5. Draftsman

As shown in the above table, the LGUs found it necessary for the SWM focal persons to sit in both bodies. It was rationalized that this organizational structure facilitates both the implementation of board policies and the bridging of technical matters that require decision-making actions. Furthermore, the SWM partnership was officially called the "Southern Leyte Pacific Municipal Environmental Alliance (SoLePaMEA)".

With the identification of the composition and functions of the governing bodies, a participatory administrative setup was defined. However, the gap between the newly formed organizational structure and the draft joint work plan needed to be linked together.

Job- and Resource-Sharing Arrangements

The preceding meetings and workshops revealed that in the Philippine context, or in other "family-oriented" cultures as well, the issue of trust and how to resolve equitable sharing of resources are crucial in democratic governance and in proper management of conflicts or potential conflicts. During group meetings, each LGU has an official stance on critical matters but may not necessarily reflect the opinion of each representative from that LGU. Therefore, inter-LGU decisions should ideally match those that are compromised within each LGU.

Table 5 Job- and resource-sharing arrangements for overall SWM program

	Anahawan	San Juan	St. Bernard
General			
Clustering of SWM programs is beneficial to all LGUs	Yes	Yes	Yes
Clustering all SWM components is better than alone	No	No	No
Clustering certain SWM components is better than alone	Yes	Yes	Yes
Assessment of SWM Components			
SWM component that the municipality of piloting as its area of specialization	Composting & Recycling	MRF establishment	IEC, Waste segregation
Responsibilities and Arrangements			
Responsible to establish pilot selected by the LGU	Solely the LGU	Depends on pilot	Solely the LGU
Responsible to operate and sustain pilot selected	Solely the LGU	Depends on pilot	Solely the LGU
SWM program clustering should be bound by MOA	Yes	Yes	Yes

GTZ-AHT and DENR-EMB/CENRO successfully pilot-tested a simple yet customized participatory workshop tool, which aims to identify job-sharing and resource-sharing arrangements for SoLePaMEA. The workshop design first encouraged each individual municipality to arrive at a consensus on a number of issues. The results from each LGU were then analyzed through a reflection workshop for the representatives to understand how similar or different each municipality perceives the proposed clustering arrangement. This exercise was undertaken for the whole SWM program and for the common SLF.

As shown in Table 5, the results of the workshop revealed how each municipality shared many similar views as regards the sharing of finances and workload. Pilot areas for each LGU were likewise uniquely identified. San Juan wanted to focus on establishing a model materials recovery facility (MRF); Anahawan would pilot recycling and composting; while St. Bernard hoped to specialize on segregation and social marketing for public participation. The distribution of pilots areas was conceptualized such that SoLePaMEA would not merely focus on sharing of facilities but also in the form of knowledge or skills transfer. The lessons from pilot components would be later shared as a model for other LGUs to replicate (GTZ 2007).

As for SLF establishment, it was unanimously decided that efforts and resources would be equitably shared by the LGUs (Table 6). This collective understanding of managing joint SWM facilities already set it apart from the previous clustering models in the Philippines where one LGU, with the support of the province or the state, establishes its own sanitary landfill and will later be joined by other LGUs within the cluster once it becomes operational.

Table 6 Job- and resource-sharing arrangements for shared SWM facility (sanitary landfill)

	Anahawan	San Juan	St. Bernard
General			
Clustering of SLF is beneficial to all LGUs concerned	Yes	Yes	Yes
Landfill Planning, Establishment and Construction			
Responsible (technically) to establish the SLF	Shared equitably	Shared equitably	Shared equitably
Responsible (financially) to establish the SLF	Shared equitably	Shared equitably	Shared equitably
Landfill Operation, Maintenance and Monitoring			
Responsible (technically) to operate and monitor SLF	Shared equitably	Shared equitably	Shared equitably
Responsible (financially) to operate and monitor SLF	Shared equitably	Shared equitably	Shared equitably
Responsibilities and Arrangements			
LGU assures that only residual wastes will be delivered to the common landfill facility	100% assurance	> 80% assurance	100% assurance
SLF clustering should be bound by MOA	Yes	Yes	Yes

From the presented results it appears that the envisioned shared responsibility to establish and operate a joint landfill may be the most prominent challenge for the municipal cluster and its involved LGUs specifically in defining “equitable” indicators (GTZ 2006).

Regular SoLePaMEA Board Meetings

The SoLePaMEA board has been the first official local SWM cluster board formed in the Eastern Visayas region. Initially working on the memorandum of agreement, the SoLePaMEA board has already held a number of joint board meetings to resolve new SWM challenges arising from the partnership.

Memorandum of Agreement (MOA)

The outputs of all the workshops to build the alliance were utilized in crafting the memorandum of agreement (MOA) for SoLePaMEA. The MOA contains general provisions, the passage of individual and joint local ordinances, LGU work- and resource-sharing commitments on pilot areas and jointly-operated facilities, the composition and functions of the alliance board and joint TWG, as well as the conditionalities for MOA termination.

It was learned in the previous case studies that the single most important factor affecting the decision of the LGUs to enter into a MOA is the over-itemization of certain provisions such that a minor clause not acceptable to one party could cause them not to join. This restraining factor was minimized when it was agreed that for special projects or for those entailing major decisions, the SoLePaMEA board could issue official resolutions supplementary to the MOA.

Pilot Activities on Areas of SWM Specialization

As previously agreed, each municipality would specialize in a selected area of SWM. Through this scheme, each pilot-test serves as an information or technology incubator for the group. Having one pilot does not necessarily preclude an LGU to undertake other programs mandated by RA 9003. This arrangement only fosters research and application of different SWM systems to save the other partners from undergoing the learning curves because the techniques learned will be shared to others. The GTZ-AHT SWM4LGUs Project has been supporting this unique initiative by providing technical assistance to the specializing LGU, often together with some TWG members from other municipalities.

A train-the-trainers training on recycling-for-livelihood program was undertaken in St. Bernard. This hands-on program taught potential replicators on how to transform recyclable materials into sellable bags, decors and accessories. More than 50 people were capacitated, around 80% of which were women, and have since then trained others on recycling skills.

Figure 2 Train-the-trainers' training on recycling for livelihood programs in St. Bernard

Since LGU-Anahawan was the one who identified composting as pilot area, a series of training programs on vermicomposting and organic farming were held for its community leaders and farmers. In return, the municipality establishes a demo-composting center and training pavilion to provide a knowledge transfer center for other SoLePaMEA partners.

Figure 3 Illustration of vermicomposting demonstration facility in Anahawan

Meanwhile, San Juan has already constructed its own MRF to serve its poblacion barangays [town proper]. During this time, the LGU was able to successfully generate income from the sale of recyclables to partially finance the salaries of personnel involved in segregated waste collection and MRF operations. At a certain period, improvements to the structure and equipment have been undertaken so the segregated collection system has been temporarily stopped. Nevertheless, this 'downtime' has lead to refuting the common LGU notion that engaging the public to segregate their wastes is politically unpopular. In fact, one household remarked to CENRO-San Juan's SWM coordinator, "*What happened to our segregated collection system? We were quite resistant to it at first but we found it quite practical in our household*. *It's a normal practice for us already."*

CONCLUSIONS

Local lessons and experiences are critical to the learning processes of each municipality and the SoLePaMEA as a whole. Although the clustering framework involved in working with SoLePaMEA had been lengthy and tedious, many benefits such as building networking, awareness raising and knowledge transfer capacitated involved local leaders during the planning process. But what sets this alliance-building model apart from other initiatives is that all LGUs agreed to share resources equitably even at the start of the planning process. This is deemed as the high road since most clustering activities so far commence with a host LGU investing on a joint facility while others join later on.

Inter-municipal cooperation seems an easy task but the experiences in Southern Leyte prove that alliance-building not only involves the technicalities of SWM implementation but also needs resolving intra- and inter-governmental issues at the local level. Defining the sharing schemes include compromises, political will and support of stakeholders in the region. In the longer run however, such efforts may be a worthwhile endeavor as clustering is the only viable option that low-income municipalities have. In addition, certain risks from this model are outweighed by the fact that many and especially smaller municipalities in the country might not have access to other sources of initial capital but its own pooled resources.

Through the MOA, agreements and commitments were officially defined. These include GTZ-espoused policy instruments such as standards, user fee systems, monitoring procedures and success factors. In this regard, SWM knowledge can be more efficiently transferred to the community if norms are set and the cluster approach is standardized.

It is also worthy to note that sustaining the pace for building an inter-municipal cooperation can be more effective with the presence of a facilitator or mediator. In many instances, DENR-CENRO San Juan's SWM coordinator, Ms. Mary Jane Honor, has been asked to facilitate or mediate in conflicting issues. The facilitator is a field officer of the national government and the LGUs acknowledge her as non-partisan. The technical knowledge on devolved environmental functions is also within the DENR so the process itself leads to knowledge transfer from the national to the local authorities. Hence this clustering model is considered as a best practice and showcase not only nationwide but could be adopted in other developing and decentralizing countries as well.

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Scenario of Solid Waste Management Program of Selected Municipalities in Bangladesh

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ABSTRACT

The report is a complementary part of the research study conducted during 2005 to 2008 in four selected Pourashavas (Municipalities) of Bangladesh namely Bagerhat, Barguna, Patuakhali and Bhola. It is noticed that traditional procedures are adopted for solid waste management (SWM) program in the study area. The quantity of Solid Waste (SW) collection or disposal is same and 64% of the daily generation and the calculated SW generation range 0.135 to 0.150 kg/capita/day. A questionnaire survey was conducted in random manner among 750 households out of 38,166 in total. It is explored from the survey that 63% inhabitants dispose of their SW in unsanitary means and 69% inhabitants expressed their satisfaction on SWM condition. The partial involvement of NGO or private sector in SWM program is appreciated for their satisfactory performance. The observations and findings obtained from the research study are stated in this paper with recommendation.

INTRODUCTION

As a consequence of urbanization and rapid growth of population, urban services face enormous challenges in meeting the requirements of the Pourashava (Municipality) inhabitants. The SWM program is one of the compulsory functions of every Pourashava. The program involves managing the activities associated with waste generation, storage, collection, transfer and transportation, processing and recovery, and finally disposal in a safe environmental manner, with due attention towards economy, aesthetics, energy and conservation. In the case of garbage, nobody seems to be interested to know where eventually his or her refuse goes. It is important to be notable that the SWM is non-stop service and reaches all corners of the urban area. The report is a complementary part of the research study conducted during 2005 to 2008 in four district level Pourashavas of Bangladesh namely Bagerhat, Barguna, Patuakhali and Bhola (Ahammed S.N. 2008).

FUNCTION OF MUNICIPALITY

Municipality (Pourashava) is empowered to perform a wide range of functions, which provide services to its inhabitants. Pourashava has to cooperate with other GOs or NGOs for some services such as sanitation, sensitization awareness, micro–credit, electricity etc. to the citizens. In practical, Pourashavas can not be able to perform all functions, mainly due to acute shortage of fund caused by poor collection of taxes, non-realization of taxes from Government and Semi-government establishment for years together and insufficient grants from central Government. The functions are categorized into two types as follows (Amzad S. K. 1999).

Compulsory Functions:

- construction and maintenance of roads, bridges and culverts.
- removal, collection and dispose of refuse, wastage and rubbish.
- provision and maintenance of streetlights.
- maintenance of public streets and provision of watering them.
- provision and regulation of water supply.
- construction and maintenance of public markets and shopping centre.

- provision and maintenance of drainage.
- provision and maintenance of slaughterhouses.
- provision and maintenance of graveyards and cremation grounds.
- control erection and re-erection of buildings.
- regulation in sanitary buildings.
- prevention of infectious diseases and epidemics.
- plantation of trees on the roadsides.
- registration of births, deaths and marriages.
- control over traffic and public vehicles.

Optional Functions:

- checking adulteration of food products.
- control of private markets and shopping centers.
- maintenance of educational institutions with stipends to poor and meritorious students.
- provision of flood and epidemic relief
- provision and maintenance of parks, gardens and playground.
- establish of welfare homes, orphanage and prevention of beggary and organization of social and voluntary services.
- establishment of public dispensaries, veterinary hospitals etc.
- provision of public toilets.
- established public libraries and reading rooms.
- registration of cattle sales and improvement of livestock.
- celebrations of national holidays.
- reception to distinguished guests.
- promotion of community development schemes.

STUDY AREA

The study was conducted in four district level Pourashavas namely Bagerhat, Barguna, Patuakhali and Bhola. The basic information of the study area is stated in Table 1(Data source: Respective Pourashava Office, PSYB 1999).

Table 1 Basic information on four Pourashavas under study area

Information parameter		Unit	Status in four Pourashavas (In 2008)			
			Bagerhat	Barguna	Patuakhali	Bhola
01	Date of establishment	Year	01 April 1958	23 July 1973	01 April 1892	10 October 1920
02	Area	Km^2	13.72	12.96	26.00	31.48
03	Population	Nos.	70,000	37,000	80,000	60,000
04	Tax payee Households	Nos.	5,579	4,706	17,792	10,089
05	Water Client	Nos.	4,100	2210	2230	2545
6.a	Latitude	--	22º 40' N	22º 10' N	22º 22' N	22º 40' N
6.b	Longitude	--	89º 45' E	90º 07' E	90º 20' E	90º 45' E
6.c	Distance from KUET	Km	40	200	155	160

MUNICIPAL SOLID WASTE

Municipal solid waste includes mainly domestic waste resulting from household activities (e.g. kitchen wastes, food preparation, cleaning, gardening etc.), from commercial establishment (like stores, offices, fuel service, restaurants, warehouses, hotels etc.), from industry, institution, road sweeping, construction debris, sanitation resides (drain dirt cleaning materials mostly semisolid sludge) on the whole. Domestic solid waste is a composition of organic food waste, papers, wood, plastic, leather and rubber materials, rags and textile products, glass, metals, inert stones, and other bulky wastes. Municipal solid waste can be broadly divided into (a) Organic or biodegradable waste such as kitchen waste, food leftover, rotten fruit and vegetables and peelings, straw and hay, leaves and garden trimmings, crop residues, animal excreta, bone, leather etc. The amount of organic waste is 70 –80% of the total municipal waste in Bangladesh and (b) Non-organic or non-biodegradable waste such as earth, ash, stone, bricks, cinders glass, plastic, rubber and ferrous/ non-ferrous metal (Ahmed M. F. and Rahman M. M. 2003).

STATUS OF SWM ACTIVITY IN STUDY AREA

In Pourashava, solid waste management program generally associates the activities like road sweeping, cutting /dressing road side grass / plant, cleaning the solid matters from drain, SW collection from every source (disposal bin, road side, market area, etc.), gather the collected SW in selected secondary spots, SW recycling and finally disposal in a safe environmental manner with due attention towards economy, aesthetics, energy and conservation. The scenario of solid waste management activities in the study area was almost similar. The status on SWM activities in the four Pourashavas is presented in Table 2.

Table 2 Status of solid waste management activities in four Pourashavas

SWM activities		Status	Respective Pourashava
01	Road sweeping.	No practice.	All Pourashavas.
02	Cutting /dressing of road side grass / plant.	Irregular.	All Pourashavas.
03	Cleaning solid matters from drain.	Irregular and inadequate.	All Pourashavas.
04	SW collection from every source (Dustbin, road side, market, etc.)	Regular.	All Pourashavas.
05	SW storage in secondary spot.	Not practice.	All Pourashavas.
06	SW disposal to the landfill.	Not accordingly.	All Pourashavas.
07	SW recycling / composting.	Composting by NGO.	Patuakhali Pourashava.

DATA ON SWM PROGRAM IN STUDY AREA

Table 3 Basic information on SWM activities of four Pourashavas

Information parameter		Unit	Status in four Pourashavas (In 2008).			
			Bagerhat	Barguna	Patuakhali	Bhola
01	Dumping site /landfill.	No. Acre	One. 1.25	One. 1.50	Nil.	Two 1.00 & 1.54
02	Dustbin availability	No.	125	92	84	65
03	Daily collection of Solid Waste (SW)	Ton	6	3	7	7
04	Daily disposal of SW.	Ton	6	3	7	7
05	Daily generation of SW.	Ton	10	5	12	9
06	SW generation - Kg /capita/ day	--	0.14	0.135	0.15	0.15
07	Equipments for SWMP :					
	◘ Garbage Truck	No.	2	2	3	2
	◘ Tractor with tailor	No.	1	0	2	0
	◘ Trolley	No.	9	15	40	25
	◘ Rickshaw -van	No.	4	5	7	8
08	SW composting. status	--	No	No	Yes	No

In the study area, it was noticed that SW was dumped generally here and there like low land inside or and outside of Pourashava and thus the dumping site or landfill was not used by the SW workers. The basic data and information regarding SWM in the four Pourashavas are stated in Table 3 (Data source: Respective Pourashava Office).

QUESTIONNAIRE SURVEY ON SWM PROGRAM

With a view to explore the people's perception on SWM, a questionnaire survey was conducted in random manner in the study area. The questionnaire contained 10 questions with probable answers and option of comments regarding SWM. The respondents were 750 nos. in total from four Pourashavas such as (a) Bagerhat Pourashava – 200 Nos., (b) Barguna Pourashava -182 Nos., (c) Patuakhali -176 Nos., (d) Bhola Pourashava – 192 Nos. The characteristics of the respondents were as follows. (a) Sex : The nos. of male and female were 485 and 265 respectively, (b) Education : The educational levels were found as postgraduate 38, graduate 82, HSC 112, SSC 162 and below SSC 356, (c) Age :The respondents with respect to age group were 8% of below 20 Yrs, 17% among 21– 30 Yrs, 28% among 31– 40 Yrs, 36% among 41– 50 Yrs and 11% of above 51 Yrs and (d) Profession :The profession was found as service holders 152, business 262, housewife 216, student 96 and others 24 nos (Ahammed S.N. 2008).

PEOPLE'S PERCEPTION

The comments of the people on SWM condition explored through the questionnaire survey from the study area are stated in the tabular formats placed below. The results had been explored from only 750 respondents (single respondent from every household) out of 38166 households in total in the study area mentioned as Bagerhat, Barguna, Patuakhali and Bhola Pourashavas (Ahammed S.N. 2008). Therefore, this perception may not be taken into consideration as the overall status on SWM of the study area.

Question 01 : Where the SW of your house is disposed of ?					Over all status (%)
Respondents' answers /comments (in figure) for four Pourashavas.					
Answer Option	Bagerhat	Barguna	Patuakhali	Bhola	
a) PS dustbin	32	68	92	22	**28.50**
b) Road side	66	85	11	5	**22.25**
c) Drain inside (/canal)	34	12	17	34	**13.00**
d) SW collector	0	9	34	21	**8.50**
e) In house surroundings	68	8	22	110	**27.76**
Total Nos. =	200	182	176	192	750

Question 02 : How the SW of your house is disposed of ?					Over all status (%)
Respondents' answers /comments (in figure) for four Pourashavas.					
Answer Option	Bagerhat	Barguna	Patuakhali	Bhola	
a) House servant	67	76	54	67	**35.25**
b) SW collector	0	9	34	22	**8.75**
c) Family member	133	87	66	103	**51.75**
d) Other comments	0	10	22	0	**4.25**
Total Nos. =	200	182	176	192	750

Question 03 : When the SW of your house is disposed of ?					Over all status (%)
Respondents' answers /comments (in figure) for four Pourashavas.					
Answer Option	Bagerhat	Barguna	Patuakhali	Bhola	
a) Morning	44	58	38	53	**25.75**
b) Afternoon	46	76	58	62	**32.25**
c) Night	20	24	42	20	**14.13**
d) No fixed time	90	24	38	57	**27.87**
Total Nos. =	200	182	176	192	750

Question 04 : Mention the daily average quantity of SW generated from your house ?					Over all status (%)
Respondents' answers /comments (in figure) for four Pourashavas.					
Answer Option	Bagerhat	Barguna	Patuakhali	Bhola	
a) Unknown	110	23	28	84	**32.67**
b) Normal	63	114	116	72	**48.66**
c) Quantity mentioned	27	45	32	36	**18.67**
Total Nos. =	200	182	176	192	750

Question 05 : Is there disposal bin (dustbin) available nearby your house?					Over all status (%)
Respondents' answers /comments (in figure) for four Pourashavas.					
Answer Option	Bagerhat	Barguna	Patuakhali	Bhola	
a) Available	63	110	109	118	**33.33**
b) Not available	137	72	67	74	**66.67**
Total Nos. =	200	182	176	192	750

Question 06: When the SW is taken over from the dustbin for final disposal?					Over all status (%)
Respondents' answers /comments (in figure) for four Pourashavas.					
Answer Option	Bagerhat	Barguna	Patuakhali	Bhola	
a) Daily	60	32	28	60	**24.00**
d) Regular	83	58	102	72	**42.00**
c) Irregular	57	92	46	60	**34.00**
Total Nos. =	200	183	176	192	750

Question 07: Are you interested for alternative arrangements of disposal bin?					Over all status (%)
Respondents' answers /comments (in figure) for four Pourashavas.					
Answer Option	Bagerhat	Barguna	Patuakhali	Bhola	
a) Interested	86	152	57	120	**55.33**
b) Not interested	114	30	119	72	**44.67**
Total Nos. =	200	182	176	192	750

Question 08: How much money do you pay per month to SW collector from your house? Respondents' answers /comments (in figure) for four Pourashavas.					Over all status (%)
Answer Option	Bagerhat	Barguna	Patuakhali	Bhola	
a) Not applicable	173	173	142	139	**83.60**
b) Taka 10/=	18	9	26	40	**12.40**
c) Taka 15/=	9	0	8	13	**4.00**
Total Nos. =	200	182	176	192	750

Question 09: Mention the consciousness of the PS citizen regarding SW disposal? Respondents' answers /comments (in figure) for four Pourashavas.					Over all status (%)
Answer Option	Bagerhat	Barguna	Patuakhali	Bhola	
a) Enough	138	46	28	17	**30.55**
b) Moderate	32	106	85	84	**40.90**
c) Poor	30	30	63	91	**28.55**
Total Nos. =	200	182	176	192	750

Question 10: Mention the over all situation of SWM program in your locality? Respondents' answers /comments (in figure) for four Pourashavas.					Over all status (%)
Answer Option	Bagerhat	Barguna	Patuakhali	Bhola	
a) Good	117	38	57	41	**33.74**
b) Moderate	43	62	74	84	**35.06**
c) Not satisfactory	40	82	45	67	**31.20**
Total Nos. =	200	182	176	192	750

OUT SOURCE SUPPORT IN SWM PROGRAM

Private sectors or NGOs somewhere provide supporting role in solid waste management program in Pourashava. They can help in making policy for improvement of recycling and collection of waste. They involve participation of the community people in solid waste activities. NGOs work in some Pourashavas actually on foreign aid for a specific period of time and in most cases the activities again go to the previous stage after end of their duration. In the study area, it was observed that supporting role on solid waste management program had been adopted by Municipal Support Unit under Municipal Services Project of Local Government Engineering Department. They organized to form Ward Level Coordination Committee in Pourashava wards and provided Rickshaw-vans for door to door collection of solid waste and disposal them accordingly. The partial involvement of NGO or private sector in SWM program is appreciated for their satisfactory performance.

RECOMMENDATION

Solid waste management is actually a complex and complementary task for Pourashava which depends on public and private sectors as well as other partners like households, communities, municipalities, private operators, service users. Municipality can not collect the total solid waste generated daily within the Pourashava area due to lack of capability of Pourashava. This incapability arises mainly from the limitation of fund. Also, the unconsciousness of Pourashava inhabitants causes extra pressure to the Pourashava authority. The authority should monitor and stress on solid waste management program with a view to ensure a healthy environment. Community participation can improve and sustain this program with the help of NGO or private sector that has already been proved in many Pourashavas in Bangladesh.

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Challenges of Waste Generation on a Densely Populated Town- A 15 Years Management Proposal for Nowapara Municipality

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ABSTRACT

Issues of Solid Waste Management (SWM) are twofold, i.e., households that need to dispose wastes in a place other than their homestead and volume of solid wastes that is in a sustainably return oriented condition. Households with high occupancy of homestead land can dispose wastes within their homesteads. Big homestead areas give notion of distant neighborhoodship which in turns blocks attention of gathering wastes for a further consideration. This hinders thoughts to collect waste from there because of scale economies in transportation in a one hand and volume of wastes generates in terms of sustainable further use on the other. The authors, hence, address a management concern for the people in high value (i.e., low amount land occupancy) urban concentrations. At present solid wastes are collected inseparated from 5% of households in Nowapara town. Household wastes and sullege are collected from densely populated areas and are dumped on private low lands on owners' request. By 2025 households with less than 5 katha homestead land will be increased by 60 times in Nowapara. An estimated volume of solid waste by that time will be increased by 55 percent at present. A comprehensive SWM plan including consideration of dumping station is an urge now for the increased urban population. The authors propose a collection system of "4-chamber waste separation" from generation sites, waste collection secondary spots and dumping area needed for next 15 years. Separation from generation spots is to ensure better recycling and reuse of organic and inorganic wastes and final dumping of clinical wastes. A forecast results, by 2015 yearly rate of compost manure from bio-degradable wastes will be approximately 1,500 ton with a 20% yearly increase rate. Moreover, recycled products will add value at the market rate in a considerable increase rate. The proposed management plan will be with the best returns if implemented by the Nowapara Municipality, as recommended by the authors in this study.

INTRODUCTION

With 25.11 sq. km. area, Nowapara Municipality established in 1996 and satisfying all Government's requirements within 10 years paurashava promoted to first class category. Day by day the population is increasing at an alarming rate as a result land distribution process is greater than ever in Nowapara Municipality. On the other hand emerging industries and commercial uses flourished the municipality's activities in its vicinity and all the activities are interlinked with the generation of wastes. Approximately 86781 (Birth Registration 2008) people are living in Nowapara municipality and near about 39.05 tons (Survey 2009) wastes are generated through all activities. Maximum wastes can not be collected due to not having needed manpower, proper management plan and vehicles. Total wastes is collecting by municipal authority based on population density area; an area having high population density, the collection preference is higher there than others. Municipal authority collects waste from 4% inhabitants from its jurisdiction and only continuing its activities within 4, 5 and 6 no. wards. In the respect of area authority can cover only 9% of the total area by 3 workers and 1 sanitary inspector; 1 pick-up van and 7 rickshaw van (Nowapara Paurashava at a glance 2009). There is no waste dumping site for municipal wastes directed to wastes dump in the private lands which can not be continued after certain time period. Even the process will continue the whole town area become throughaway society within short time. On the other hand urbanization process is increasing at a faster rate so the population is also increasing in the municipal jurisdiction area through birth and migration. With 12 years of municipality's age it is the time to make a perfect plan for solid waste management and to control the activities in a proper planned manner.

OBJECTIVES

- Identify the existing efficiency of Municipality in municipal solid waste management.
- 15 years waste management proposals for Nowapara Municipality

CURRENT STATUS OF SOLID WASTE MANAGEMENT

Employment

To serve 25.11 sq. km. area only 1 conservancy inspector is monitoring all the works done by the employee like sweeping, drain cleaning etc. 46 workers are engaged in cleaning and sweeping and only 3 workers are engaged in waste collection. As the official time sets 9 am to 5 pm after that time period one supervisor control the whole works with the direction of inspector.

Available vehicle*:* 7 numbers among 17 numbers of vans, 3 numbers among 4 numbers of conservancy mini trucks are well for the work.

Waste Collection Area

Paurashava consists of 9 wards but municipal authority is continuing their works within 3 wards (4, 5 and 6) partially. Figure 1 shows the covered area.

Existing Dumping Site

Authority does not have any dumping site but they are using one private land to fill up and site is just beside the secondary school named Shankarpasha High School. After filling up the land authority must find another place for filling. Although authority proposed a dumping site of 1.89 acre just outside the municipality. Location of proposed dumping site is mentioned in Figure 1.

Waste Collection and Dumping Time

All the cleaners are cleaning roads before 9 am. Sometimes they can not complete within timeframe if there is any disruption in doing so. After 9am authority starts door to door collection and as the present dumping site is not far away from collection area so no motorized vehicle is needed for dumping.

Waste Separation

There is nothing notices about waste separation from collection to disposal stages. Existing practice of solid waste management: 3 (three) 'systems' of waste management are coexisting side by side in Bangladesh. One is the **`Formal System'**,, next is the **`Community Initiative'** and 3rd one is **`Informal System'** (SAARC 2004). In formal system municipality is accountable for Solid Waste Management. Practically in this system the concept of transfer stations, resource recovery, minimization and recycling are still missing. **Community Initiative** is based on primary solid waste collection by CBOs and NGOs and **Informal System** is to involve informal labor force in recycling trade chain but **Community Initiative** and **Informal System** are totally absent in the municipality.

MSW GENERATION AND COLLECTION EFFICIENCY OF NOWAPARA MUNICIPALITY

Wide-ranging waste characterization studies have not been conducted yet but municipal authority measure the amount of waste collected from different source by private weighbridge. Municipal authority now collects wastes from about 400 households each day. By considering the total waste in 7 days it can be revealed that per capita waste generation rate is 0.45 kg. Solid waste generation in Nowapara is growing proportionately with the growth of population. Table 1 shows the growth in solid waste generation over the years.

The Table 1 depicts that solid waste generation in Nowapara Municipality is growing with the growth of population.

According to municipal activities there are different sources exist in Nowapara Municipality. Municipal authority selected some sources where wastes to be collected within municipal jurisdiction area with the collaboration of CBO (Community based organization). CBO is not involved with these activities enormously but municipal authority covers the maximum works now. Table2 shows the types of sources of waste and collection efficiency of municipality.

Table 1 Solid waste generation in Nowapara Municipality

Year	Total population	Waste generation rate (kg/cap/day)	Total waste generation (Tonne/day)	Waste collection (Tonne/day)	Collection efficiency
2001	73006*	0.40****	29.20	0.5	1.71%
2008	86781**	0.45****	39.05	1.6	4.09%

Source: BBS, 2001, ** Birth registration, 2008, ** Conservancy section, 2009*

Table 2 depicts that from all the sources mentioned, with little assistance CBO municipal authority can collect wastes from approximately 3.65% of the total residential unit, 63.44% of commercial units, 31.25% of institutions, 22.22 % of clinical wastes and all municipal services waste. On the other hand authority is not collecting industrial wastes, construction wastes, agricultural wastes and processing wastes due to lack of manpower and available resources.

Table 2 Present collection status from different sources

Source type	Source unit	Coverage in unit
Residential	10965	400
Commercial	465	295
Industrial	23	0
Institutional	80	25
Hospital/Clinic	9	2
Construction and demolition	115	0
Municipal services	200	200
Process and Manufacturing	2	0
Agriculture	6568	0
Total	18427	922

Source: Municipal Authority, 2009

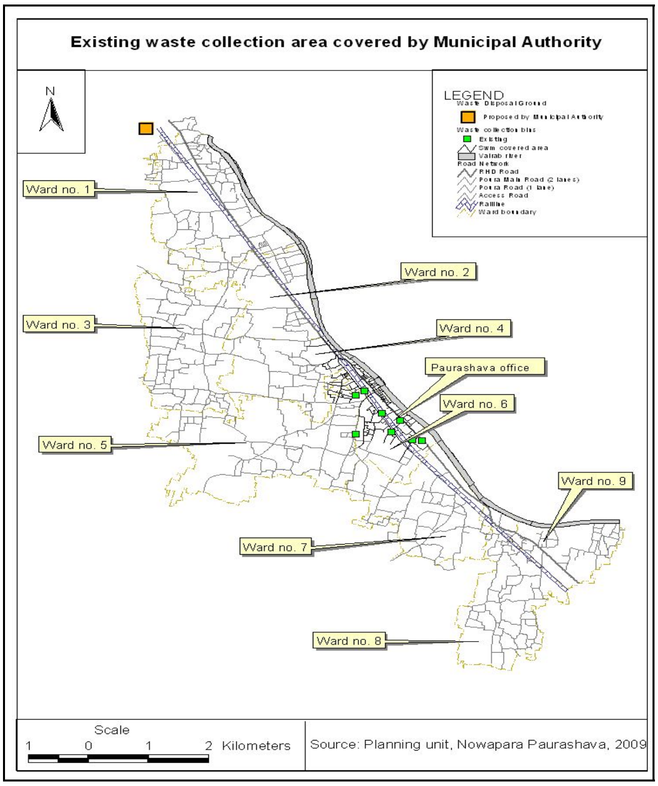

Figure 1 Existing waste collection area covered by Municipality

YEARLY POPULATION AND PROJECTED WASTE GENERATION FOR NEXT 15 YEARS

As per census of 2001, the population of the Paurashava is 73006 (BBS, 2001) with a high growth rate of 9.84% but the birth registration held in 2008 revealed that the total population of Paurashava is around 86781 where the growth rate is about 2.5%. Though the national population growth rate is 1.41%, Nowapara municipality with its emerging industrial and commercial activities population growth rate is higher than the national growth rate. Nowapara Paurashava was established in 1996 so that within 5 years the population growth rate became higher because of in migration and industrial setup but after 10 years the growth rate is about 2.5%. Among these three growth rates 2.5% was accepted by the municipal authority (MIDP for Nowapara Municipality, 2008) and if everything remains unchanged projected population can be calculated with 2.5% population growth rate. Projected population is calculated by **Exponential Method** of population projection which is expressed below.

Table 3 Yearly population, waste generation rate and total waste generation of Municipality

Year	Population***	WGR	Total waste (kg/day)
2009	88951	0.45	40027.95
2010	91174	0.46	41940.04
2011	93454	0.47	43923.38
2012	95790	0.48	45979.20
2013	98185	0.49	48110.65
2014	100640	0.50	50320.00
2015	103156	0.51	52609.56
2016	105734	0.52	54981.68
2017	108378	0.53	57440.34
2018	111087	0.54	59986.98
2019	113864	0.55	62625.20
2020	116711	0.56	65358.16
2021	119629	0.57	68188.53
2022	122620	0.58	71119.60
2023	125685	0.59	74154.15
2024	128827	0.60**	77296.20

WGR=Waste generation rate
*** Source: SAARC, 2004*
**** Source: MIDP of Nowapara Parashava, 2008*

Exponential method of population projection

$$Pn= Po+(1+r)^n \quad (1)$$

Where, Pn= Population in projected year,
Po= Population in base year,
r = Growth rate,
n= Projection year

PROPOSED 15 YEARS PLANNING STRATEGIES FOR WASTE MANAGEMNT

Considering all existing, projected future activities and projected population figure authors suggests here some important strategies according to the Municipality's characteristics and practices in different cities and backlog in actions taken for sold waste management. Authors select some sectors to be flourished mentioned below.

Updated Digital Map Preparation

Municipal authority has digital maps of municipal jurisdiction area prepared by LGED through UGIIP (Urban Governance & Infrastructure Improvement Project) and more than 70% correct land use databases but does not have extensive use of that map with different activities so in the first step authority must prepare a complete usable map for waste management. It may contain the plot to plot

land use, building type, households and members of each household and age of every member of that family.
Benefits: More accurate and complete database makes the municipality strong to manage and to take the decision and to serve the people as early as possible.

Installment of Waste Transfer Station

With the ribbon development Nowapara Municipality has some advantage that all ward but ward no. 3 are connected with the Khulna Jessore National Highway. Waste transfer station can be constructed by the side of Khulna Jessore Highway. Transfer station should be cleaned regularly.
Benefits: Only 12 km of JK road is in municipal jurisdiction area. As municipal authority is collecting waste by waste collection van (motorized) so 8 numbers transfer station along the Jk road will reduce the fuel cost to transfer waste rather than collecting waste from different location in different points and will avoid the transfer activities from calm and sensitive area like school, college and residential area etc as municipal authority decided to construct a dumping site just beside the JK road Highway. Location of proposed dumping side is pointed on the map. Authors did not propose any location for transfer station because it totally depends on available land so municipal authority can decide about the matter.

Encourage CBO to Collect Waste from Door to Door

Authors are suggesting to collect waste from door to door by CBO. Though the activity of CBO is already exist in Paurashava in small scale. Authors propose to strengthen the activities of CBO so that they can collect waste from households, commercial centers, clinics, hospitals and agricultural sources. All industries were established along Jessore Khulna road so municipal authority can collect all the industrial wastes during garbage truck's movement from starting point to dumping site.
Benefits: Municipal cleaner clean waste everyday with minimum wages. Maximum wage range of a cleaner is about 1000 taka to 1500 taka per month. They mainly clean road, drain, kitchen markets, curb site wastes etc (Conservancy section, 2009). Only 3 workers are collecting waste from door to door in the municipality. They are collecting 0.18 tons wastes from 400 households. If CBO can collect waste from households they can either collect some money at the rate of 15 to 20 taka from each household so that they can earn money and can maintain some employee whether municipal authority do not have any legal power to charge money for waste collection. Involvement of CBO will decrease the cost burden of municipal authority. Municipal authority must make a plan to collect waste and inspect all the activities by the CBO so that they can work without any biasness.

Municipal Authority Must Keep Transfer Station Clean, Hygienic and Odor Free as All the Transfer Station Will Establish Along the Busiest Road in Nowapara Named Jessore Khulna Highway

Benefits: Activities to be done for clean and keep odor free, municipal authority has responsibility so that they can make themselves as a liable institution to the people. It will also ensure the people's perception to municipality and will strengthening the beautification of the town.

Ensure a Sanitary Landfill Site

Benefits: Municipality must have a dumping site and it should be sanitary landfill site so that municipal waste can collect waste and dump into it on the other hand after 15 years the landfill site can be use in other purposes like commercial centers or even a residential area. Though municipal authority proposed a dumping site having 1.89 acre to concerned ministry outside the municipal boundary where authors proposed 4.64 acres land for next 15 years. Without any dumping site municipal authority has to use private land like now.

Provision of Litter Bins at Public Places

Benefits: At the commercial places and all the other places there should be provision of litter bins so that people can use it frequently rather than throw on the road or public places.. On the other hand some sorts of waste separation activities can be performed by the people.

Conversion of Organic Wastes into Compost

Benefits: After successful separation of waste from source and collection decomposable waste should convert into compost fertilizer. Compost fertilizer is salable and it has some demand in the market. It is the matter of money earning and alternative of chemical fertilizer.

Building up Public Awareness

Benefits: Without public participation it is not possible to execute this plan. There are some rules, regulations; laws, by-laws, acts etc are readily available in Bangladesh but no use in practical life. Authors are suggesting in this matter that municipal authority and Upazila Parishad both can jointly work in building up public participation. Though this is not the mandatory works for Upazila Parishad however as a growth center people from different location gather here for barter.

Financial Strengthening of Local Bodies

Benefits: According to Municipal Ordinance in 1977, Municpal Tax Rules in 1960 and also Model Tax Schedule in 2003 municipal authority can collect not more than 7% value of existing building cost as a conservancy tax. In 39th monthly meeting municipal authority decided to collect only 3% as a conservancy tax. Authors suggest increased conservancy rate to furnish municipality's fund and to increase conservancy services to make Nowapara as a beautiful town. Otherwise Municipal authority can increase their conservancy services by taking loan from bank and then people will pay more with the satisfaction of services. After increasing services, authority can charge exact money to get more to pay the loan. Authority will decide what to do according to their financial capacity.

Adequate Personnel Should be Sanctioned According to the Growth Rate of Urbanization

Benefits: 43 workers, 1 conservancy inspector are working in Municipality. 40 workers are working to clean the road, drain, market places and commercial centers and 3 workers are working only for waste collection. This 3 workers can collect wastes from approximate 400 households but 16346 households are there in the municipality. Survey depict that as there is no permanent dumping site, authority decided to make a permanent place then they will increase labor forces to collect and to manage waste in a proper manner.

Collection Time Should Avoid School and All Official Time

Benefits: Survey portrays people's perception about collection and transfer time that they encourage collecting wastes before 9am for door to door collection and needed times for transfer according to situation. Authors are giving emphasize about peoples perception.

Encourage Electricity Generation Plant by Waste

Benefits: In dumping site an electricity production plant can be encouraged and it will enhance the capacity of power of municipality to keep people free from load-shading.

Finally Monitoring of All the Activities to be done by Controlling Authority of Municipality

Benefits: Waste management is a continuous work and authors here suggesting to monitor all the activities of municipal workers and CBOs which will ensure the total system to facilitate people in large scale.

Combine Works among Formal System, Community Initiative and Informal System is Needed to Promote Effective Solid Waste Management

Benefits: Authors propose to develop all the systems with joint collaboration to strengthening management capacity and enhance coverage.

APPOXIMATE AREA NEEDED FOR DUMPING SITES

Calculation of an area needed for dumping site considers waste composition, waste collection efficiency, total wastes generation, percentage of wastes converted into compost fertilizer, settlement of the untreated waste deposited in the landfill, reusable wastes to be separated etc. Here authors consider projected waste generation, projected waste collection efficiency, present reusable wastes percentage and settlement of the untreated waste etc. If there are any initiatives to make compost fertilizer and power generation plant by wastes land sizes will be varied then.

The table 4 depicts that more than 83% of total wastes can be use for compost fertilizer production and here authors suggest improving compost fertilizer production phase by phase with the capacity of municipal authority or if there is any private initiative municipal authority should encourage to do so.
Total lands for dumping site depends on collection efficiency and wastes to be dumped in the site and design years. Total procedure to calculate the area is described below:

Table 4 Waste composition in Nowapara Municipality (by weight)

Waste Components	Composition (%)
Food and Vegetables	72
Papers products	7
Plastics	5
Metals	0.75
Glass & Ceramics	0.25
Wood	0.50
Garden wastes	4
Others	9.5
Medicine & Chemicals	0.5
Leather	0.5
Total	100

Source: Field survey, 2009

Table 5 Calculation of waste to be dumped into dumping site

Year	Total wastes (Tonnes/Year)	Collection efficiency (%)	Total collected wastes	Wastes to be dumped
2009 (J-D)	6866.79	4.09 (Existing)	280.85	264.00
2010	14389.63	10	1438.96	1352.63
2011	15070.11	20	3014.02	2833.18
2012	15775.46	30	4732.64	4448.68
2013	16506.76	40	6602.70	6206.54
2014	17264.79	50	8632.40	8114.45
2015	18050.34	60	10830.20	10180.39
2016	18864.21	70	13204.95	12412.65
2017	19707.78	70	13795.45	12967.72
2018	20581.53	80	16465.22	15477.31
2019	21486.71	80	17189.37	16158.01
2020	22424.38	90	20181.94	18971.03
2021	23395.48	90	21055.93	19792.58
2022	24401.13	95	23181.07	21790.21
2023	25442.29	95	24170.18	22719.96
2024 (J-J)	13260.16	100	13260.16	12464.55
Total/Avg	293487.55	65% (Average)	198036.05	186153.88

Projected Total wastes generation in next 15 years: 293487.55 tonnes and with the increasing efficiency of municipal authority 198036.05 tonnes will be collected within next 15 years and 186153.88 tonnes will be dumped into dumping site considering 94% of the total wastes will be dumped. 6% of plastics, metals, glass & ceramics are excluded from the total waste because it is reusable. According to UGIIP, LGED average weight of $1m^3$ waste is about 1 tonne. On the other hand 35% of the total area should be reserve for road network in the dumping site (LGED, 2009). With consideration of all aspect of dumping sites, area can be calculated by following method. Total settlement of the untreated waste deposited in the landfill ranges from 40% to 20% of the initial waste layer height (W. Stepniewskique, 2009). Without any experiment authors fix 30% as a mid point of that range.

Area needed for dumping site = {(Total volume of wastes/ 1metre) X 1.35 X 0.3} sq. m.
= (186153.88/1) X 1.35 X 0.3 sq. m.
= 75392.32 sq. m.
= 1859.24 decimals (If the dumping site's height is 2.30 ft)*
= 929.62 decimals (If the dumping site's height is 4.60 ft)
= 619.75 decimals (If the dumping site's height is 6.90 ft)
= 464.81 decimals (If the dumping height is about 9.2 ft) **

** Deducted 30% from 1 meter height from deposited wastes and 40.55 sq. m. = 1 decimal.*
*** 4 times higher height of 2.30 ft*

Above calculation revealed that increasing collection efficiency up to 100% within 2018 AD Nowapara Municipality must have 619.75 decimal lands for waste duping site if deposited wastes height is about 9.2 ft.

TRANSPORT ROUTE OF COLLECTION AND DUMPING

To avoid school and colleges and all other institution's routes authors proposing only Jessore Khulna Highway to collect waste from transfer station to dumping ground by motorized vehicle and NGOs or CBOs will collect wastes from door to door and dumped into transfer station. 8 numbers of transfer stations are placed here as 8 numbers of wards boundary touch Jessore Khulna Highway. One transfer station will be big enough to manage 2 number of ward's wastes as shown in Figure 2.

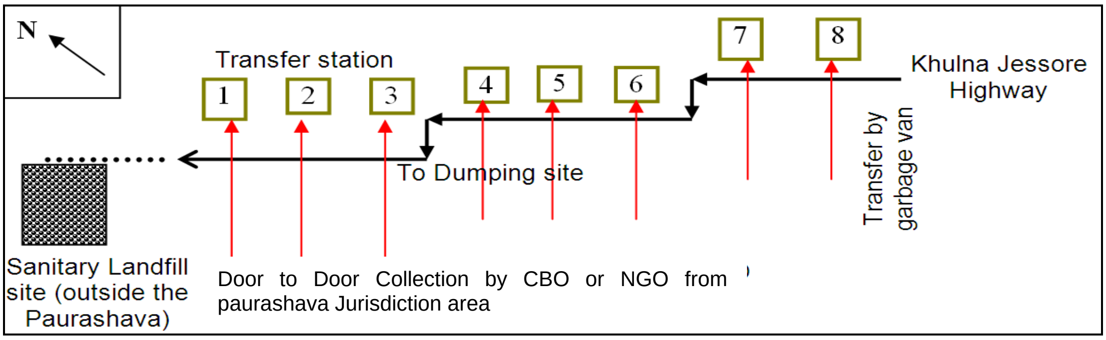

Figure 2 Flow diagram of waste management proposal

CONCLUSIONS

Nowapara Municipality is situated beside the Bhairab River and this river-way, parallel national highway and railway are thriving the town and flourishing commercial and industrial activities all over the area. People of the municipality are enjoying all sorts of advantage of combined transportation facilities. As a result huge activities generated huge wastes in the town. In 11.2 km long and average 2.24 km wide municipality flourished with 25 light and heavy industries and different commercial activities which were established by the side of Jessore Khulna Highway and the Bhairab River. All the practices and efforts should reflect the better future but practically all the activities are not in planned manner and not target oriented. As an emerging area, Nowapara Municipality should develop in a proper way to make beautiful, livable town in near future. Proper management and initiatives can lead organized and succeeded outputs.

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Municipal Waste Management Mechanism for Khulna City: A Practice for Better Environment

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ABSTRACT

The rapid development and high population growth of the major cities in developing countries have resulted into a significant increase in household waste and possess a tremendous challange for the local authority. Khulna is one of the fast growing commercial cities in Bangladesh with a population of 1.9 million which produce about 450 ton of municipal solid wastes per day. Khulna City Corporation (KCC) and community based NGOs are taking care of only 42% of the total waste generated while the rest of them are unattended. In fact, most of the wastes are collected from door-to-door without any sorting and either dumped in open space or improperly landfilled which is likely to contaminate the air and ground water. This research is aimed to find potential municipal waste management options for Khulna city, where waste could be used as a resource rather than simply dumping it into the landfill site.

INTRODUCTION

Municipal solid waste has become a major concern now-a-days as the amount of waste generation has increased tremendously due to rapid urbanization and industrialization, population growth and improved life-style. Furthermore, waste manangement policy without considering comphrehensive plan along with poor management techniques and lack of appropriate technology is making the situation more wasteful threatening the environment and public health. It is certain that the developed and industrial countries produce huge amount of indstrial and commercial wastes; whereas the developing countries do not have mass scale industrial development but still they produce big amount of domestic wastes through daily consumption of fooding, clothing and others. As a developing country Bangladesh will has the same feature, having a huge population, large consumers, high amount of solid waste and poor management system. Bangladesh is undergoing rapid urbanization and significant internal rural-urban migration, resulting in a growth of city population. Therefore, major cities in Bangladesh are facing urban environmental threat in terms of unorgannized loads of solid waste, poor water supply and sanitation.

Khulna is the third largest metropolitan, industrial and port city in Bangladesh having a population of 1.13 million and covering an area of 45 square kilometre (Murtaza 2002). The growth of trade and economic activities resulted in a sharp increase in city population from 0.62 million to 1.13 million from the year 1991 to 2002. The amount of solid waste has also increased with the increase of population because of the change in consumption patterns and availability of products in the market. According to available statistics, more than 250 tons of garbage is produced per day from which the KCC is able to pick up and dispose of only 42% of its produced solid waste (Salequzzaman *et al*. 1998). The city is facing serious health risk due to uncollected domestic waste on the streets and other public places resulting into clogged drainage system and contamination of water bodies. This is very acute during the rainy season especially in the congested unplanned neighborhoods where roads are very narrow and municipal trucks cannot pass (World Bank 2000).Waste management in the city has been in a total mess as the City Corporation authority is still not familiar with any modern waste management system. In this situation, some innovative civic authorities of non-governmental organizations (NGOs) and the communities such as 'Prodipan' in Khulna have been successful in developing participatory community-based solid waste management (Murtaza 2002).

This study mainly focuses on community based organized solid waste management system in Khulna city as an alternative to minimize and manage the waste. As there are not many modern solid waste management techniques used in Bangladesh, therefore, the local community with NGO and City Corporation authority has come up with their own mechanism to manage the solid waste in the city through small scale recycling and land filling techniques. The aim of this study is to evaluate the community-based solid waste management techniques and their effect on the environment both from positive and negative perspectives

STUDY AREA

Khulna is located in the south-western part of the country between 22^0 47’ 16” to $22^0$52’ north latitude and $89^0$31’36” to $89^0$34’35” east longitude, following is the location map in Figure 1 of Khulna City. The city is located along the rivers the Rupsha and the Bhairab.

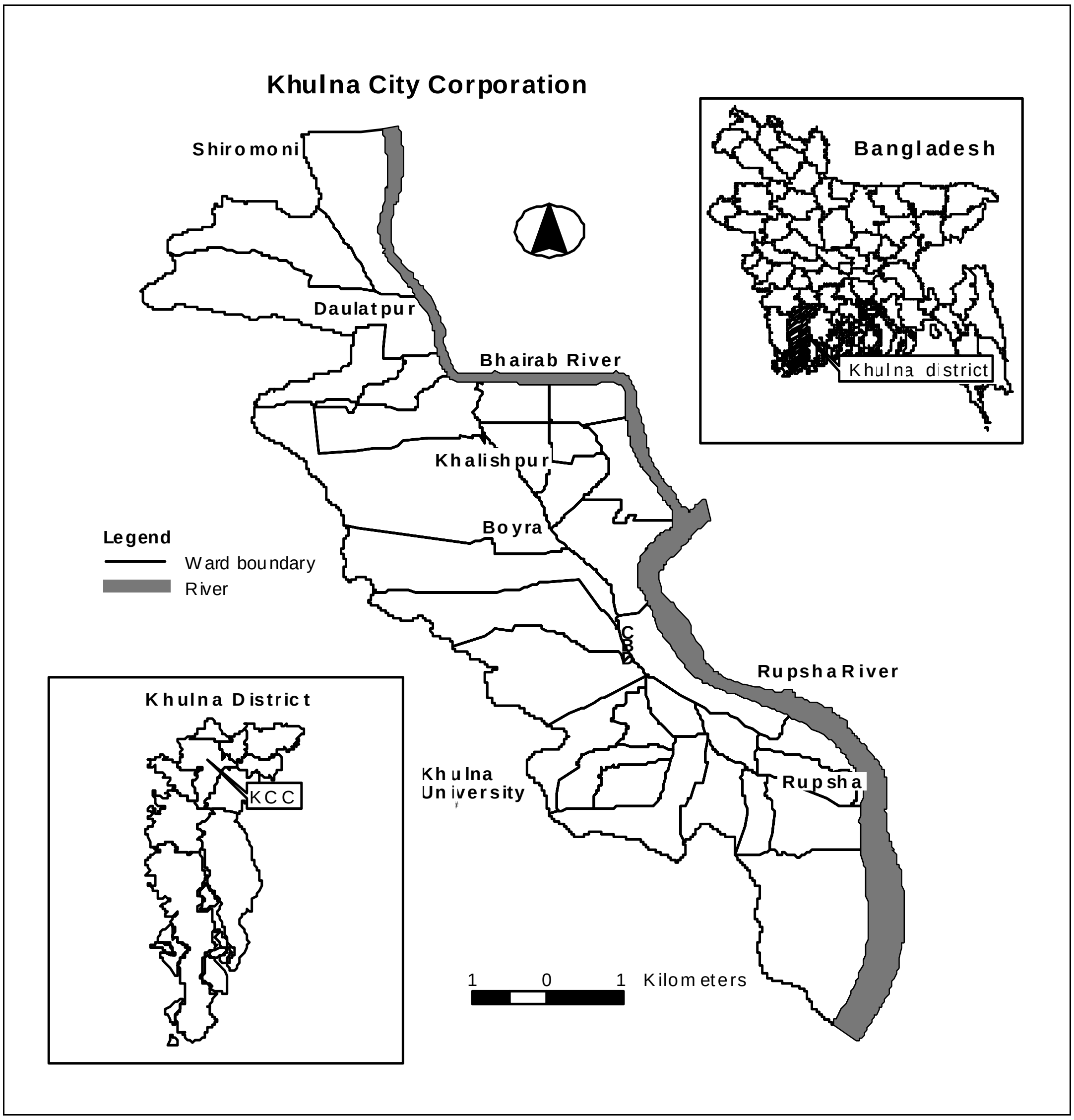


Figure 1 Map of the study area, KCC (KCC Year Book 2000)

Most of the manufacturing industries are located along the rivers that act as industrial pollutants sink. At the same time, municipal solid wastes are also dumped into those rivers because of improper management, posing a direct threat to the urban environment, ecology and human health. The KCC is responsible for collection, transportation and treatment of solid waste according to the KCC Ordinance 1984; but they failed because of lack of resources and other constrains.

MUNICIPAL SOLID WASTE IN KHULNA CITY

Municipal Solid Waste Management has become an acute problem for Khulna city. The solid wastes in Khulna city are originated from residential areas, i.e., houses, street sweeping, commercial, industrial and other sources. In general, there is a dearth of information regarding sources, volume, composition characteristics, etc. concerning the solid waste in Khulna city. The following Table 1 presents some major sources and characteristics of municipal waste in Khulna city.

Table 1 Source and characteristics of municipal waste in Khulna City

Source/Type	Unit	Quantity Produce
Domestic	Kg/day/household	0.5 – 1.0
Retail and Sale Market	Kg/day	50 – 200
Slaughter House	Ton/day	2 – 3.5
Hotels and Restaurants	Kg/day	50 – 150

[Source: Environmental risk assessment action plan Khulna city 2000]

It has been observed that 70-80 percent of the generated wastes are organic in nature and easily biodegradable. On the other hand, the remaining 20-30 percent of wastes are inorganic and need better treatment to manage with care (Murtaza 2002).

ROLE OF KCC IN WASTE MANAGEMENT

As a public authority, KCC is responsible for managing the municipal waste in the city. Conservancy Department of KCC is responsible for the collection, transportation/removal and disposal of waste in Khulna city. At present there are 356 workers and about 50 officials engaged by conservancy department (KCC) for collection and disposal of refuse for 114,000 households and 790 different small and medium scale industries (Asian City Development Conference 2000). Every day the department collects about 220 tons of municipal wastes. On this basis, the quantity of solid waste generated per capita / day in Khulna city is 0.3 Kg. But it has been reported that the per capita / day waste carried out to the disposal site is about 0.2 Kg on an average (KCC Year book 2000). The rest 0.1 kg (average) amount of waste are remain left in the dustbin and some drop from the open truck because of carelessness of the staffs.

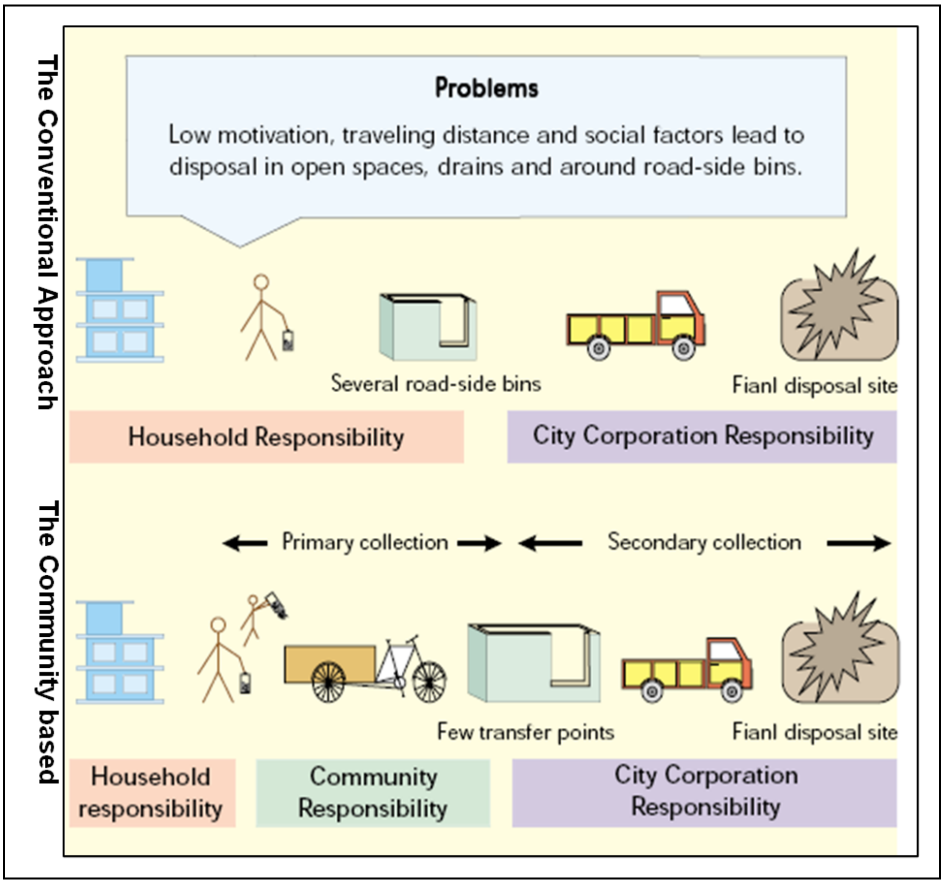
The city corporation authority collects wastes from 1200 roadside city corporation masonry bins. The households are expected to dispose their wastes on the roadside masonry bins for the KCC waste management authority. KCC trucks collect those wastes for final disposal as Rajbandh landfill area is located at a distance of 9 kilometer from city centre. The solid waste is dumped at that location without any pollution control measures or treatment options. The leachates from open waste dump pollute the surface water around the site. With 25 garbage trucks, 462 cleaners and an annual budget of USD 25000, KCC is not well equipped to manage the municipal wastes of a city with 1.13 million population, therefore, different development organizations with foreign funds have come up with the idea of community based waste management techniques. Community based waste management is not a modern technology; it is a way to minimize the waste and install better management practices with public private partnership and community participation

COMMUNITY BASED WASTE MANAGEMENT IN KHULNA CITY

Shortage of financial support, lack of modern technology and proper management encouraged the private sector to come forward to get involve in waste management process through community based approach. The aim was that the local households pay for door-to-door waste collection rather than dumping waste to the masonry bins located at the corner of the road. With the success of the door-to-door waste collection process KCC along with one of the assigned NGOs named Prodipan came up with a community based waste management proposal for Khulna city which was funded by the Swiss Agency for Development and Cooperation (SDC). The project started in 1997 and the operation is undergoing in more organized and cooperative manner. Different strategies were adopted at the beginning of the project and maintained by the selected NGO. This selected NGO is responsible for door-to-door collection and KCC is responsible for disposal and treatment. The local NGO was directly involved with the community and the City Corporation providing legislative support to the whole system. The main strategies of the project were balancing local needs with wider institutional, technical and environmental constraints; addressing the needs of all sectors of the community; motivating and organizing local people to help them to find solutions to problems at the local level.

COMMUNITY BASED WASTE MANAGEMENT PROCESS

In the community based waste management approach, the households, local community (NGO) and the City Corporation are jointly involved at different stages. On the other hand, according to the conventional approach, the households and City Corporation were responsible. Therefore, the proper management process was not at a satisfactory level. As the community based management system the NGO makes aware the community members about their responsibilities and ensures willing participation. Therefore when there is no future external support by NGOs or other organization the community could run the system at a sustainable level with KCC. Following Figure 2 presents the difference between conventional and community based approach of waste management in the City Corporation boundary of Khulna. In the conventional approach, waste is generated at home and usually stored until a certain amount has been accumulated. It is the responsibility of the generating household to transport the waste to the nearest roadside bin which is provided by the city corporation. The city corporation is responsible for the transfer of this waste from the roadside bins to the final disposal site. In the community based approach, Khulna city is divided into small areas called primary collection blocks. These consist of approximately 500 households which are all served by one rickshaw van. Waste generated at home is stored and collected daily by a primary collector employed by the NGO, who transports the waste to nearby transfer points, normally in a rickshaw van. This primary collection is the responsibility of the community. Transfer points are places where waste is unloaded from primary collection vehicles to be taken away by secondary transport. Several primary collection blocks are served by a transfer point. The waste is then collected from the transfer points and taken to the final disposal point by a large truck. This is secondary collection and is the responsibility of the city corporation.



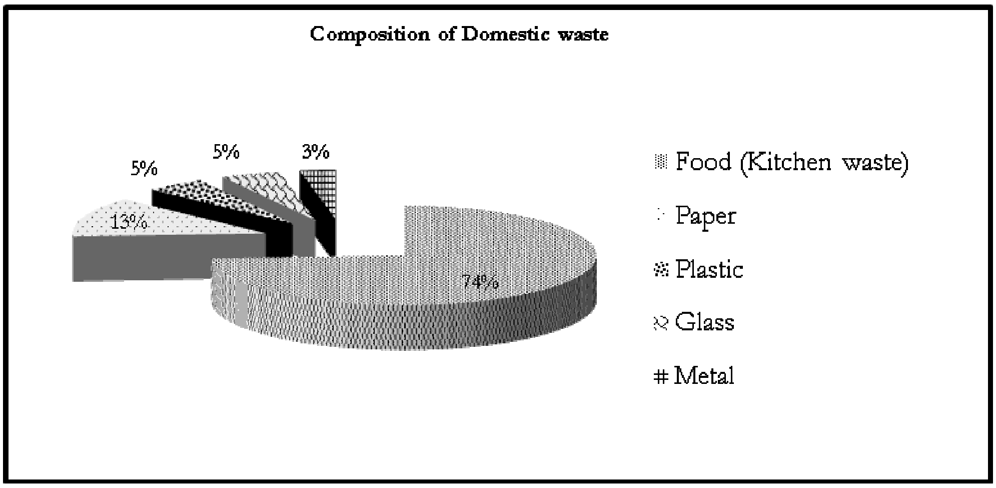
[Source: World Bank 2000]

Figure 2 The Conventional and community based approach of waste management in Khulna city

ALTERNATIVE WASTE MANAGEMENT TECHNIQUES AT THE COMMUNITY LEVEL

Under Community based waste management process different techniques are used to manage the domestic wastes. The major compositions of domestic wastes in Khulna city are given in Figure 3. Introducing the alternative community based waste management techniques would be a low-cost in house mechanism to manage the waste at local level; for example

- waste minimizing at household level
- local level recycling, and
- barrel type domestic composition in slum areas.



[Source: Salequzzaman et al. 2002]

Figure 3 Percentage of domestic waste composition in Khulna City

Waste Minimizing at Household Level

This is the first stage of waste management. The community authority fixes the size of a bin for each family. The bin is about 18" long and 12" in diameter. The household has to pay a minimum monthly charge for this size and that is only 10 Taka (0.2 USD) per month. But if the household produce wastes more than this size of a bin the authority will not collect that, or the household has to pay more. With extra price imposing method the community authority tries to minimize the volume of the wastes. The following Figure 4 shows the standard size of a dustbin under community based waste management system.

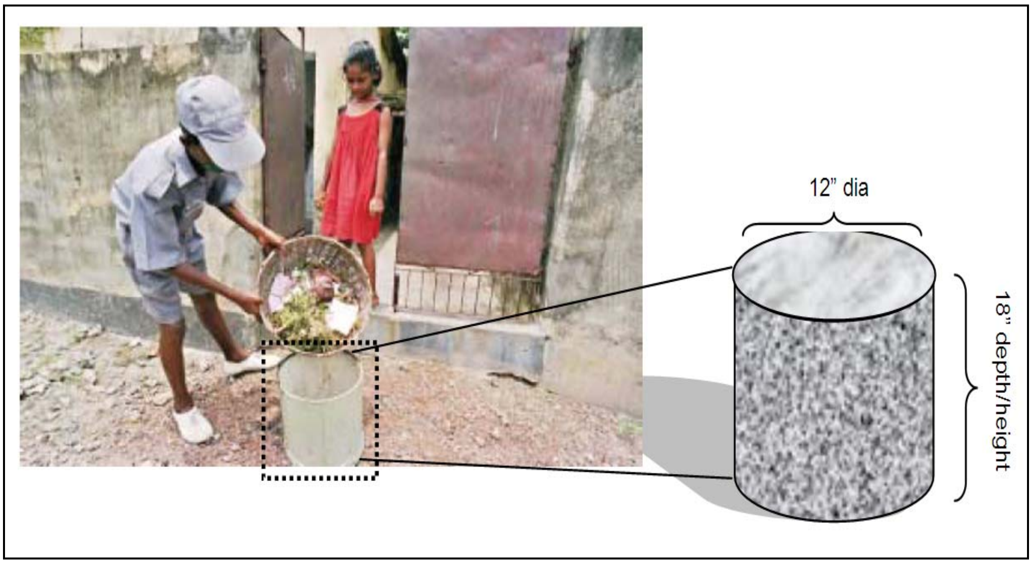


Figure 4 Standard bin sizes for the community waste minimization

Local Level Recycling

In general, wastes having some market value are being reclaimed or salvaged in three stages. In the first stage, housewives separate refuse of higher market value such as paper, bottles, fresh containers, old clothes, shoes, etc. and sell them to street hawkers. In the second stage, mostly children of slum dwellers 'Tokai' carry out salvaging by collecting different items of low market value from waste collection bins. Scavengers (e.g. poorest community of the city) at the final disposal sites do the third stage of salvaging when municipal trucks unload fresh refuse. The reclaimed materials reach the waste and old materials shop through street hawkers who purchase old materials directly from households and through solid waste collectors who reclaim the materials from bins and final disposal sites. These reclaimed materials require intermediate processing like washing, drying and sorting. The refuse dealers separate the materials in proper form and sell them to consumers as well as supply them to appropriate processing factories for reuse as raw materials.

Barrel Type Domestic Composition in Slum Areas

Generally, in low-income settlements the major portion of the waste generated is biodegradable. Slum dwellers are motivated to dispose their inorganic waste in the yellow barrel provided by local community organization, which is subsequently carried to nearby KCC dustbins, for final disposal. It was found that from a one 200 liter barrel, compost worth between Tk. 900-1000 (18-20 USD) could be produced each year. The households sharing the barrel can also share the income from sale proceeds of the compost. This model is successful in achieving a behavioral change by minimizing littering in the slum. The slum dwellers are quite enthusiastic about the project as they are seeing the benefits of clean environment, health benefit and earning extra income from their waste, which was previously creating pollution and nuisance in their slum.

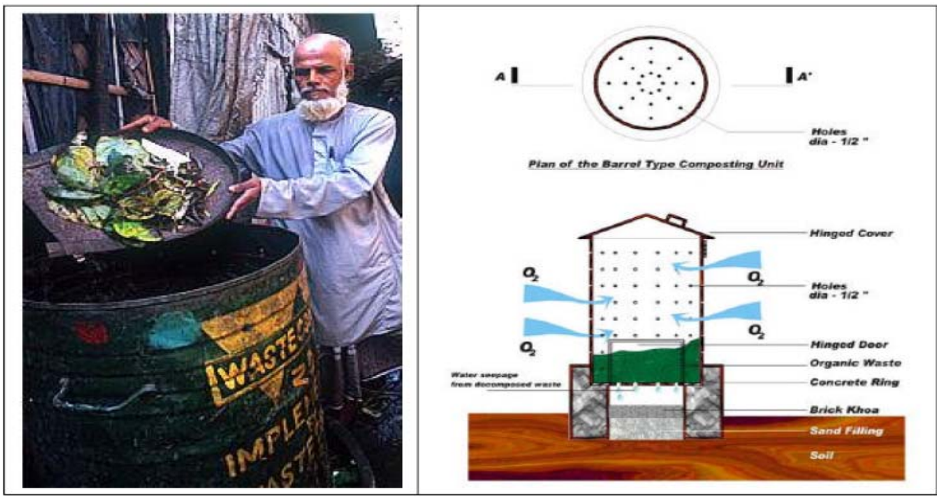
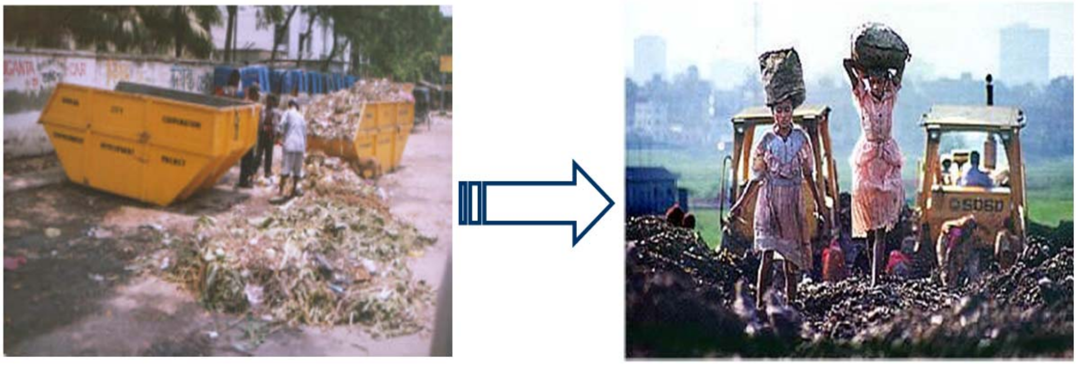


Figure 5 In home composting using the barrel method

The success of community based waste management method depends on successful public awareness and motivation. Therefore, the local NGO Prodipon who started the community based waste management in Khulna city, also started public awareness program from the beginning of the project. This included formation of the local community group among the household members to monitor the project and develop awareness among the community. Furthermore, the NGO has a community feedback system to improve their service to the community and ensure better environment.

COMPARISON BETWEEN CITY CORPORATION AND COMMUNITY BASED WASTE MANAGEMENT

KCC used the conventional approach for municipal waste management where the City Corporation has no control on the volume of waste generation and dumping by the households and others. They only provide masonry bins located at roadside and collect the wastes from the bins and dump to the final disposal site. KCC has failed to manage the waste with increased growth of population. City Corporation uses land filling and disposal as the final stage of waste management. The following Figure 6 shows the origin and destination of City Corporation waste management stages.



Road side dumping by the city dwellers Road side dumping by the city dwellers

Figure 6 Conventional waste management by the City Corporation

Under community based waste management, the volume of waste is reduced from the source through different techniques and even they use small scale recycling methods to introduce reuse of things and minimize the volume. Community based method also introduces domestic waste composting techniques for the slum dwellers and the low income people. Community based waste management success completely depends on people's motivation and willingness to pay. The community based waste management method has served better than the City Corporation as they have been reducing the volume and making the community aware about waste management and has given them alternatives to manage the waste.

CONCLUSIONS

In Khulna City the municipal waste management is a both way approach, where the KCC, Community Based Organization (CBO) and the beneficiaries are linked as top and bottom up approach. KCC collects and disposes the municipal waste from the public dustbin and other secondary disposal points and dump to the final landfill destination without proper treatment. This causes serious environmental problems to the surrounding environment as well the to the ground water. The community based waste management is a new step forward to manage the waste in Khulna city but still there are more steps needs to taken to improve the waste management system in Khulna city:

- Inclusion of waste recycling in City Corporation Ordinance/Act as a system in municipal waste management.
- All activities of NGO's under community based waste management system should be strictly/closely coordinated, monitored and overseen at the apex level.
- Develop a regulatory framework that guides the community base waste management.

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Assessment of Municipal Governance for Solid Waste Management in Secondary Towns in Bangladesh: A Report Card Analysis of Mymensingh Pourashava

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ABSTRACT

This paper attempts to link municipal governance and solid waste management with the purpose of creating sustainable urban Solid Waste Management (SWM) system. The main objective of this paper is to assess the performance of SWM and identification of constraints and opportunities concerning SWM of Mymensingh Pourashava. The framework of urban good governance developed by "The Urban Governance Initiative (TUGI-UND)" used to conduct this study. TUGI developed a set of indicators on good urban governance those are localized with the context of Bangladesh specially with the context of Mymensingh Pourashava. The translated report card with the indicators of good urban governance was conducted among different stakeholders i.e., municipal council, municipal officials including conservancy section, civil society representatives and urban poor representatives including the waste pickers. The result of report card survey is 42.69%. It indicates that the level of governance in Mymensingh Pourashava in relation to SWM is poor. According to the scale developed by UN-HABITAT this grade indicates that more commitment and effort is needed for enhancing municipal governance for SWM in Mymensingh Pourashava. During the study it was also found that the present capacity of Mymensingh Pourashava in terms of physical, financial and human resource is also very poor for successful SWM operation. Based on the existing reality a new SWM piloting supported by GTZ started to establish a systematic approach to develop overall capacity development of Mymensingh Pourashava. Considering the overall situation, the researcher has proposed a set of recommendations for improving the SWM performance of Mymensingh Pourashava. This is believed by the researcher that this research work will guide further research regarding urban governance improvement in relation to SWM in Bangladesh.

INTRODUCTION AND BACKGROUND

Bangladesh is one of the most densely populated countries in the world and has many problems related to basic needs like food, clothing, education, housing, and health. It has been identified by many International donor agencies/Development partners that lack of Good Governance is the main obstacle to its development and the local government institutes such as Municipalities and Union Parishad (UP) can play a vital role in promoting the Good Governance of any country by solving local problems with efficient use of local resources. Municipalities as the principal structures of Urban Local Government have long history in Bangladesh for providing basic services and playing a key role in Urban Development. Since the independence in 1971, Bangladesh has been experiencing rapid urbanization; between 1975 and 2005, the percentage of the total population in Bangladesh living in urban areas rose from 10% to 25%. Despite the recent decline in overall population growth, rural to urban migration has sustained a high rate of growth. The urban growth rate currently stands at 5-6% per annum, almost twice that of rural areas. If this trend continues, more than half of the population of Bangladesh will be living in urban areas by the year 2030. With this pressure of urbanization the urban local government institutes in Bangladesh is not equipped to provide all the services efficiently to the citizens. So, improvement of governance is the key area of intervention to the government of Bangladesh to improve the basic service delivery to the citizens. Referenced to TUGI the Good Governance is both the goal and the process. It only can help us find solutions to poverty, inequality, and insecurity. It creates an environment in which civil organizations; business community, private citizens and other institutions can assume ownership of the process of city development and the management of their own communities. The characteristics of Good Governance are: (a) Participation, (b) Rule of Law, (c) Transparency, (d) Responsiveness, (e) Consensus Orientation, (f) Equity, (g) Effectiveness & Efficiency, (h) Accountability, (i) Strategic Vision. Among the basic urban services SWM is the most important basic urban service. The Urban Governance Initiative (TUGI); UNDP developed report card to measure the level of governance efficiency considering these core characteristics of good governance. In this study the Mymensingh Municipality has been analyzed on these core characteristics of good governance and the report card will be used for ranking of the status of governance in terms of SWM.

OBJECTIVES

The main objectives of this research paper are:

- To assess the efficiency of Governance of Mymensingh Pourashava in relation to Solid Waste Management.
- Identify constraints and opportunities of improving SWM and Review the GTZ supported SWM pilot to address the challenges of Mymensingh Pourashava.
- To develop a set of recommendations to improve the overall Municipal Governance in relation to SWM.

METHODOLOGY

This research conducted basically on the framework of good urban governance developed by UN-HABITAT. The report card was conducted among

1. Municipal Councilors-05 out of 28 (03 male and 02 female)
2. Municipal Officials-25 (senior and mid level including health department)
3. Civil Society Representatives- 25 (Journalist, Lawyer, NGO officials, Local social and religious leaders)
4. Urban Poor representatives-25 (20 Cluster and CDC leaders including 05 waste pickers).

This Report Card used to assess the performance of Mymensingh Pourashava overall aspects of Good Governance in relation to SWM. Each respondent was supplied with a translated report card with defined 36 indicators. Four Focus Group Discussions (FGD)s were organized for the above four categories of respondent. Through the FGD they graded on the indicators. Each respondent awarded points (1 point for ‘very poor’ to 5 points for ‘very good’ and 0 for ‘no initiative’). These points were eventually converted into percentage based on the evaluation scale developed by TUGI-UNDP.

Table 1 Scale of performance

Score	Performance
85% to 100%	Very good. (Keep it up)
65% to 84%	Good. (but still room to improve)
50% to 64%	Fair (Can do much better)
35% to 49%	Poor (More commitment and effort needed)
Bellow 35%	Very Poor (Something drastically wrong)

Source: The Urban Governance Initiative (TUGI-UNDP)

For better understanding of solid waste management situation different reports and publications has been consulted as secondary information sources.

STUDY AREA

Mymensingh, is one of the rapidly growing and densely populated secondary towns of Bangladesh, with an estimated present population of 0.375 million in the municipal area. The rapid growth in population over the last two decades has created tremendous pressure on urban services, utilities and shelter affecting the low-income people adversely. The Pourashava is located in the district headquarters. It lies between 24’ 43” and 24’ 45” north latitude and 90’ 23” and 90’ 25” east longitude. The town is bounded by the Brahmaputra River in the North-eastern part, Kakardhari union in the north, Kewatkhali union in the south and Akua union in the west. The Mymensingh municipality was established in April 08, 1869. The current area of Mymensingh Pourashava is 21.73 sq km and it is divided into 21 wards. The first official Chairman of Mymensingh Pourashava was Mr R Porch and Mr Sreechandro Kanto Ghosh was recruited as the first unofficial Chairman in 1886. Current Municipal Council is constituted by one Mayor, seven female councilors and twenty one ward councilors. According to the Pourashava own source the total population of Mymensingh town is 375312 people in 2005. The literature rate is 60.4%. Among total population 51.91% is female and 48.09% male. The population density is 6032 people per sq km. Beside this according to the government official data (BBS 2001) the total population in Mymensingh is 227047 people. The overall SWM situation in Mymensingh town area is poor and the general people repeatedly mark that Mymensingh is a dirty town.

SWM SITUATION IN MYMENSINGH POURASHAVA

For understanding overall SWM situation in Mymensingh Pourashava the important aspects to know is Waste Generation, Collection and Transportation, Disposal of waste, Hospital/Clinical Waste Management, Street Sweeping/Drain Cleaning, Solid Waste Recycling including Composting. In this paper all these aspects of Solid Waste described very briefly.

Waste Generation

According to STIFPP-II report 115 ton of solid waste was generated in Mymensingh town in 2004, based on assumed waste generation rate of 0.5 kg/cap/day (ADB et.al, 2004). However, this estimate is much on the high side for the town of Mymensingh, which has an estimated population of 0.375 million. In India, for a city with population between 0.1 million to 0.5 million, waste generation rate is found to be 0.21 kg/cap/day (Supreme Court Report, 1999). According to the Action Plan for Solid Waste Management of Mymensingh Pourashava prepared by Waste Concern in March 2005 the waste generation rate is 0.19 kg/cap/day. Beside this according to the baseline survey conducted during March to June 2008 by MATI (a Mymensingh based local NGO) the waste generation rate is 0.27 kg/cap/day. So, considering the latest data the total amount of Solid Waste generated in Mymensingh Pourashava is 101 ton/day. As per the Action Plan for SWM 79.4 to 93.72% wastes are Compostable. The average percentage of organic waste is 84.21% while inorganic portion is 15.79%. The large quantity of organic contents present in the Mymensingh's waste composition indicates the necessity for frequent collection and removal. This also indicates the potentials of recycling of organic waste for resource recovery.

Collection and Transportation

In majority of the areas community bin system of waste collection is being practiced in Mymensingh. Recently, there some door-to-door collection initiatives of solid waste in some neighbourhoods of Mymensingh Pourashava started. There are 370 dustbins within its jurisdiction area of Mymensingh Pourashava. The practice of widely spaced communal bins is usually a failure because the demand placed on the households goes beyond willingness of the residents to co-operate. In total 510, cleaners are engaged by Mymensingh Pourashava for cleaning the town. For removal of wastes from bins and other collection points, Mymensingh Pourashava has 7 trucks and 12 power tillers of different capacities. But 2 trucks remain out of order permanently due to technical problems. Usually these trucks made one trips per day. As per Pourashava own source maximum 70% of the total generated waste can be collected per day by the municipality with its present capacity of Mymensingh Pourashava. About 31 tons of wastes are not collected by the Pourashava. These wastes are duping on the open spaces that creates unsanitary environment for the citizens.

Disposal of Waste

Final disposal of solid waste is being done in Mymensingh by uncontrolled crude dumping in lowlying areas. The present solid waste disposal site is located near Shambhuganj Bridge, 4 km far from the city centre. This crude dumping site is in operation since 1992. Total area of the waste disposal site is 3.14 acre having a depth of 6.7 meter. According to the Action plan for SWM about 50% of the waste is dumped in the Shambhugonj waste disposal site while the rest 50% is dumped in the river and other open spaces. So, waste disposal system of Mymensingh is unsanitary which needs urgent improvement.

Hospital/Clinical Waste Management

According to the Action Plan that per bed waste generation rate in Mymensingh as 1.1 kg and there are 1025 beds distributed in 35 clinics, 2 hospitals and 6 public health centers (Waste Concern

2005). Thus the total hospital waste generated in Mymensingh works out at 1.12 tons/day and 25 percent of the generated hospital waste is bio-medical. At present there is no separate hospital waste collection system in the town. All the hospitals and clinics dispose their waste in the municipal dustbin, which is subsequently collected and mixed with the municipal waste and disposed in the same dumpsite creating severe health hazards.

Street Sweeping/Drain Cleaning

There is 34.25 km of pucca (metalled) road and 12.15 km of kutcha (non-metalled) road inside the Pourashava area. Moreover, 83 km of pucca drain and 66 km of kutcha drain is also maintained by the Pourashava. Street sweeping and drain cleaning is a part of solid waste management activity. At present, in most Pourashavas, sweepers are employed for about six hours starting at 7 am. Each sweeper is assigned a certain length of road for which he or she is responsible. When a sweeper completes cleaning of the assigned length of road, he or she quits for the day. Street sweepers are paid on daily basis at a rate of Tk. 40/day. Road sweeping operation is likely to be manual in the foreseeable future and the basic equipment is brooms, shovels and handcarts.

Drain cleaning activity, though a responsibility of the conservancy section of the Pourashavas, is only indirectly related to the solid waste management vis-à-vis the disposal of the dirt material removed from drains. Generally, the local practice is to remove the dug-up-materials, which are mostly made up of grit, sand and decayed organic substances, on the roadsides to dry for several days before collecting them for disposal. Though it is easy and convenient to collect and dispose the dried up materials, as per the action plan the practice has several shortcomings, which include: Sludge left on the roadside gives an ugly sight to the town; Heaps of sludge are obstruction to pedestrians and other traffic; Sludge is dispersed by the traffic and part of it may fall back into the drain nullifying the cleaning effort and As the sludge may contain harmful bacteria, protozoa and other micro-organisms, the practice may lead to spread of diseases.

Solid Waste Recycling in Mymensingh

In Mymensingh, informal sector is playing an important role in recycling of solid wastes. The existence of waste, mainly inorganic, has opened quite an extensive possibility for various groups of the community to utilize it. Informal sector is also playing a prominent role in collection of recyclable materials. All the buyers of the recyclable items belong to the informal sector and only a few formal manufacturers are involved in using recyclable material as raw material. The main items of recycling in Mymensingh is News Papers, Magazines, Books, Waste Paper, Plastic Buckets, Soft Plastic, Sandals, Shoes, Polythene Bags, Saline Bags, PVC pipes, Ball pens, Old Container Toys, Broken Glass. Bottles, Lights, Neon Tubes, Old Scraps, Iron, Iron pipes, Construction Materials, Steel sheet, Used nails, wire etc and the average generated amount per day is 2.6 tons. These recyclable materials normally collected by Tokai, Feriwala, Vangari Dokans and sometimes Municipal officials.

Compost Plant

As more than 80% wastes is Compostable so there is a huge potentiality of composting in Mymensingh Pourashava with it's wastes. In 2005 a compost plant was established with the financial assistance from UNICEF and technical assistance from Waste Concern. The capacity of this compost plant is three-ton and it is owned by the Pourashava. But at this current moment this compost plant is not functioning. As per Pourashava source the main challenge was marketing of fertilizer with due certification from Government of Bangladesh and due to unavailability of the operation cost this plant is not running now.

MAIN PROBLEMS IN RELATION TO SWM IN MYMENSINGH POURASHAVA

The Action Plan of SWM in Mymensingh Pourashava identified following problems:

- Unsatisfactory operation of community bin system, unsatisfactory solid waste management services (systematic control of generation, storage, collection, transport, separation, processing, recycling, recovery and final disposal of solid waste),
- Inadequate street sweeping and drain cleaning,
- Uncontrolled crude dumping of waste, unutilized organic waste,
- Improper management of clinical waste, lack of technical expertise,
- Lack of awareness among different groups of citizens.

STAKEHOLDER ANALYSIS AND ONGOING PROJECTS

Table 2 different stakeholders and on going projects in relation with SWM in Mymensingh

Name of the Stakeholder	Role in Municipal SWM
National Level	
Local Government Division under MLGRD&C	Municipalities are administered by Local Government Division (LGD) under MLGRD&C in Bangladesh. The main role of LGD is policy formulation, recruitment of senior officials for Pourashavas, financial allocation for ADP implementation and monitoring of overall management. Under this division there is two small units for administering Pourashavas named as Poura-01 for class A & Poura-02 for class B&C category Pourashavas.
LGED and DPHE	LGED and DPHE the engineering departments under LGD basically implementing different donor supported projects in Local Government Institutes (Pourashava, Upazilla and Union Parishads) here in Bangladesh. Some of these projects have the components of SWM in Pourashavas. In Mymensingh Pourashavas these two departments are also implementing some projects having SWM as a component.
Development Partners	Different development partners provide financial and technical supports to Government of Bangladesh in implementing different projects in Pourashavas. They have strong role on overall urban development in Bangladesh. In Mymensingh DFID, ADB, UNDP, KfW & GTZ is active through different development projects.
Municipal Level	
Mayor	Mayor is the most important person of decision making as he is both the head of Municipal Council and Executive functions of Pourashavas. He is also the chair of Town Level Coordination Committee is a forum newly introduced to facilitate the participation of different stakeholders in formal decision making process.
Councilors	As members of Municipal Council and heads of different standing committees; councilors are also playing vital role in overall decision making process. They are also the chair of Ward Level Coordination Committee to facilitate the people's participation in ward level planning. They are also the key responsible person for overall SWM in his/her ward area as the cleaners/sweepers are to directly reporting to him/her.
Municipal Bureaucracy	Municipal Bureaucrats are also playing vital role specifically in SWM because conservancy section is under department of Health, Conservancy & Family Planning department and they mainly responsible for secondary collection from waste bin to central dumping ground. Besides Engineering Department is for overall supervision of vehicle management and infrastructure development in line with SWM like construction of dustbin, transfer station, Compost Plant, Dumping Station etc.
Different donor supported projects	In Mymensingh different donor supported projects are being implementing. The projects with focus on SWM are: 1. Second Urban Governance and Infrastructure Improvement (Sector) Project supported by ADB, KfW & GTZ together with GOB: Under this project a separate SWM piloting is being implementing in ward: 04, 06 & 08. 2.Secondary Town Integrated Flood Protection (Phase-02) Project supported by ADB & OPEC together with GOB: Under this project different infrastructures like construction of 07 transfer station, land acquisition and construction of central dumping ground, procurement of two garbage trucks to be implemented. 3. Secondary Towns Water Supply and Sanitation (Sector) Project supported by ADB together with GOB: under this project Sanitation and SWM activities targeted to be implemented in Mymensingh Pourashava. 4. Urban Partnership for Poverty Reduction Project supported by DFID, UNDP/UN-HABITAT: this project has not specific focus on SWM but strong potential to introduce the approach within its strong community level network in the slum areas of Mymensingh Pourashava.

Citizens of Mymensingh	Citizens of Mymensingh Pourashava can play the most vital role in implementing any SWM related interventions. Normally the wastes are thronging haphazardly and contributing the identity of Mymensingh as a dirty town. So, strong awareness development campaign focusing all level of the people's of Mymensingh town with systematic approach is the most important aspects of overall SWM in Mymensingh Pourashava.
Local NGOs and Community Organizations	In Mymensingh only one out of forty three local NGOs involved in SWM but there are some community initiatives on House to House collection and dumping to pourashava dustbins. Local NGOs and CBOs are also another important stakeholder in Mymensingh Pourashava.
Social and Religious leaders	As wider acceptance of Social and religious leaders in the society they can play vital role in awareness raising activities related to SWM in Mymensingh Pourashava.
Defense Party	In Mymensingh Defense Party is active on community vigilance activities. Besides it's regular work they are also active in house to house collection system some areas of the town. As they are working with their own commitment so institutional supports to link up with the formal Municipal SWM system can be developed the sustainable system of SWM in Mymensingh Pourashava.

REPORT CARD ASSESSMENT FOR SOLID WASTE MANAGEMENT

With the overall situation of SWM in Mymensingh Pourashava it is most important to dig out the root cause of the problem to improve the status of over all SWM. It is essential to know the current management practice and the tool developed by UN-HABITAT has been used to understand the people's perception and overall level of Good Governance in relation to SWM in Mymensingh Pourashava. All the characteristics of Good Governance developed by THE URBAN GOVERNANCE INITIATIVE (TUGI) and under all nine thematic areas of good governance there are some indicators in relation to SWM. The 36 indicators under the nine thematic areas are localized in context of Bangladesh particularly in the context of Mymensingh Pourashava. Then the report card conducted among four types of stakeholders and in the following tables A, B, C& D used as A for Elected Officials, B for Senior Municipal Officials including Health department, C for Civil Society & D for Representatives from Poor including Waste Pickers). The grades presented in the tables are the average score of each group of the respondents.

THE REPORT CARD ASSESMENT

Participation

Sustainability of the initiatives made by Pourashava and the effective delivery of the services is possible with the participation of the stakeholders concerned. Participation as regards to SWM envisages greater awareness among the general public, waste retrievers, Pourashava officials and all other stakeholders involved. The indicators of participation used to conduct the card are:

- A good understanding among the general public about SWM in the Town.
- Collection of non-degradable waste at the household level by the waste retrievers.
- Initiatives made by the Pourashava to involve private sector and civil society at the city level and the CDCs/CBOs/NGOs.
- Functioning of the Ward Committees/TLCC.

Rule of Law

Sound and efficient promulgated by the Pourashava in relation to its City and its problems is expected to clear the deck towards the efficient management of the SWM. These rules or policies may pertain to the operationalisation of door to door collection programme, coverage of slums or low income settlements, monitoring and enforcing mechanisms. It is also important that there is a mechanism of the redressal of the grievances. The indicators of Rule of Law used to conduct the card are:

- Gradual Introduction and Extension of Door to Door Collection of segregated Household Waste to all the Municipal/Corporation Wards and all other wastes including hospital waste and imposition of strict penalties against defaulters.
- Law specifying mechanisms to organize SWM in slum/low income areas.

- Redressal of the grievances of different stakeholders relating to SWM.
- Functioning of the courts to the extent of supporting the programme of Pourashava.

Transparency

One of the virtues of good governance could be making known to the general public all the issues concerning SWM. Evolving good and sound transparency strategy is expected to result in greater participation of the stakeholders and also in bringing accountability among those involved in executing the jobs. The indicators of Transparency used to conduct the card are:

- Consultation Processes in vogue in relation to Budget
- Community (CBOs/Mass Producers) involvement in Awarding of Contracts
- Coordination between officials and the people's representatives.
- Provision of information by the Pourashava to other stakeholders in respect of planning, roles, functions and penalties.

Responsiveness

Good Governance is eventually expected to make the institutions and process to serve all stakeholders. This can happen only when there is clarity about all the issues involved both at the city level and ward level. The indicators of Responsiveness used to conduct the card are:

- Pourashava's strategies & Practices in holding consultations/meetings/dialogues with different stakeholders' viz., public, private sector, NGOs, Elected Representatives etc., at the city level to understand the needs and aspirations.
- No of municipal wards managed by the private and the civil society.
- Priority given to the management of Solid Waste in the City
- Extent of City covered in the Solid Waste Collection and Disposal system by Pourashava.

Consensus Orientation

Adoption of strategies towards effective participation of all the stakeholders, greater responsiveness, strategic vision and effectiveness and efficiency could be realized only through consensus on the management of Solid Waste collection and disposal. The consensus has to be across party lines, among the political and administrative heads and between civil society and private sector. The indicators of Consensus Orientation used to conduct the card are:

- Practice of all party consensus on major, important and strategic decisions.
- Consensus between the Mayor and Councilors on such vital issues as Mobilization of Resources, Communication Strategies and policies and programmes on SWM in general.
- Institutional Mechanisms to consult the private sector and the civil society partners. Frequent consultations with civil society and private sector.
- Use of Mass Media i.e. the press for consensus orientation.

Equity

Municipalities are committed to the issue of equity through its policies to cover the slum or low income settlement as also the central city, listening to the voices of women who are directly going to be affected by the policies and programmes of the Pourashava towards SWM and also ensuring the participation of the stakeholders such as the private sector in the solid waste Disposal programme. It is also important to involve such vulnerable groups such as the waste collectors in the programme. The indicators of Equity used to conduct the card are:

- Strategies adopted by the Pourashava for effective SWM in Slums/Low Income settlements and Central area of the Town.
- Initiatives by Pourashava to scale up the initiatives of the NGOs and CBOs in SWM to the city level.
- Consultation strategies adopted by the Pourashava to enlist the cooperation of the women members of households and other producers of waste like the traders, hotels, restaurants, hospitals etc.,
- Efforts made towards involving the waste retrievers in SWM.

Effectiveness and Efficiency

Type of personnel in the managerial positions, effectiveness in terms of coverage of SWM in the city, strategies towards the capacity building of the personnel will influence the effectiveness and the efficiency in relation to SWM. The indicators of Effectiveness and Efficiency used to conduct the card are:

- Type of Personnel placed at key managerial positions.
- Percentage of coverage of slums in the door to door collection system.
- Percentage coverage of wards in the Pourashava area.
- Strategies towards the capacity building of the personnel.

Accountability

Accountability of all the stakeholders to the policies and programmes envisaged under the Solid Waste Collection and Disposal Programmes become crucial in working towards good governance in the city. As far as the Pourashava is concerned it has to be from the councilor down to the sweepers. The party in power should also be accountable to the policies and programmes. The indicators of Accountability used to conduct the card are:

- Municipal staff's awareness of accountability in respect of SWM.
- Responsiveness of the Health Officer to the problems confronted by different stakeholders relating to SWM at the Ward Level.
- Leadership, dynamism and commitment displayed by the Mayor.
- Accountability by the private Sector and the Civil society to the objectives set by the Pourashava.

Strategic Vision

The Pourashava should have a clear vision of the SWM Programme in the city and work towards the realization of the same through active, sustained and effective participation of all stakeholders. The indicators of Strategic Vision used to conduct the card are:

- Macro Perspective Plan for SWM for the City by Pourashava
- Private Sector's compliance to the Zero Garbage among stakeholders
- Availability of statistical data on SWM in the Pourashava
- Actions initiated by Pourashava towards using Garbage as a resource

EFFICIENCY OF MUNICIPAL GOVERNANACE IN RELATION TO SWM

From the above tables the grades are calculated and presented in the following table to measure the overall efficiency of Mymensingh Pourashava in relation to SWM.

Table 3 Performance of Mymensingh Pourashava in relation to SWM

SL	Characteristics of Good Governance	Scores				
		Municipal Council	Municipal Officials	Civil Society	Urban Poor	Average
1	Participation	9.86	10.93	6.95	6.24	8.495
2	Rule of Law	8.26	11.43	6.79	7.72	8.55
3	Transparency	10.12	11.45	6.7	7.97	9.06
4	Responsiveness	9.89	10.59	6.76	6.46	8.425
5	Consensus Orientation	10.02	11.58	7.33	6.95	8.97
6	Equity	8.95	10.08	6.62	7.18	8.2075
7	Effectiveness & Efficiency	9.43	9.89	7.8	7.27	8.5975
8	Accountability	8.91	10.73	6.84	6.15	8.1575
9	Strategic Vision	9.92	9.69	6.49	7.44	8.385
Total Score		85.36	96.37	62.28	63.38	76.8475
Level of Governance in relation to SWM		47.42%	53.54%	34.6%	35.21%	42.69%
Average Score				**42.69%**		

Source: Author, May 2009

The overall performance of Mymensingh Pourashava on good governance in relation to Solid Waste Management is **42.69%**. It is under the category of *poor;* so more commitment and effort is needed for establishing good governance in relation to SWM of Mymensingh Pourashava. From the above table it is shown that the grades from Civil Society and Urban Poor are lower than the grades provided by Municipal Council and Municipal Officials.

CAPACITY OF MYMENSINGH POURASHAVA IN SWM

Human Resources

Human resources are the most important machinery of any organization. The capacity of any organization very much depends on the capacity of the human resources of that particular organization. The officials involved in SWM in Mymensingh Pourashava are presented in the following table:

Table 4 Human Resources involved in SWM in Mymensingh Pourashava

SL	Position	Remarks
01	Medical Officer (01)	Currently on study leaves. Secretary is in additional charge for the duty of Medical Officer in Mymensingh Pourashava.
02	Conservancy Inspector (01)	The man presently holding this post basically a *Health Visitor* but currently he is serving as "Acting Conservancy Inspector".
03	Day Labour/Cleaner/Truck Driver/Sweeper (510)	They are contracted as temporary staff on Master Role basis.

Source: Administrative Department, Mymensingh Pourashava.

All the temporary staff of Health Department is under the councilors. In each wards there is one supervisor and on average 20/25 staffs are deployed in each ward for overall solid Waste management including street sweeping and drain cleaning.

So, from the above table it can be easily interpreted that no regular municipal staff is involved/responsible for SWM of Mymensingh Pourashava that impacted badly on the overall performance of Municipal Governance in relation to SWM of Mymensingh Pourashava.

Financial Base

Another most important aspect of capacity of any organization is its financial base and the skills of resources mobilization. The financial base of Mymensingh Pourashava for routine SWM is its Conservancy Tax. Conservancy Tax as part of holding tax is calculated by the rule set by the government: in Mymensingh it is calculated on 20% of annual valuation of holdings excluding the rental value for two months for operation & maintenance. The structure of holding tax as per the assessment conducted during FY 2005-06 is given bellow

Table 5 structure of financial base of Mymensingh Pourashava

Assessment Head	Assessed Amount	% of total valuation
Holding	12269810.00	6%
Conservancy	12269810.00	6%
Water Bill	7822881.01	5%
Street Lighting	5929022.63	3%
Total	38291524.82	20%

Source: Accounts Section, Mymensingh Pourashava, June 2009

Collection Efficiency/Revenue income from Conservancy

Collection efficiency of holding tax in municipalities of Bangladesh is poor. The efficiency of Mymensingh Pourashava in last three years is given bellow

Table 6 Holding tax (conservancy) collection efficiency of Mymensingh Pourashava in last three years

Financial Year	Demand (Current + Arear) in Conservancy	Collection	Efficiency
2005-06	21000000.00	6667290.00	31.749%
2006-07	20053526.00	10553369.00	52.626%
2007-08	20898000.00	9010173.00	43.115%

Source: Accounts Section, Mymensingh Pourashava, June 2009.

Expenditure

The routine expenditure in SWM is presented in the following table. The expenditure of infrastructure improvement (dustbins, compost plant, dumping ground, procurement of garbage trucks, vans etc) is not considered here.

Table 7 Expenditure in SWM sector of Mymensingh Pourashava in last three years

Head of Expenditure	Finacial year (s)		
	2005-06	2006-07	2007-08
Salary of Regular Officials	351600.00	351600.00	351600.00
Salary of Master role Officials	4562972.00	6485279.00	8028955.00
Special Cleaning programme	2165874.00	3021991.00	3338740.00
Maintenance of Garbage trucks	1119881.00	1782953.00	1300888.00
Fuel Cost	1200000.00	1500000.00	1800000.00
Cleaning materials procurement	57163.00	215163.00	1075.00
	9457490.00	13356986.00	14821258.00

Source: Accounts Section, Mymensingh Pourashava, June 2009

Comparison of Income & Expenditure

It is very important to compare the revenue income and routine expenditure in SWM of Mymensingh Pourashava. The following table shows the revenue income and routine expenditure of Mymensingh Pourashava.

Table 8 Revenue income and routine expenditure of Mymensingh Pourashava in SWM

Financial Year	Income	Expenditure	Subsidy
2005-06	6667290.00	9457490.00	-2790200.00
2006-07	10553369.00	13356986.00	-2803617.35
2007-08	9010173.00	14821258.00	-5811085.30

Source: Accounts Section, Mymensingh Pourashava, June 2009

It is found in the above table that routine expenditure excluding infrastructure improvement can't be met by the present revenue collection. So, SWM in Mymensingh Pourashava is running by subsidy from other income sources. This is the main reason of unsatisfactory SWM in Mymensingh Pourashava and it should be the major area of governance improvement in relation to SWM. So, it now clear that the present capacity of Mymensingh Pourashava in terms of physical, financial and human resources is very poor to improve the overall SWM.

SWOT Analysis

The strength, weakness, opportunities and threats analysis in Municipal Governance in relation to SWM of Mymensingh Pourashava with a group of participants (officials from conservancy section, project officials and citizen representatives). The main findings are presented in the following table:

Table 9 SWOT Analysis

Strength	**Weakness**
-Better network with community (Primary Groups, Community Development Committees, Clusters) for implementation of SWM interventions. -Big Municipal Council (1 Mayor + 28 Councilors). -Different categories of educational institutes (BAU, AMC, Medical College, Girls Cadet College etc) located in Mymensingh Town with better performance.	The main weakness of Mymensingh Pourashava in terms of SWM is - Poor management system. - Poor staff capability. - Vacant positions of key officials in the Organogram. - Backdated Organogram and limited scope of capacity development. - Poor revenue base and collection efficiency is also poor. - Dependency on Central Government and External funds. - Corrupt practices in financial management.

Opportunities	Threats
-Different donor supported projects (UPPRP, UGIIP-2, STIFPP-2, STWSSP, BMDF etc). -Potentialities of local business sector for partnership development in SWM. -Governance reform support from LGED (Urban Governance Improvement Action Programme).	-Lower attention of central government on urban development, reform of municipalities and Municipal Solid Waste Management. -Without external project support there is lower possibility of improvement of Solid Waste Management situation of Mymensingh Municipality.

Source: FGD in May 2009

APPROACH OF GTZ SUPPORTED SWM PILOTING FOR CONTRIBUTING IN MUNICIPAL GOVERNANCE OF MYMENSIGH POURASHAVA

Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) is a government-owned international cooperation enterprise for sustainable development with worldwide operations. On behalf of the German Ministry of Economic Cooperation and Development (BMZ), GTZ-Bangladesh provides technical cooperation to the Second Urban Governance and Infrastructure Improvement (Sector) Project, UGIIP-2, of the Government of Peoples Republic of Bangladesh. GTZ works in partnership with Local Government Engineering Department (LGED) of Ministry of Local Government, Rural Development and Cooperatives (LGRD&C). As part of this Technical Cooperation GTZ conducted a baseline study by a local Community Based Organization named MATI. Together with this SWM baseline study several workshops and roundtables organized and existing successful local SWM models evaluated. For effective participation (community and CBO's), stakeholder coordination and overall SWM capacity development of Mymensingh Pourashava, GTZ supporting to develop and manage a self-sustained, community-driven Solid Waste Management Pilot in selected three wards. The pilot initiative will concentrate on establishment of an effective system of Kitchen Waste Management and composting with the purpose to be replicated to other wards of Mymensingh as well as other project towns under UGIIP-2.

To establish a self-sustained, community-based Solid Waste Management of kitchen wastes for organic, compostable waste (based on existing household collection system, transportation to municipal transfer points, composting and marketing of compost fertilizers) in Mymensingh Pourashava, GTZ engaged an experienced organization named Practical Action Bangladesh having extensive and successful experience in urban SWM in terms of project design, implementation, operations management, marketing of composts etc as the lead of a consortium having four Mymensingh based local NGOs, defense party, and active Community Development Committees (CDC) organized by UNDP supported UPPR project to work closely. Bangladesh Agriculture University (BAU) with its long reputed research credential is supporting the consortium specially in quality compost analysis and on farm demonstration of produced composts. The consortium will also revive the Eco Park was established with the assistance from UNICEF to ensure operations cost-recovery, and establishment of a functional management of the Eco-park to produce composts. The main components of SWM piloting are:

Component A

Establishment of an effective primary collection system and disposal to transfer stations: the main focus of this component is establishing source separation by extensive awareness raising campaign. The objective of the component is to create awareness among Pourashava residents on SWM, effectively establish a sustainable door-to-door solid waste collection system and primary disposal of kitchen wastes in the transfer stations

Component B

Management of Eco-park, composting and research on alternative SWM solutions: The objective of this component is to revive the functionality of the Eco Park of Mymensingh Pourashava to ensure operations cost-recovery, and establishment of a functional management of the Eco-park to produce composts.

Component C

Quality control, marketing of composts and operational cost recovery: The objective of this component is to acquire appropriate certification from the composts from a recognized government/autonomous agency on an annual basis, and establish a proper distribution channel to market the composts at local level

Component D

Institutional capacity development and community awareness building: The objective of this component is to develop capacities of the participating organizations (i.e. community based organizations, non-governmental organizations, and municipal authority), ensure adequate capacity development of existing and new service providers and establishment of functional linkages and coordination between service providers and Pourashava conservancy department.

Parallel with this piloting the main interventions of UGIIP-2 will be focusing on implementation of Urban Governance Improvement Action Program (UGIAP). UGIAP is basically a set of activities to support municipal reforms has already been started the implementation in Mymensingh Pourashava. It comprises specific activities under the thematic areas like (i) citizen awareness and participation, (ii) urban planning, (iii) women’s participation, (iv)integration of the urban poor, (v) financial accountability and sustainability, and (vi) administrative transparency. As UGIIP-2 is a performance based project it is expected that Mymensingh Pourashava will perform well and its financial base will be strengthen and overall capacity will be developed with equipped human resources.

CONCLUSIONS

Municipalities have primary responsibility for improving the living environment specifically Solid Waste Management (SWM). Mymensingh municipality is also concerned about SWM and already implemented different projects. Based on the findings of this research it can be concluded that the present solid waste management situation is very poor. Additionally there is big component of SWM under ADB funded Secondary Towns Integrated Flood Protection (Phase-02) Project but the situation remains unchanged. And the result of the report card on assessment of good governance in terms of SWM shows the efficiency of Mymensingh Pourashava is poor. So, special attention is urgently required for the governance improvement in relation to SWM in Mymensingh Pourashava. In Bangladesh the overall situation of SWM is similar as Mymensingh Pourashava. Generally Governance improvement was ignored in all interventions of SWM but the present analysis by using the report card developed by UN-HABITAT identified the different dimensions of the problems related to SWM in Mymensingh Pourashava and it can be used in all other Municipalities to diagnosis the actual problem lies with SWM. If proper attention is given to improve the performance of all the indicators of Good Governance in relation the SWM; the overall situation can be improved to establish sustainable Solid Waste Management system in Bangladesh. As the pilot project on SWM under the umbrella of UGIIP-2 project supported by GTZ it is expected that the overall situation will be improved after the successful implementation. However in Mymensingh the main problem is poor governance that relates to weak institutional capacity, inadequate delegation of authority, HRD problem, lack of citizen participation, corruption, lack of ownership and many more. So, SWM can not be improved isolately without improving Pourashava governance in general.

RECOMMENDATIONS

Based on the current exercise the following recommendations are proposed to improve Municipal Governance in relation to SWM of Mymensingh Pourashava and for Bangladesh widely. For overall improvement of Municipal Governance in relation to SWM some reform in central level with special attention to reform the municipal structures. Whatever for ensuring sustainable SWM system by the Urban Local Governments of Bangladesh the following recommendations are presented in the following table.

Table10 Recommendations

Central Level Reforms:	
-Reform in MLGRD&C,	-Strengthen the existing unit under LGD to look after the overall Pourashava management. -Preparation and execution of comprehensive nationwide urban development policy with a focus of SWM. -Regularly review the performance of Pourashava on SWM.
-Establishment of effective Local Government	-Re-establishment of a strong and independent local government commission with strong focus on promoting good governance in

Commission (LGC)	local government institutes. -If strong local government commission established then the overall management responsibilities of Ministry can be shifted to LGC. -Facilitating of planning and budgeting of Local Government Institutes may be an important role of LGC.
Reorientation of LGED and DPHE,	As these departments are playing important role in municipal infrastructure development and supporting to improve management capacity for efficient service delivery; their orientation in Municipal Governance in relation to SWM should be established. These are basically engineering department and very much depended on consultants so; professionals from other discipline (Urban Planning, Economics, Environmental Management etc) having different dimensions of Municipal Governance should be recruited as their regular employee.
-Coordination among different development partners,	Development partners have strong role in introducing different new approaches both in central and local level. So development partners should- -Focus on restructuring all the institutions to meet the current challenges of SWM.
-Integration of NGOs and Civil society in the decision making framework in central as well as Pourashava level.	NGOs & Civil societies have a strong facilitating role now days specially media is playing strong role. So, NGOs and civil society can -Focus on SWM and overall urban development. -Advocate with government for policy changes.
Municipal/Local Level:	
-Capacity building of Pourashava elected representatives,	-Mayor have most important role. Particularly the mayor of Mymensingh Pourashava needs some orientation on better urban management and SWM with focusing on good urban governance. -The councilors feel that they are accountable to the people but basically they have minimum role in Pourashava management except participating in the council meetings. There are 21 ward councilors in Mymensingh and there is opportunity to be utilized them as manpower in SWM and overall Pourashava management. There current involvement in SWM should be more institutionalized. -Regular training is needed for developing their management skills. -Activating the standing committees may play good role in promoting good governance in Mymensingh Pourashava. -Ward Councilors are suppose to chair the Word Level Coordination Committee (WLCC), functional WLCC and the decisions taken in WLCC to be included in Town Level Coordination Committee (TLCC) and Municipal Council as agenda can play important role.
-Reform of municipal bureaucracy,	Municipal bureaucracy is most important machinery in overall Pourashava management. As the present capacity of the staff of Mymensingh Pourashava is not satisfactory and SWM is totally depended on temporary officials. The following things can be done for developing equipped Municipal Bureaucracy- -Restructuring the present Organogram having separate department/cell for Solid Waste Management. -Recruitment of qualified professionals in this new department/cell with adequate trainings for their capacity development. -Awarding/rewarding and punishment system may be introduced. -Activation of WLCCs and TLCC as a platform for citizen to participate in Municipal decision making system.
-Establishment of self-local government by proper taxation and better financial management without corrupt practices.	-The holding tax management system should be improved immediately to promote good governance. -Changes are also essential in assessment, collection, tax base and others organizational attributes of the holding management system. So that adequate funding can be generated internally for SWM in Mymensingh Pourashava.
-integration of business	Though business sector is not playing significant role in SWM in

communities in SWM interventions.	Mymensingh Pourashava but they have good potentiality in this sector. Public Private Partnership concept on overall SWM can impact a lot for overall SWM of Mymensingh Pourashava.

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Cost Analysis for Municipal Solid Waste Transportation Planning in Khulna City of Bangladesh

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ABSTRACT

The growth in urban population and daily activity have resulted in an increased of solid waste generation. *Uncontrolled urbanization in Khulna, the third largest metropolitan city in Bangladesh, has placed a heavy stress in the management of municipal solid waste (MSW). In the process of solid waste management (SWM), more attention needs to be paid towards collection as it itself requires 60-70% of the total cost. Transportation plays a vital role in waste collection and disposal. But there is no systematic plan for the collection and transportation of solid waste in Khulna City Corporation (KCC) Bangladesh. Hence an attempt is made in this study to propose a favorable route for MSW collection and hence to reduce the distance travel by the vehicle for the ultimate disposal. For effective management, in this study the entire area of KCC has been divided into four regions. The best possible route is planned based on two criteria namely distance and time. In the proposed route network the existing facilities is properly utilized by providing an appropriate time schedule for working hour and minimum travel distance which contribute to a large amount of saving to the total SWM cost.*

INTRODUCTION

Solid waste can be defined as useless, unwanted and discarded material coming from production and consumption. Waste is produced in all level of human activities. Waste source include residential area, commercial area, industrial area, construction and demolition, treatment plants and agriculture activities. Now-a-days result of increasing population and rising living standard, solid waste generated by human is becoming a serious major problem. A variety of environmental and health problem arises due to mishandling of solid waste. The major activities associated with the management of solid waste are generation, on site handling and storage, collection, transport, processing and recovery; final disposal (Rahman, et al. 2008). Transportation is considered as one of the major components of solid waste management. Therefore waste collection and transportation cost must be regarded as an important issue in order to increase the efficiency of waste management. An effective route planning can play important role to minimize the overall cost and to increase efficiency of solid waste management. The major concern of this study is to minimize the transportation cost by effective utilization of available resources and time.

STUDY AREA

Khulna, the third largest metropolitan city of Bangladesh, stands on the banks of the Rupsha and the Bhairab rivers, located in the southwest of the country on the middle of the axis of Jessore - Mongla port. Khulna is also an important river port city of Bangladesh well connected by the rivers Rupsha and Bhairab and located at the lower extreme of the Ganges delta, Khulna city acts as a place of trade and commerce and is a production center for the region. Khulna obtained its status as a formal town after the establishment of the municipality in 1884 during the British colonial regime. Many industries such as Newsprint mills, Shipyard, Jute mills, Jute bailing presses, Hardboard mills, etc. were established and associated commercial activities also increased manifold. Khulna attained the status of a City Corporation in 1990. Administratively, it is divided into 31 Wards as shown in Figure 1. Over the period, Khulna city experienced continuous population growth accompanied by periodic changes to its territorial area. Again, due to the establishment of Khulna University, Khulna Medical College, Khulna University of Engineering and Technology, Teacher's Training College, Agricultural Training Institute, etc. along with increased activities resulting from the expanding shrimp export; Khulna has gained tremendous potential for further socio-economic activities and physical development. Density of people is increasing every day and therefore, accommodation, pollution and waste management systems became problematic. The solid waste management responsibility mainly lies with the City Corporation. There are some NGOs and CBOs who assist the city corporation in handling the kitchen and residential wastes (PREGA 2005).

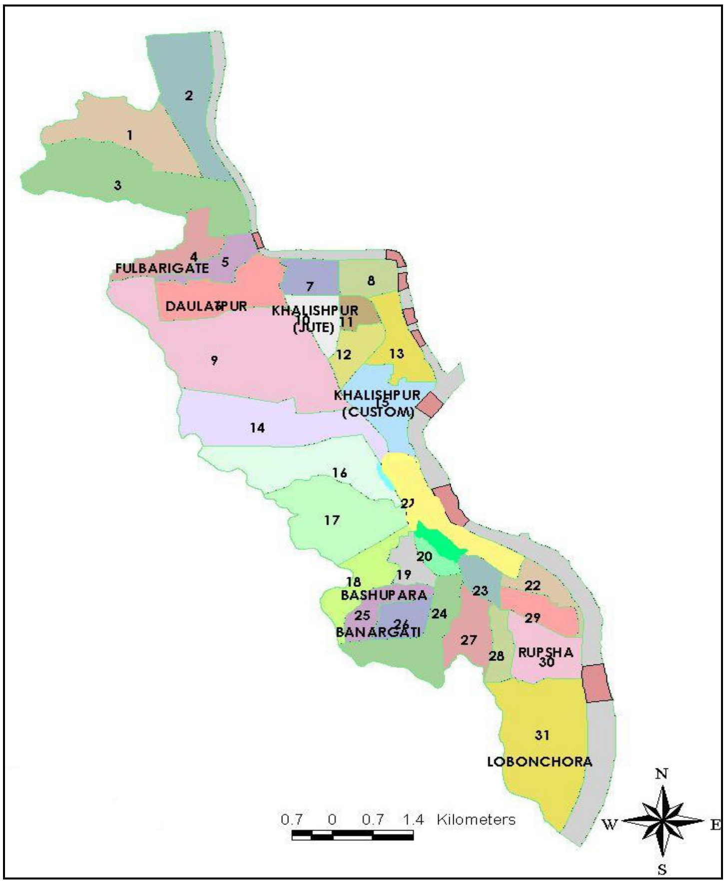

Figure 1 Map of study area

METHODOLOGY OF THIS STUDY

Methodology is a logical as well as systematic part of the study to guide scientific investigation. A method involves a process or technique in which various stages or steps of collecting data or information are explained. The methodology of this study covers some sequential steps as presented in Figure 2 and hence reveals as:

- Data such as number of vans, manpower used and salary, working area, number of households were collected from NGOs and CBOs.
- Number of vans used for the collection of MSW in the KCC area and the expenditure involved in this purpose were collected from the authority of KCC.
- Man power involved and their salary were collected from KCC authority.
- The number of vehicles and their capacity, existing secondary points and their location were collected from the authority of KCC.
- The existing route from secondary point to the disposal site was mentioned by KCC authority.
- From the collected data existing transportation cost for MSW management is calculated.
- New transportation route is proposed based on the distance and time.
- A comparison is made between the transportation cost for proposed and the existing route.

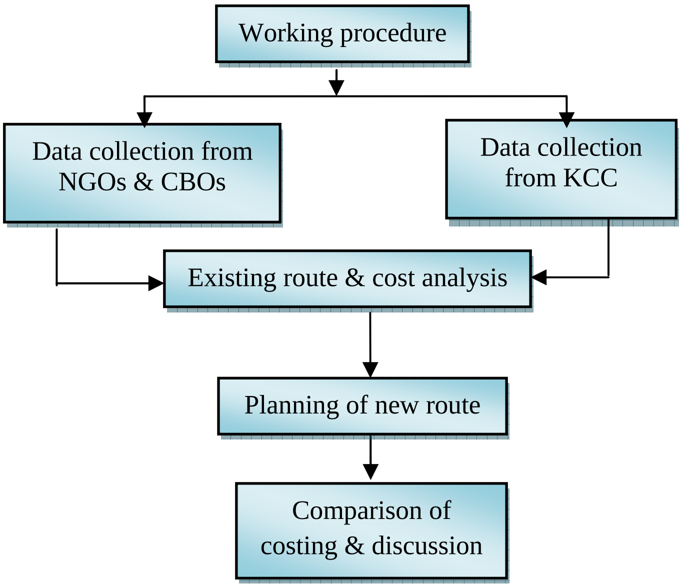

Figure 2 The flow chart of methodology of this study

Existing Transportation System of MSW in KCC

There are two types of solid waste collection and transportation to the disposal site in Khulna City Corporation. These are:

I) Conventional System and II) Participatory System

Conventional System

Waste is generated in the home and usually stored until a small amount has been accumulated. In the conventional system it is the responsibility of the householders to carry their wastes to the nearest solid waste bins or similar facilities which are provided by the city corporation and deposit wastes there as depicted in Figure 3. The city corporation is responsible for the transfer of this waste from the roadside bins to the final disposal site. Usually the city corporation's truck visits these locations at regular intervals and collects and hauls the accumulated wastes to disposal sites.

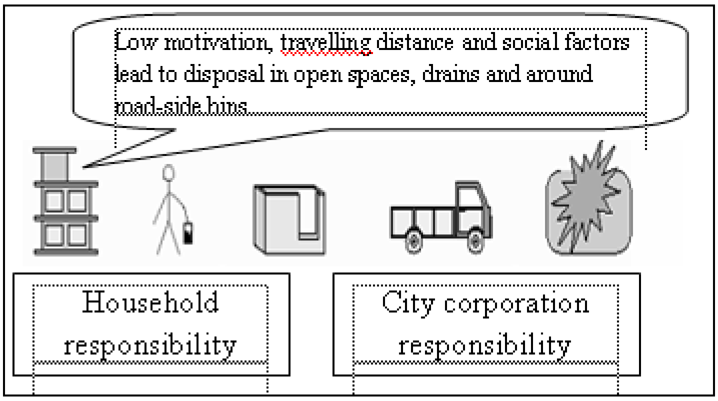

Figure 3 Conventional waste collection systems in KCC (after Salequzzaman 2004)

Participatory System

Waste generated in the home is stored in a bin, basket or bag and collected everyday by a primary collector who transports the waste to nearby transfer points, normally in a rickshaw van. This is primary collection and is the responsibility of the community. The collection of waste of community as presented in Figure 4. Transfer points are placed where waste is unloaded from primary collection vehicles to be taken away by secondary transport. Several primary collection blocks are served by a transfer point. The waste is then collected from the transfer points and taken to the final disposal point by a large truck. This is secondary collection and is the responsibility of the city corporation.

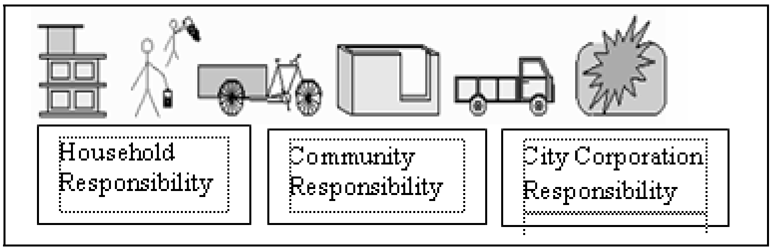

Figure 4 Community based waste collection system in KCC. (Salequzzaman, 2004)

Vehicles Used by KCC for Transportation of MSW

Khulna City Corporation uses various types of truck, such as container trucks (single & double), dump trucks (small & big), Vacuum Tanker, Garbage Loader etc to transfer the MSW from secondary point to disposal site. The container trucks are generally used for those secondary points where container is filled with waste. The other trucks are used for the dustbin based secondary points. The garbage loader is used to load the trucks in various secondary points. Vehicles used for transportation of MSW in KCC as shown in Table 1.

Table 1 Vehicle for Waste Collection by KCC (capacity and types of vehicle)

Sl. No	Type of vehicle	Number of vehicle	Capacity (tons)
1	Hino Truck	3	5
2	Dump Truck (B)	7	5
3	Dump Truck (S)	2	3
4	Container truck	5	5
5	Double container	2	10
6	Container	1	3
7	Normal truck	5	3
8	Cargo truck	2	5
9	De-slugging Vacuum Tanker with Tractor	2	5
10	Garbage Loader	1	-

Source :Transport pool, KCC, 2008

Secondary Points & Its Condition

Figure 5 Map of KCC showing the location of important secondary points

There are about twenty six numbers of important secondary points exist in Khulna City Corporation. Beside those points small bins are also available. But the condition of those secondary points and the bins are not well planned and environment friendly. Containers are provided in some secondary points but dumping outside the container is a regular practice. In some secondary points there is no specific boundary for waste dumping. The locations of those existing important secondary points are shown in Figure 5.

Cost Involved in KCC Vans

The cleaners of the KCC sweep the roads and clean the drains daily. They accumulate the wastes at the road and drain sides. Once the street sweeping and drain cleaning have been done, the cleaners collect the wastes in cane baskets and hand carts to dump them at the nearest collection point or dustbins. Generally KCC vans are used to transfer these wastes to nearest secondary points or dustbins. City dwellers dump their household wastes at the nearby KCC dustbins too. The total cost involvement for this operation is about 2, 73,000.00 in Taka.

Cost Involved in Transportation of MSW to Disposal Site

Wastes are transported to the disposal site by the means of trucks. Two types of secondary points are available in KCC such as container and dustbin. To transport the waste from secondary point to disposal site various types of trucks are used. Various types of costs are involved in this section such as fuel cost, salary of driver, labor and supervisor.

1. Driver and labour cost : 260400.00 (BDT)
2. Fuel cost : 294714.00 (BDT)

Total : 555114.00 (BDT)

Cost Involved in NGOs and CBOs

Some NGOs and CBOs are working together to collect the solid waste from residential area. Usually vans are used for the collection of solid waste from house to house. They collect the waste from houses and dump it to the secondary disposal sites. In Khulna City Corporation, there are about 17 NGOs & CBOs are working for house to house collection. Most of the NGOs & CBOs is operating by donor fund. Generally the house to house service provider used to take about 2, 5, 10, 15, 20, and 30, 50 BDT from the households as per the condition of the locality or the community. The details information of the cost and revenue of NGOs and CBOs existing in Khulna City are given in Table 2.

Table 2 NGOs & CBOs Involvement of MSW Collection

Sl. No.	Name of NGOs/CBOs	Working Area	Number of House Hold	Manpower involve	Number of Vans	Revenue Earned (app.)	Expenditure (TK/M))
1	Rustic	17, 18*	4200	24	11	84000.00	70900.00
2	Clanship	16, 17*	750	4	2	7500.00	5000.00
3	Nabarun S.	24, 27*	1300	11	5	26000.00	15900.00
4	SPS	9,14,15*	1000	9	4	15000.00	14200.00
5	Samadan	13, 15*	1200	9	4	12000.00	13200.00
6	BRIC	4, 5, 7	900	6	3	9000.00	9000.00
7	Muktir Alo	21*, 23	1400	9	4	12000.00	9600.00
8	Rupayan	19, 20	2000	12	5	20000.00	15900.00
9	CHD	16	500	7	3	5000.00	9100.00
10	Protisruti	22	1900	5	2	9000.00	7000.00
11	Goti	20*	420	2	1	4200.00	3500.00
12	IBC	1*, 2*	820	5	2	8200.00	7500.00
13	NoboJagoron	16*	200	2	1	2000.00	3000.00
14	Commitment	11	450	3	1	4500.00	3000.00
15	SIAM	25, 26	1200	9	4	12000.00	15200.00
16	PUC	24*	1380	6	3	20700.00	13700.00
17	PUC	27	2100	14	4	18000.00	14200.00
18	BRDC	2*	150	1	1	3000.00	1750.00
	Total		21870	138	60	272100.00	231650.00

Planning of Proposed Route

For the proposed route planning the necessary data such as population, waste generation rate, the capacity of the container is required. The existing transportation facilities are important for new route planning. The most favorable route for the transfer of MSW is proposed which is based on two criteria.

Distance

The route was generated taking the location of secondary points take into consideration. Distance of different routes is calculated from the map of KCC.

Time

The total travel time of the vehicle in each road segment is considered in this case. Total travel time in each road is equal to the travel time of the vehicle and container changing time. The travel time of the vehicle is calculated by considering the length of the road and the speed of the vehicle in each road. The container changing time is the total time consumed by the vehicle to collect the solid waste from the secondary points.

Considerations for New Route Planning

Some factors which are considered for new route planning are given bellow.

1. The daily working hour of the Driver and labor is 8.00 hour.
2. The secondary points are considered as container system (except Daulatpur area).
3. New proposed disposal site is selected at about 2.2 Km away from Khulna- Jessore road. (Rahman et al. 2008). The tentative cost is given in Table 3.
4. KCC branch office at Khalishpur is considered as a new Garage for Vehicles.
5. Open dumping beside the road & drainage should be controlled by legislation.
6. All the waste is transferred from house hold and small bins to the secondary points.
7. The velocity of transportation vehicle is constant throughout the route (20 kmph).

Table 3 Installation cost

Operation	Quantity	Cost (taka)
Construction of a new landfill	5 Acre	30000000.00
Preparation of new garage	Existing facility is enough.	
New container	24 nos	2880000.00

Planning of New Route

The population, generated waste and number of secondary points of the selected study area as illustrated in Table 4. The vehicle schedule is given in Table 5 including the relevant expenditure, required time and the route. In addition, for the simplicity of the proposed route plan the data is taken from different sources as:

- Total area of KCC is divided into four parts.
- The waste generation rate is considered constant (0.297 Kg/capita/day) for all part of the city.
- The population is calculated from Bangladesh population census 2001.
- The new route is proposed based on generated waste in different area.

Formula used for determining present population, $P = p_0 (1+r)^n$, Where, Population growth rate, (r) = 1.70%, Number of years, (n) = 7

Table 4 Calculated present population, generated waste and secondary points for new route

Area	Population (Nos.)	Generated waste (tons)	Secondary points (Nos.)
Khalishpur	264453	78.5	9
Khulna Sadar	261981	84.00	10
Sonadanga	193589	58.00	6
Daulatpur	147975	40.00	4

Table 5 Oil consumption and required time for proposed route planning in different vehicle

Truck no	Working Area	Capacity of truck (tons)	Total Distance	Number of Shift	Oil consumed	Time required	Route
01	Khalishpur Area	5	54 km	2	18 liters	4 hrs. 40 minutes	(G~19~D~21~D~15~D~G)
02	Khalishpur Area	5	77 km,	2	26 litre.	5 hrs. 10 minutes	(G~18~D~14~D~16~D~G),
03	Khalishpur Area	5	67 km,	2	24 litre.	4 hrs. 40 minutes	(G~17~D~22~D~20~D~G)
04	Khulna Sadar Area	10	87 km,	1	30 litre.	5 hrs. 22 minutes	(G~4~D~5~D~9~D~G & G~27~D~6~D~G)
05	Khulna Sadar Area	10	87 km,	1	30 litre.	5 hrs. 40 minutes	(G~3~D~2~D~26~D~G & G~1~D~27~D ~G)
06	Sonadang a Area	5	106 km,	2	36 litre.	6 hrs. 24 minutes	(G~8~D~10~D~12~D~G)
07	Sonadang a Area	5	102 km,	2	34 litre.	6 hrs. 6 minutes	(G~7~D~29~D~11~D~G)
08	Daulatpur Area	5	38 km	2	14 litre.	6 hrs. 08 minutes	(G~23~D~25~D~G)
09	Daulatpur Area	5	40.4 km	2	14 litre.	6 hrs. 12 minutes	(G~24~D~28~D~G)

Oil consumption = 3 km per Litre & vehicle speed 20 kmph.

The route of Truck no 03 in Khalishpur area and Truck no 04 in Khulna Sadar area are presented in Figure 6 and the route for Truck no 07 in Sonadanga area and Truck no 09 in Daulatpur area are presented in Figure 7.

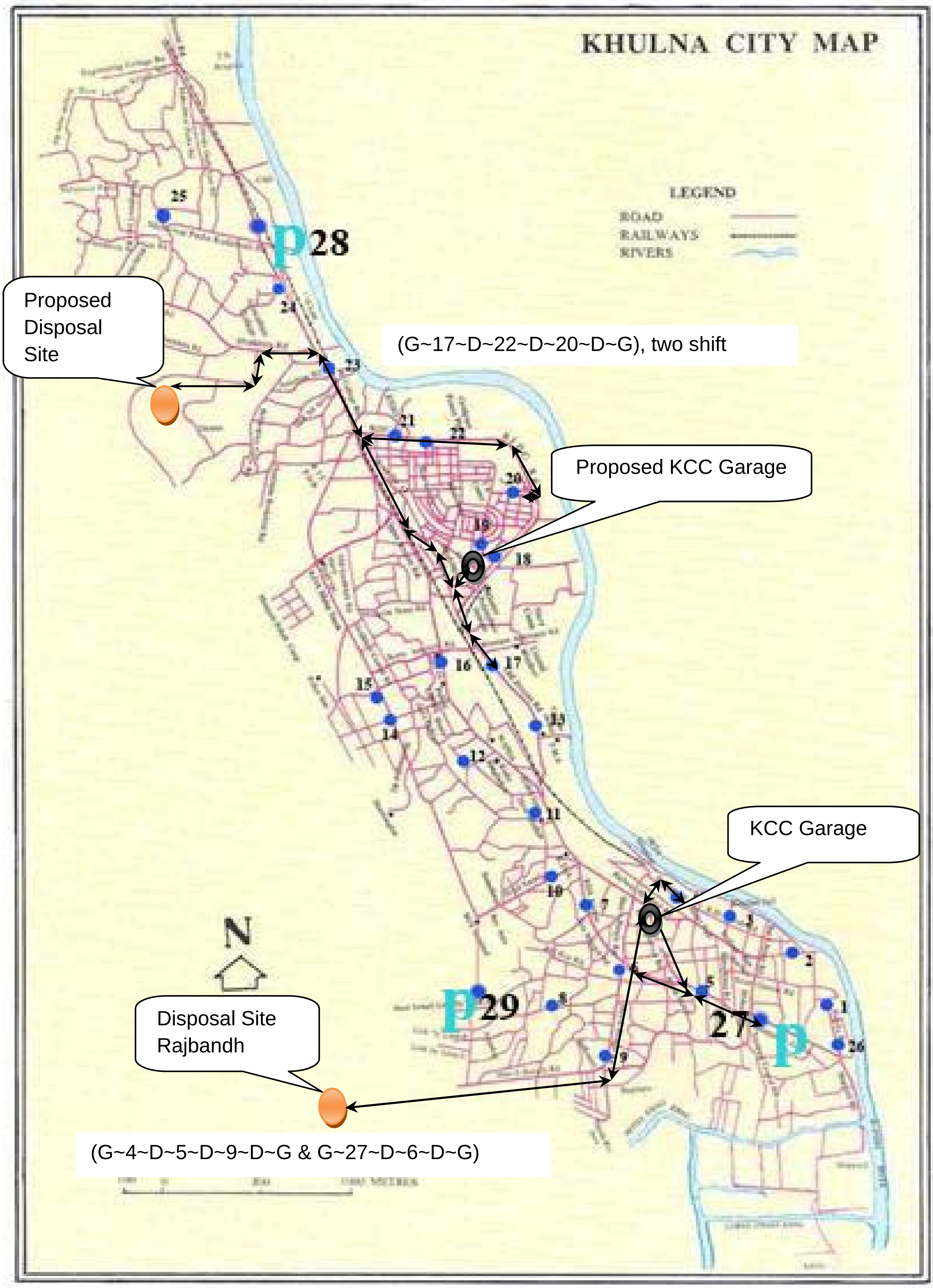

Figure 6 Route for Truck no 03 in Khalishpur Area & Truck no 04 in Khulna Sadar Area

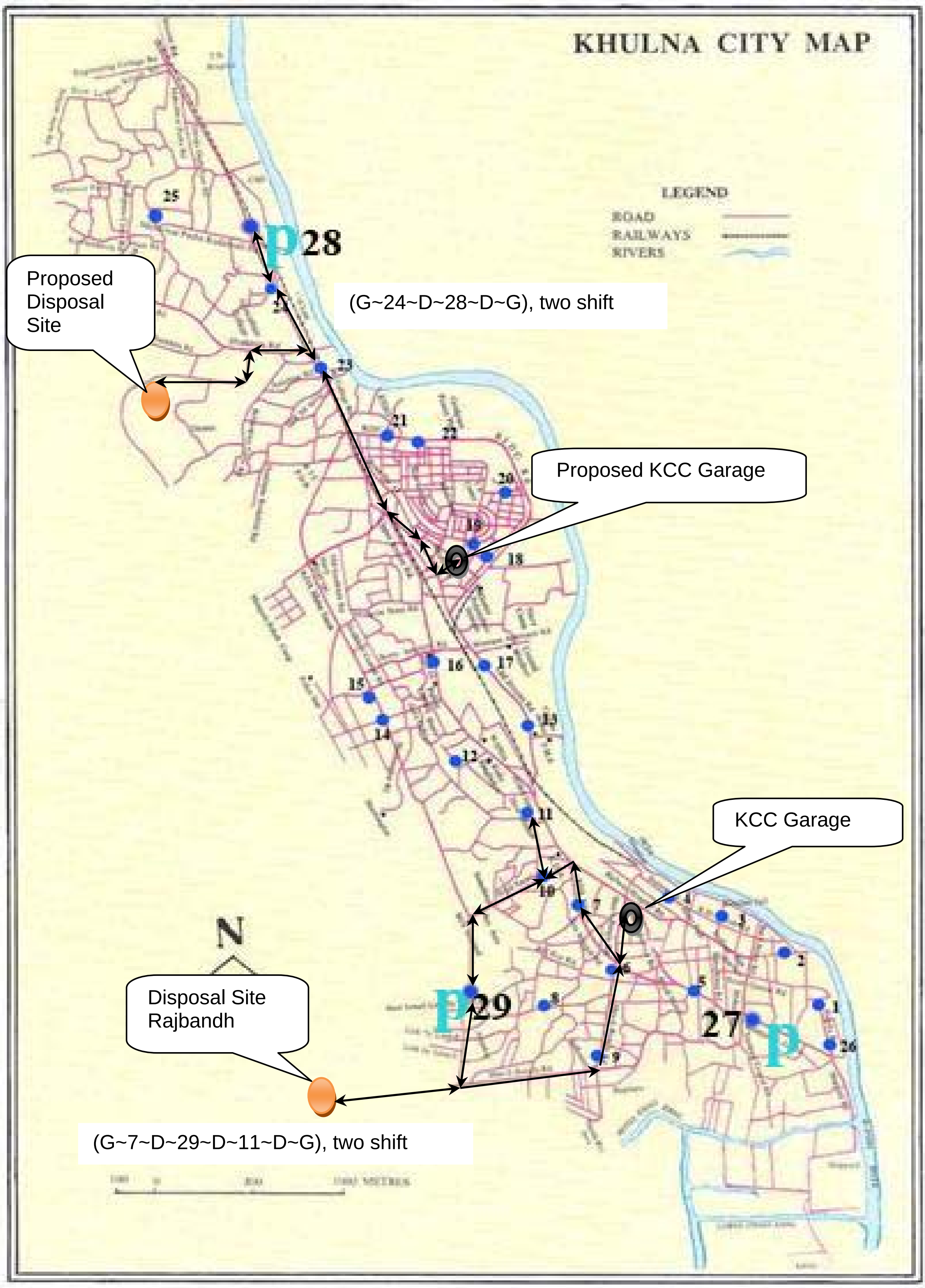

Figure 7 Route for Truck no 07 in Sonadanga Area & Truck no 09 in Daulatpur Area

Cost Involvement of Proposed Route

Only seven container trucks and two dump trucks are required for new route. The number of drivers and helpers are decreased to 9 nos. and 11 nos., respectively. But one more supervisor is required for new garage. The cost for proposed route is shown in Table 6.

Table 6 Cost analysis for proposed route

Types	Amount/month	Rate (BDT)	Cost (Taka/ month)
Fuel Cost	6780 litre.	42.00	284760.00
Driver Salary	9 Nos.	6000.00	54000.00
Helper Salary	11 Nos.	3000.00	33000.00
Supervisor Salary	2 Nos.	6500.00	13000.00
	Total cost		371760.00

DISCUSSIONS

The existing transportation system for MSW in KCC is not systematic and well planned. Dumping outside the bin is a usual practice in Khulna city. There is no scheduled time for the short period of time collection and transportation of MSW in Khulna City Corporation. So, MSW is not regularly collected from small bins and road sides. Proper guideline for the working hour of the driver, helper and worker are not defined. A driver or helpers are working only in one station. The study reveals that their working hour is very short period of time. For primary collection NGOs and CBOs are active but their working area is limited. Proposed systematic plan overcomes these limitations by providing definite working hour, standard salary structure and most favorable route. In the proposed route most of the secondary points are container system. The driver can replace the filled container with empty container with in short time. So the time will be saved and the number of labors will reduce in the proposed system.

CONCLUSIONS

About 237 litre of fuel can be saved per months which contribute to a large amount of savings in terms of money and time to the solid waste management. The total amount of money Taka 1,83,354.00 can be saved per month by providing new route planning. Although installation cost for the new disposal site and purchase of new containers is very high but it can be recovered within three years. So, the proposed planning is only feasible for long term project and indeed solid waste management is a long term activity.

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Integrated Solid Waste Management in Greece

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ABSTRACT

Waste management has proved to be on of the Greece's most complicated environmental, political, legal and social problems. There are over than one thousand unauthorized dumping sites in Greece. The absence of organized facilities, the widespread and fierce social opposition to the creation of legally authorized landfill sites, poorly drafted administrative procedures that will more than likely lead to condemnation by the courts and an imperfect and cumbersome legal framework in relation to waste management all mean this is on of the fields in which the country has one of the poorest records in its environment policy.

The manuscript will develop along the following lines: a) brief but necessary examination of the facts surrounding waste and basic waste management law provision in Greece, b) an outline of national approach to recovery mechanisms also will be presented, c) the permit requirements provided for under national law will be examined including a reference to the nature of the waste management services and d) the objectives of the integrated solid waste management plan.

INTRODUCTION

The basic tendencies that determine the European institutional frame of management of solid waste is:

- the synopsis of thematic strategy for the solid outcast
- the basic conclusions from the efforts of recycling in EC
- the new tendencies that are expected the next five-year period

The waste constitutes always most serious environmental, social and economic problem for the all modern economies. The volume of waste increases with growth rate proportional or even occasionally bigger than the economic growth. The way of production and handling of waste influences all of us, from the individual citizens and the small enterprises, up to the public beginnings and the international trade. The production and the management of waste are connected closely with the way at which we use the resources. The production of excessive quantities of waste constitute clue of disadvantageous use of resources, the recuperation incorporated in the waste of materials and energy can us help we use the resources better. In consequence, the policies for the waste can and it should they aim at the reduction of total environmental repercussions that they are connected with the use of resources.

The will of Europe to face the waste at environmental equitable ways creates places of work and occasions for the enterprises. The European sector of management and recycling of waste has high growth rate and appreciated annual turnover above 100 billions of Euros. The sector of is intensity of work and ensures from 1.2 until 1.5 millions posts. The industry of recycling supplies always bigger quantities of resources in the manufacturing industry: at least the 50% of paper and steel, the 43% of glass and the 40% of not ferrous metals that is produced in the EC emanate today from recycled materially.

The collection of reliable statistical elements for the waste is difficult affair. Exist reliable data on 2002 with regard to the waste of buildings (510 millions tons), the waste of manufacturing industry (427 millions tons), the urban waste (241 millions tons) and the waste from the production of energy and the water supply (127 millions tons). This from only his means that each year are produced in the EC above 1.3 billions tones of waste, from which the 58 millions tons it is known that it is dangerously.

Exist however voids with regard to the data on the waste from quarries and mines, from the agriculture and the forestry, from the fishery as well as from the sectors of services and state, and consequently the real number are higher.
The produced urban litter per individual and per year is round the 530 kilos. However, this medium price withholds important differences between the member states. As an example, the annual at head production of waste in the EC the 10 amounts in 300 until 350 kilos, while in the EC the 15 are roughly 570 kilos. As generally speaking, the total volume of waste increases with growth rate equal or even bigger than the rate of economic growth. Statistical elements for entire the EC the 25 with regard to the treatment of waste are been disposed only for the urban waste, which represents the 14% of roughly total of produced waste. This will change from time (2006) because the new regulation on the statistics of waste with base which the European Statistical Service will collect and publish statistics on the production and management of all goods of waste. At the present moment, the 49% of urban waste are sold via sanitary burial, the 18% incineration and the 27% are recycled or composting. There are great differences between the member states. In certain, sanitary burial suffers the 90% of urban waste, in other only the 10%. The proportion of recycled urban waste increases, but this is compensated almost entirely by the increase of produced urban waste. In consequence, the sanitary burial decreases slowly. As an example, the quantities of plastic waste that lead to spaces of sanitary burial it was increased at 21.7% from 1990 up to 2002, even if the percentage of plastic waste that was suffered sanitary burial was decreased by the 77% in the 62%. The recycling of urban waste was doubled from 1995 until 2003 and today corresponds almost in 82,3 millions tones annually. The incineration increases and from this is produced energy that amounts with 8 millions tones of oil.

THE GREEK STATUS

Municipal waste in Greece is steadily increasing and the latest official data for 2001 estimated it at 4,559 thousand tons/year, whereas today it is estimated to have reached 5 million tons/year (Figure 1). Estimated quantities per region presented in Figure 2. About 39% of the waste is produced in Attika region. Of the total waste generated in Greece it is estimated that some 8.8% is recovered while the remaining 91.2% is deposed of, legally or illegally. The 39 existing authorized and controlled landfill sites cover 53% of the population, while the remainder of the population is served by 1,453 unauthorised landfill sites currently in operation in Greece. On top of this, there are an additional 1,173 abandoned illegal waste tips

The records on the recovery of waste in Greece are relatively recent. In 2001, it was estimated that 21% of recoverable municipal waste, primarily packaging waste, was actually recovered and it is estimated that 1/3 of the 800,000 tons of packaging waste generated every year is unofficially recycled**.**

The basic legal instruments on waste management in Greece are the following:

- Article 12 of Law 1650/1986 on the Environment which lays down the principal obligations in relation to waste management.
- Joint Ministerial Decision 50910/2727/2003 on the management of waste - which transposes the Directive into national law and includes the National Waste Management Plan - introduces the tool of Regional (and Inter-regional) Waste Management Plan as the operational tool for waste management planning, determines the obligations of the management authorities and the Regions, regulates the permits of waste management operators and sets a time limit for the eradication of uncontrolled dumping.
- Joint Ministerial Decision 29407/3508/2002 on sanitary landfill of waste, transposing Council Directive 99/31 on landfill of waste. The Decision *inter alia* sets strict operational guidelines for Sanitary Landfill Sites; mandatory processing of waste both at a national and at Landfill Site level, establishes targets for reducing the amount of waste deposited by landfill and provides for planning and licensing.
- Law 2931/2001 and associated Presidential Decrees for the recycling of packaging waste, transposing Council Directive 94/62/EC on packaging waste and related Directives on other wastes (used tyres, end of life vehicles, waste oils, electrical and electronic waste and batteries). Quantitative targets are set for recovery and their enactment is primarily an implementation of the ‘polluter pays’ principle, since producers of products and producers of waste are obligatorily involved in the set up and management of relevant Alternative Management Systems.

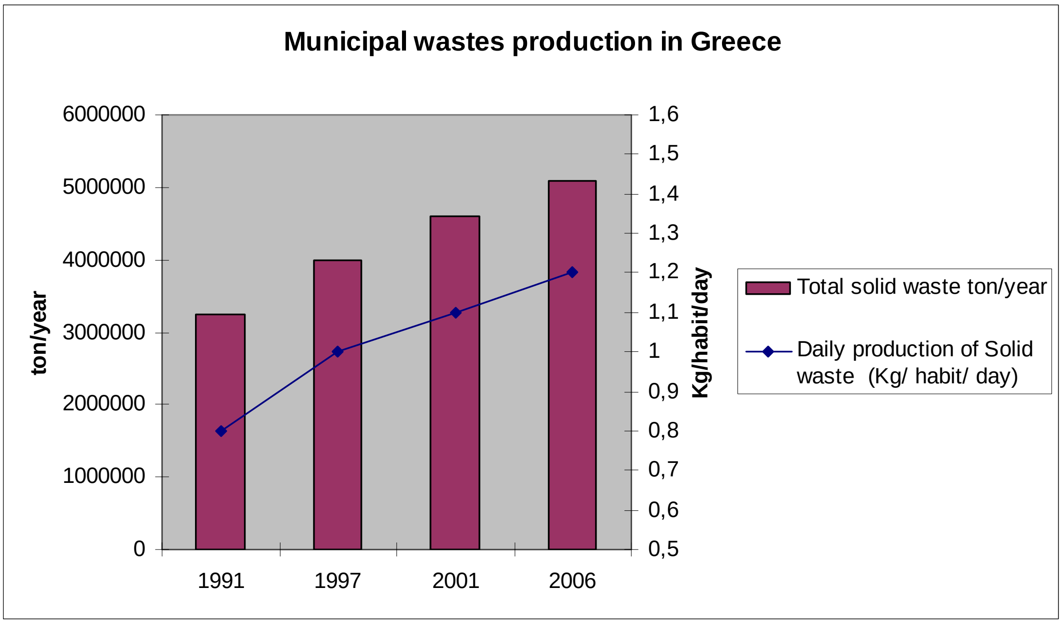

Figure1 Municipal wastes production in Greece

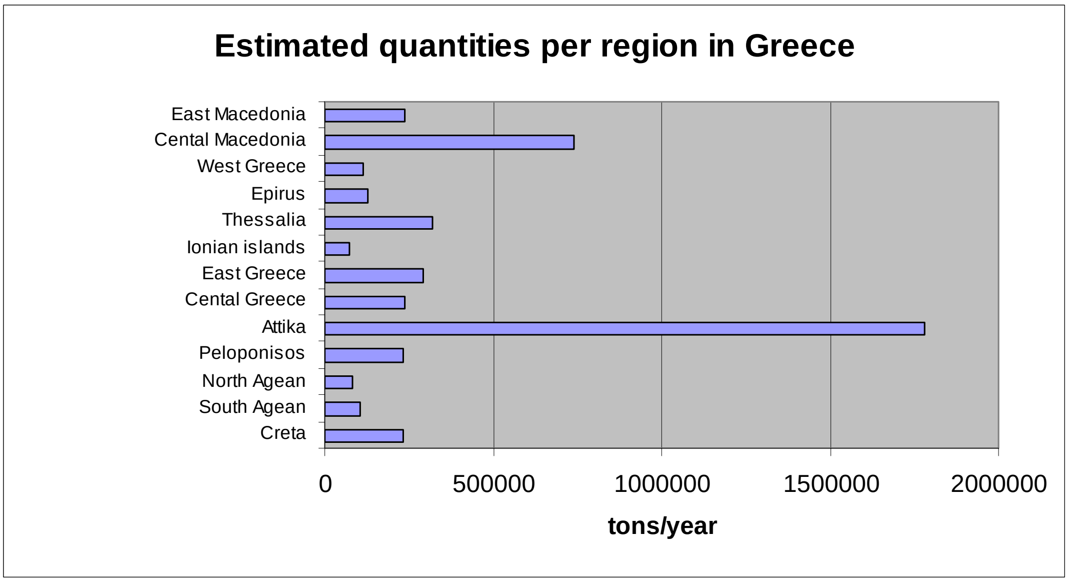

Figure 2 Estimated quantities per region

AXES OF POLICY IN EC

The policy of EC on the waste is supported in a significance that is known as hierarchy of management of waste, with base which the various alternative choices of management of waste are characterized from "most optimal" as "worst" from environmental viewpoint. These choices are:

- Prevention of creation of waste
- Re-use of product
- Recycling or composting of product
- Recuperation of energy via incineration
- Disposal in space of sanitary burial

However, the hierarchy of waste should not be faced as absolute rule, same that different methods of treatment of waste can have different environmental repercussions. Thus, if certain alternative choice of management of waste, that is found regular in lower place of hierarchy, causes less environmental repercussions in certain concrete case, it should also it is applied. The import of new significance of "circle of life" aims at as it ensures that is selected most optimal from environmental viewpoint alternative choice in each concrete case. The main objective of strategy is it changes Europe in society of recycling, which seeks it anticipates the creation of waste and, in the cases that can, it uses him as resource. More concretely, the thematic strategy aims at the followings:

- in the reduction of environmental repercussions
- in the promotion of prevention of creation of waste
- in the aid of activities of recycling
- in the modernisation and in the simplification of legislation for the outcast
- in the improvement of application of legislative action

For the Recycling

For the recycling the strategy forecasts a lot of moreover action at the next years. Certain of this action should be materialised immediately, while other it is better be undertaken after are become obvious the repercussions from the first application acts and from existing legislation which still has not been placed in force. The committee is to use also other ways in order to it achieves the objectives of new strategy. As an example: "It prompts the member states to improve the conditions of market for the activities of recycling and the commercial demand for recycled materially, including this questions in the national maps of course of application of plan of action of EC on the environmental technologies, which should have been submitted up to the end 2005. It will ensure that the European chalk-lines that are been disposed for research and growth in the sector of technology of waste face the important environmental repercussions of waste. In the frame of revision of governing lines with regard to the government owned aids for the protection of environment, the Committee will clarify the conditions under which is possible the issuing of government owned aids for the support of activities of recycling of waste. It will support also the distribution and the transport of most optimal practices with regard to the sensitization, the education and the motives for the prevention of creation of waste and for their recycling in national, regional and local level. The thematic strategy for the waste will be revised in 2010. If in the future is judged necessary the promotion of recycling of concrete categories of waste, this it is likely to be achieved per material rather despite per product as it has happened up to today. As an example, in the frame of objective for the recycling plastic it can be promoted the recycling of pipes from waste of demolitions as well as from plastic bottles, from agricultural membranes as well as from bumpers of cars. With objectives of such type it is possible are developed the fractions of waste that present the higher possibility of recycling with the lower cost.

Cost of Recycling

Is fact, that it is not possible is calculated the total cost for the application of management of litter of packing in the countries of EC. The reason is that does not exist transparency in the all individual administrators, thus, is impossible they are determined the precise sums and then result comparative conclusions on the separate management action between the countries. The cost is connected immediately with the economic profits of products that will result. For this reason, it is judged as essential condition the viability of systems of management, but also the guarantee of markets for the products that result. The high prices can be faced with corrective actions, as an example with further aid of competitiveness. A cause that affected considerably in the rise of cost is the absence, before year 1997, material and technical infrastructures in somebody from the member states the EC (e.g. Ireland, Greece). This make forced to have increased expenses, in combination states that had been organised from in the old days (e.g. Austria and Germany). The effectiveness of actions depends also, from how much the producers participate or undertake the cost of system. Companies that do not pay what corresponds to them (free riders) overloads the operation of system. The collaboration with the private sector, because the obligation that was presented with the beginning "polluting pays", had very positive results in the reduction of weight but also in the quantity of waste of packing, as they shouldered also part of cost. The mixture however this, led in they can the interests of industries influence the decisions and the measures that were taken.

In conclusion, despite the recognition that the application of Directive, that concerns the recycling of packing, was in general lines successful, it is recognized that were not satisfied the all requirements of relative Directive. The basic priority up to today was the satisfaction of objectives of Directives of EC on the recycling. However, with regard to the future, is essential a additional approach which will optimise the efficiency and the viability of actions, with as much as possible bigger environmental profits and smaller cost. The discovery of solution that would ensure so much the environmental expediency what the economic viability of system remains a very important challenge. It is explicit that the period of important changes in the institutional frame of management of solid waste in the EC already has begun. The next years are expected to be modified drastically so much the tools

For The Composting

There are certain action that should be undertaken in level of EC on the promotion composting. They include the determination of models of quality for the products compost so as to can are developed markets for them. The committee intends she has him the ready before the coming into application of revised directive - frame for waste. An other action they are the high environmental models that are in effect for installations where biological treatment is applied. This will be achieved via the future revision of directive.

The legislation of EC renders explicit that the member states should take into consideration their all relevant environmental questions when they work out the national policies for the waste. This means that the beginnings the member states, in which the composting is required in order to is improved the territory, should be focused their interest in the action that is required in order to is achieved the particular objective. The committee will help in the frame of this process providing him in 2006, not legislative guidance for the growth of national strategies and drawings for the waste with regard to the management of biological waste. Finally, it will be supposed is taken into consideration the potential of use of composting product for the increase of content of soil in coal.

Incineration

The environmental safe incineration can contributes considerably in the recuperation of energy resources from the waste, in the cases that constitutes part of environmental optimized strategy. The environmental profit depends from the quantity of energy that is in point of fact exported from the incineration waste. In the frame of new strategy for the waste, the Committee decided she further improves the attribution of recuperation of energy from the waste determining ambitious elements of comparative evaluation for the installations of incineration of urban waste. This will be achieved via the revision of directive. The new method of comparative evaluation of energy output will determine how much an installation of incineration can be characterized as installation of recuperation or as installation of disposal. The characterization as installation of recuperation provides better access in the market and the quantities of recovered waste can be included in the frame of obligatory objectives of recuperation that is determined in the directives of EC (e.g. for the waste electric and electronic equipment).

The waste of packing constitutes one from the more important and increasing currents of waste. This ascertainment prompted the EC to include in the relative Directive that drew up in 1997, concrete quantitative and direct measurable objectives for the restriction of final disposal. The states-member should have recycled the 25% of total sum of produced waste of packing up to 2001 and the 55% up to 2008. In point of fact, the all countries of Europe the 15 accomplished in 2001 they achieve the objectives, while certain these, in very precocious stage in deed, have achieved already the objective the 55%.

There are important differences in the existing situation of recycling between the countries of EC. The differences depend, from the quantity of waste that produces each country, up to the percentages of litter that recycle also the means that use. The results that achieves each country are influenced by factors, as the time beginning of effort, the level in which was found the country in combination the recycling the given time moment and the policy which they follow for the achievement of objectives that has placed the EC (e.g. who institutions take part in the management, who pay the cost of recycling, in who currents of waste are focused the efforts etc).

Institutions of Recycling

Each country has selected various institutions for the application and the control of programs of recycling. The factors that shouldered the management and the cost have as below. The official state initially, which undertook it incorporates the European legislation in the legislation of each country and it practices controlling action.

The local self-government has also administrative or even occasionally controlling role. The not speculative organisms and institutions, which were recommended with the intervention of state or local self-government, acting exclusively or even in step with other institutions and constitute permitted systems of management.

The companies' producers following the beginning "polluting pays" overwhelms tax for the management of their waste and participates in administrative forms. Is given also the possibility the industries producers of undertaking the management of their waste. Usually, when the industries are persons in charge for their litter, the objectives of recycling that are assigned to them they are higher. The problem in this cases is that they cannot be checked with the same facility from the controlling bodies and is not easy the collection of statistical elements slower, contrary to the organised institutions (compliances schemes). There are also the advisoryrole in the planning of strategy of trade unions, universities as well as Not Governmental Organisations.

Reinforcing Actions

The measures that take the European countries for the support of administrative systems include two goods of tools, the administrative and finances. In the administrative actions they are included the “responsibility of producer of pollution”, actions of prevention (e.g. briefing and sensitization common, special tax for certain type packing, and economic motives of profit (deposit-refund systems), the obligatory collection, the prohibition of burial for certain goods of waste and/or currents of waste, as well as tools that intend they improve the markets for the use of secondary recycled materials. In the economic actions they are included a line of taxes. Such taxes are the taxes that are addressed in the consumers (e.g. for the plastic sachets) as well as taxes that are addressed in the industries-company, as are the taxes for the burial and combustion of litter (decrease itself or are reversed in the event that the producers of waste proceed in action of recycling or recuperation). Finally, aiming at the prevention, the beginning “polluting pays” constitutes an economic motive in order to is decreased the sum of packing that is placed in the market.

PRINCIPALS OF RATIONAL NATIONAL PLANNING

In the present unit concern in the management (transport, treatment and final disposal) the litter that remains after by any chance application of programs of separation in the source are reported. The continuously stricter requirements for treatment, recuperation and exploitation of materials, disposal and protection of environment, increase very considerably the cost of management of solid waste. Under these conditions the decision-making equitable for the management of Urban Solid Waste acquires national importance one and influences the developmental course of country.

For the decision-making right it will be supposed are analyzed complex technical, economically and social subjects, and is combined the necessary action so as to is ensured the observation, with most optimal economically way, multiple legal and other requirements, that often become stricter with the byway of time. For the confrontation of this subject, the students should abandon the practical approaches of recent past and use new methodologies and advanced systems of software and of course be based on argued technical and economic elements for the available alternative technologies.

A reasonable process for the achievement of above objectives is presented schematically in the diagram of Figure 3 and includes the following in succession stages:

- decision-making strategic that concerns in the use of alternative approaches and technologies for achievement of desirable objectives.
- rational choice of places for creation of central Integrated management of solid waste
- configuration of Most optimal in detail Drawing of Management

Decision-Making Strategic

The objective in this phase is the choice of most expedient combinations of methods of segregation in the source, collection and transport, treatment and disposal, without the need of training of in detail plans of action. The strategic decisions that are taken in this phase are based on certain admissions (e.g. expected output of alternative systems of segregation in the source and their time development) and should allow the configuration of form of management which:

- It is in position it achieves the all requirements they arise from the directives of EC. (75/442/EEC, 94/62/EC, 2004/12/EC, 99/31/EC etc).
- It is economically efficient. The estimate of economic efficiency in this stage becomes, obligatorily, with regard of formal elements of cost of collection, transport and disposal.
- they are environmental efficient. He is appreciated with Analysis of Circle of Life, that provides total balances of raw material, energy and emission of pollutants of each activity and products of this. With this method they can be evaluated with right way alternative administrative approaches and methods of treatment and be placed equitable priorities. The last ones often differ from what at first sight is presented obvious. As an example, a drawing of management

that gives accent in the recycling of materials is likely that it will be proved energy more efficient and environmental friendlier than other form that gives accent in the energy exploitation of Urban Solid Waste.

Because of the importance that it has the above analysis in the decision-making strategic, are developed continuously new systems of software, which help considerably the work of engineers, e.g.

Rational Choice of Places for Creation of Central Integrated Management of Solid Waste

Fundamental objective of relative methodology is the estimate of biggest economically distance the transport of Urban Solid Waste in order that the treatment and/or disposal in big central installation rather in small local. For the aim this cost of transport will not be supposed to exceed the economy of scale from use of central installation.

The estimate of marginal distances, in which the increased cost of transport is compensated by the bigger economy of scale of central integrated management of solid waste, they are proved much bigger than that as generally speaking. From the above analysis it results also that the cost of transport of waste, even in big distances, is limited compared to the cost of treatment and disposal. This provides important flexibility in the planning of management of litter, extending in the case of big urban regions the horizon of search of young persons of socially acceptable places integrated management of solid waste, without important additional cost. The central these integrated management of solid waste can serve widest regions of region with big economy of scale, so the final economic result is even positive. According to this analysis begins with regard of capable number of places, somebodies from which it can they are known as particularly suitable and remainder they can be fixed approximate in first phase, without research of field, so as to they provide satisfactory territorial cover of region of study. With the mentioned before step to step process, is achieved progressive exclusion of most of the initial places that were considered so as to they remain essential. In this process priority is given in the maintenance of places that is known as particularly suitable.

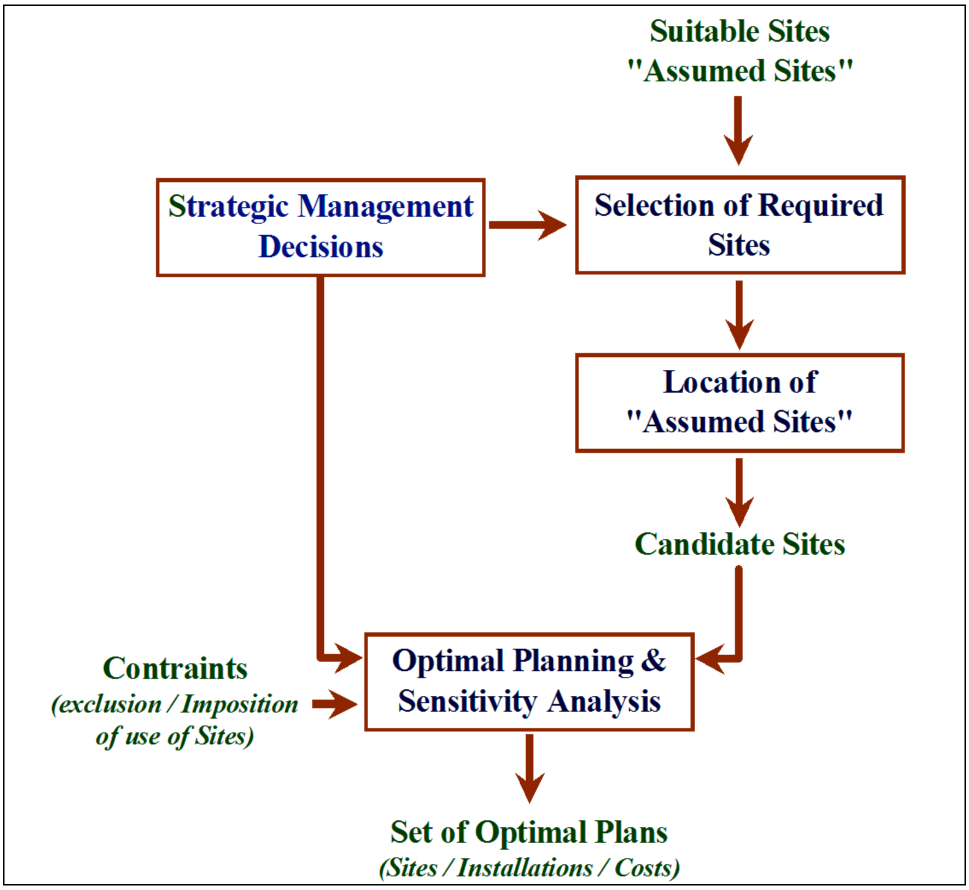

Figure 3 Schematic representation of process configuration of rational drawings of management Urban Solid Waste

The above process of initial choice was applied trial in Continental Greece so that is appreciated most optimal number of integrated management of solid waste and specified their places. The process begins with regard of candidate places of integrated management of solid waste, that can be considered as particularly suitable, as big mines new suitable places (Ritsona, Viotia), but also existing suitable integrated management of solid waste (Attica with the factory of Aerobic Mechanics - Biological Treatment, Larissa and Xanthi).

CONCLUSIONS

Most of waste management law in Greece follows the development of European waste management law. It is the transposition of Directives that shapes it. This characteristic, coupled with late transpositions and delays in implementation, often leads to inappropriate implementing measures that are soon outdated. In addition, a bizarre approach to the hierarchy of implementing measures can be seen, usually following acute pressure, either from the European Commission, or urgent local demands associated with waste management. The legacy of spectacularly fragmented and incomprehensible legislation is epitomised in the following two illustrative examples;

(a) the Regional Planning for Attica was completed through the pre-choice of landfill sites by a special amendment in a Law in Parliament and
(b) the Administration opted for licensing a (public) waste pressuring unit as a 'productive investment' and not as a waste management facility.

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Establishment of a Waste Management and Ecology Center in Bayawan City, Negros Oriental, Philippines

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ABSTRACT

With the enactment of Republic Act No. 9003, otherwise known as the Ecological Solid Waste Management Act of 2000 on January 26, 2001, various stakeholders especially Local Government Units (LGUs) in the Philippines were tasked to upgrade their solid waste management systems. So far, most municipalities in the Philippines still operate dumpsites that scarcely fulfil the minimum standards in water, soil and air protection. In August 2004, Bayawan City finalized its solid waste management plan which proposed the establishment of a Waste Management and Ecology Center. The presented paper summarizes the experiences of LGU Bayawan City in planning and implementation of its integrated solid waste management system that highlights the establishment of a clay-lined landfill, a composting plant, a materials recovery facility and a sludge treatment plant to address the problem of waste disposal.

INTRODUCTION

Republic Act 9003 declared that it is the policy of the State "to adopt a systematic, comprehensive and ecological solid waste management program" that ensures the protection of public health and environment. Section 37 of Article 6 specifies that no open dumps shall be established, that they should be converted to controlled dump within three years after effectivity of the law, and the establishment of a sanitary landfill five years after the enactment of R.A 9003. One of the municipalities which are on the way to implement RA 9003 is Bayawan City. Bayawan City proposed to enhance its local solid waste management system and to implement the legal prescriptions of RA 9003 by establishing a new 10-Year Solid Waste Management (SWM) Plan, which includes the implementation of a Municipal Waste Management and Ecology Center.

Based on the outline of the SWM Plan, the LGU conducted a site selection survey, prepared the needed planning documents and was issued the required Environmental Compliance Certificate from the Environmental Management Bureau in June 2008. Since then, various construction works are being conducted to accomplish the first fill unit of the landfill; a composting plant; a material recovery facility; a septage treatment facility and a wastewater treatment facility to treat the leachate from the landfill and the supernatant from the septage treatment tank. The project focuses on the application of appropriate technologies and utilizes local equipment, local expertise and local materials to reduce project cost as far as possible.

As part of the legally prescribed planning process, Bayawan City conducted a waste characterization in the year 2003. Evaluation of the waste characterization data was the main initial consideration to outline the municipal solid waste management system. The results showed the actual composition of waste generated (biodegradable, recyclable, residual and special waste) within the collection area, and provided a basis for its projection for the whole LGU. Whereas, the quantity of waste generation determines the following:

- land area requirement for a sanitary landfill;
- type and specifications of collection trucks and collection system;
- frequency of waste collection activities;

- area requirement for material recovery (MRF) and composting facilities.

The waste characterization conducted in 2003 revealed a per capita waste generation of 0.58 kg/day. With an average of 4.5 persons per household, the approximate daily waste generation per household is about 2.5 kg/day. In Table 1, the main findings are projected.

Table 1 Waste characterization Bayawan City

Composition	Waste generation 2009 (tons/year)[1,2]	%	Waste collected 2009 (tons/year)[1,2]	%
Bio-degradable	8,300	56	3,215	51
Recyclable	2,223	15	1,054	17
Residuals	4,150	28	1,967	31
Special Wastes	148	1	70	1
TOTAL	14,821	100	6,306	100

Note:

1. Based on the waste characterization performed in 2003 with an average waste generation rate of 0.58 kg/cap/day for urban and an assumed per capita production of 0.29 kg /day for rural barangays.
2. Based on the following population figures (census 2007 with a growth rate of 1.2 percent): 27,117 urban, 12,139 rural collected, 73,665 rural not collected 112,912 totals.

Currently, Bayawan City collects its waste from 10 out of the 28 barangays (smallest administrative division in the Philippines). In terms of population, the collection area covers approximately 35 percent. Out of 10 barangays in which collection finds place, 7 are urban and 3 are rural. In the rural areas biodegradables are not collected due to lack of access roads and high costs of collection. Instead, backyard composting is promoted. Based on a 0.58 kg/cap/day waste generation rate for the urban area and an assumed generation of 0.29 kg/cap/day for the rural barangays, the total waste generation within the present collection area of Bayawan City can be assessed at 17.3 tons/day. This number can be divided into 8.8 tons biodegradable, 2.9 tons of recyclables, 5.4 tons of residual waste and 0.2 tons/day of special waste.

However, with the extensive information and education campaign (IEC) conducted in line with the implementation of a fee system for the collection of both biodegradable and non-biodegradable waste, it is likely that the current waste management practices may render the 2003 data inapplicable. To verify changes in waste generation a follow up waste analysis and characterization study was recently conducted, which will be finalized in July 2009. The study may also assist to adjust the planning of detailed components for composting and material recovery at the Bayawan City Waste Management and Ecology Center (BCWMEC) as well. In addition, the results will also clarify if the projected lifespan of the sanitary landfill is sufficient to accommodate residual waste from neighboring municipalities later on.

SITE SELECTION AND PLANNING

On many occasions, site selection in the Philippines is based on availability rather than on suitability. This often results in waste disposal sites located in former fishponds, watershed areas, natural depressions, former mining sites and other non-suitable areas. However, for Bayawan City site identification strictly adhered to the availability and suitability requirements. Bayawan City started to search for suitable sites away from the shoreline and watershed areas. In addition, areas with steep slopes were excluded. Applying these criteria, a few areas were left to choose from, especially since most areas complying with the given restrictions are used for agricultural purposes and therefore considered as valuable lands. Despite the restricting conditions, two target sites were identified, - designated as sites A and B - which after ocular inspection, were subjected to a hydro-geological survey by the Mines and Geosciences Bureau (MGB).

The soil analysis of site A demonstrated a permeability of 4×10^{-6} cm/sec, a lower permeability if compared with the legal standard of 1×10^{-6} cm/sec for a category 2 landfill. However, the sample was taken randomly and does not secure the given permeability for the site as a whole. For site B, the MGB conducted a hydro-geological survey as well. Initial findings showed that the area is suitable for SLF establishment. The results for the permeability analysis showed a value of 1.2×10^{-7} cm/sec. For this value the same argument applies as for site A. The permeability value does not provide a sufficient protection since the finding was based on random sampling. In addition, the permeability factor is very close to the prescribed legal standard. Therefore, for both identified sites a liner needs to be installed in order to avoid leachate leakage into the groundwater system.

Legal instruments for the land ownership of the property, by the LGU of Bayawan City, were processed accordingly to address social concerns. From the beginning, the landowners of site A signified their objection to the proposed establishment of sanitary landfill (SLF) on the identified site. At the second site, dialogues and assemblies were conducted to ensure social acceptability of the proposed SLF. A barangay resolution was passed to legitimize acceptance of the local residents.

Prior to SLF site development planning, topographic and parcel surveys were conducted by the City Engineering Office. By using the topographic map, the site development plan was drawn including the following components: sanitary landfill (SLF), Septage treatment facility, waste water treatment facility, composting plant, Materials Recovery Facility (MRF) and an administration building. After designing the general site development plan, the task of the involved Bayawan City engineers was to identify and establish the detailed engineering components for project implementation. The first and most challenging part was to plan out the first fill unit of the SLF component.

In order to avoid unnecessary filling of recoverable materials within the SLF, a MRF component is added to the project. With the MRF, where recyclables, biodegradables and residuals will be segregated, the lifespan of the SLF can be extended significantly. Assuming that only 5.4 tons residuals arrive at the landfill and the SLF operation is able to attain a compaction rate of 0.4 tons/m^3, the lifespan of the SLF unit 1 will be in the magnitude of approximately 9 years.

Other aspects that considerably influence the lifespan of the cell are the compaction rate and segregation. To show the influence of these factors a calculation was made using the following formula:

$$T = \frac{V}{w/d * \frac{1}{c}} \qquad (1)$$

Where,

V – available volume of SLF
w – tons of waste disposed every day
T – landfill lifespan in days
d – density of collected waste with 0.20 tons/m^3
c – factor of waste density after waste compaction
e.g. 2 meaning a compacted density of 0.4 tons/m^3

Table 2 shows the lifespan of the first cell for 3 different scenarios. From the table it becomes clear that segregation together with compaction contribute significantly to the extension of the lifespan.

As stated earlier, currently 35 percent of the population is served with collection services. The municipality is planning to extend their services. In addition, it is expected that neighboring municipalities will apply to dispose their waste at the BCWMEC as well. Taking these two aspects in mind, the lifespan of the firs cell will most likely not reach its prediction of 9 years.

Table 2 Scenarios for the lifespan of the Bayawan Landfill

Estimated lifespan (years)						
Landfill Cell	Area	Average fill-height	Storage capacity	Non-segregation non-compaction	Segregation and non-compaction	Segregation and compaction
Fill unit 1	10.000 m^2	4.5 m	45,000 m^3	1.4	4.6	9.2

TECHNICAL DETAILS AND EXPERIENCES

The Liner

At the Bayawan City landfill an engineered base liner was installed in order to collect the leachate and to avoid the pollution of groundwater and surrounding surface waters. Choosing an engineered lining system was intended to comply with the permeability factor as requested by law. Furthermore, it cannot be assumed that a given natural site provides an equal distribution in terms of permeability for the site as a whole due to geological considerations.

To cut on cost, soil was used as bottom liner instead of an expensive synthetic liner. The material chosen for the liner was bentonite as a clay additive instead. Bentonite was chosen due to its known swelling capacity and hereby closing any voids within the 75 cm thick base soil liner. By using a synthetic liner it was expected that costs for liner construction would at least double (Paul, 2003).

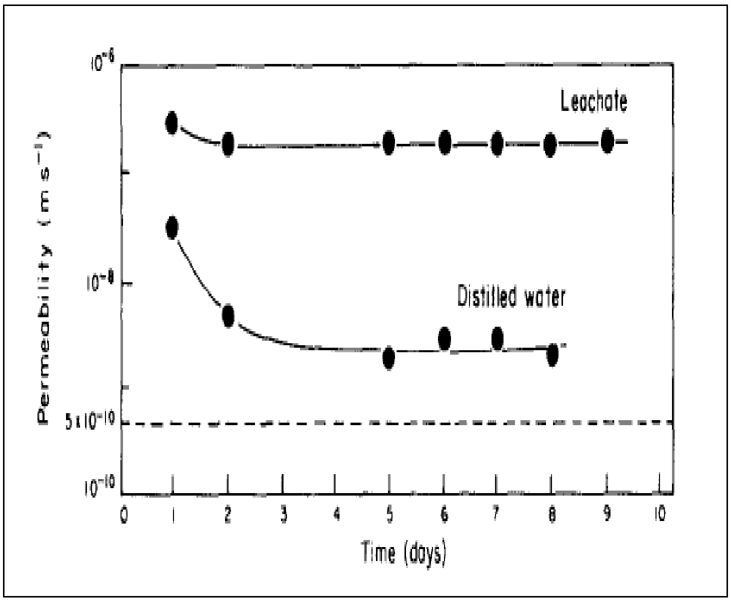

Figure 1 Comparison for the permeability of a bentonite-clay liner with the use of leachate and water (after Hoeks et al., 1986)

Planning of the first cell followed the legal prescriptions of RA 9003 and applicable technical standards. Initially it was proposed that a 20 - 80 mixture (20% bentonite clay/80% host soil) should be used. However, hauling cost to bring in bentonite clay was expensive, since the bentonite clay source is located at the other side of Negros Island more than 200 km away from Bayawan City. Hence, the viability to further reduce bentonite content to 10% of the base liner was explored. A study performed by Hoeks et al. (1986) revealed that the permeability coefficient could already be reached by adding three to four percent bentonite. However, it has to be mentioned that the tests were run under laboratory circumstances. In addition, due to difficulties in the mixing of clay and impurities present within the delivered bentonite it is unlikely to meet laboratory conditions. Furthermore it has to be considered that leachate behaves more aggressive towards a bentonite liner compared to distilled water. The study by Hoeks et al. showed that the permeability of sand-bentonite mixtures is about 100 times greater for leachate than for distilled water (Figure 1). To safeguard the quality of the clay liner and to especially check whether the permeability coefficient meets the standards set by RA 9003, several samples were sent to the Department of Science and Technology (DOST). The outcome of the sampling for the 10-90 mixture (10 percent bentonite/90 percent host soil) was 3.44×10^{-8} cm/sec, which confirmed the use of the mixture as liner, having exceeded the permeability coefficient of 1.10^{-6} cm/sec as set by RA 9003 for a category 2 landfill. The optimized clay liner mixture translates to cost savings of approximately 22,000 USD for the municipality. Figure 2 shows the final design of the first disposal cell.

The technical design shows that the municipality has chosen for a roof profile within the base liner. In order to ensure stability of the cell, a side slope of 1:3 was chosen (vertical to horizontal). The produced leachate is guided towards the buffer lagoon by the sloping bottom liner. The transverse slope of the cell is defined at 4 percent and the longitudinal slope is defined at 2 percent for the leachate piping. After the lagoon the leachate will be treated by the wastewater treatment system. Besides proper collection and treatment of leachate an important aspect of the landfill operation is the monitoring of groundwater and surrounding bodies of surface waters in order to safeguard the proper functioning of the installed liner system. For groundwater monitoring, several wells were strategically placed surrounding the cell. To determine the actual water depth and flow direction, a survey was conducted. The results of the survey are represented in Figure 2 and include the water level of each well together with the contours.

After the issuance of the Environmental Compliance Certificate, the LGU Bayawan City started with the site development which included: construction of the access road, site fencing, and excavation works at the fill unit 1 and the base liner construction. As elaborated during a landfill construction workshop, working with clay is a challenging job. In order to reach maximum compaction, 3 layers of 25 cm each were installed.

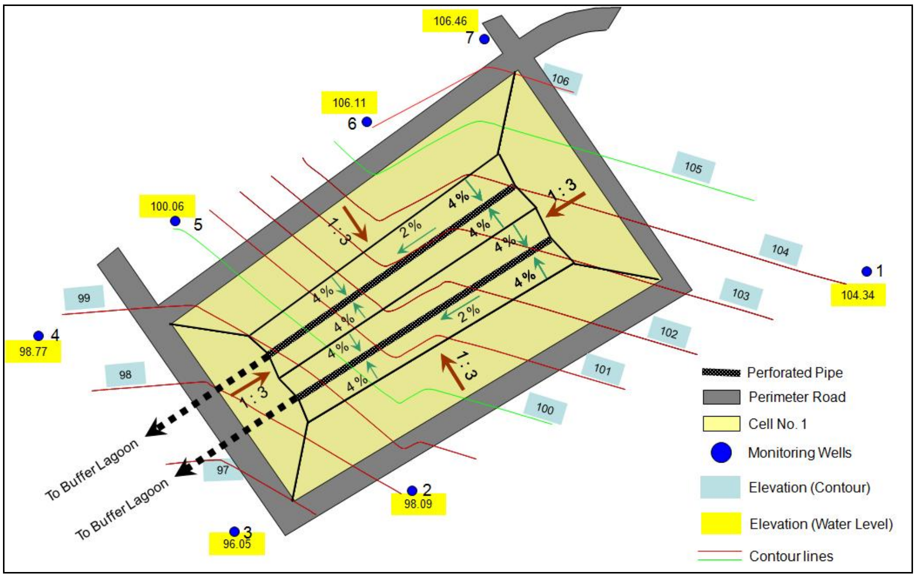

Figure 2 Technical details for the first disposal cell

Each layer should be compacted at around a moisture content of 26 %. Preferably, the compaction should take place at the wet side (a little bit above 26 percent). Instead of being a summerlike and dry month as expected, April 2009 turned out to be rather wet and brought a total of 15 rainy days with a corresponding 199 mm ample rainfall. Data from the municipal weather station showed that there were 3 rain events in which more than 20 mm rainfalls were measured. Consequently, the construction of the sanitary landfill faced an unexpected delay due to the changing weather patterns.

Protection and Drainage Layer

Having the bentonite-clay liner in place, a protection layer of sand was placed on top to protect the liner from the gravel which was placed on top to serve as drainage layer. The used sand has a grain size between 2/8 mm, whereas the lime content should preferably be less than 20 percent. The latter seemed hard to reach due to the abundant presence of limestone in the Philippines.

After installing the protection layer the drainage layer was installed. This layer forms the heart of the system and ensures that the leachate is properly channeled towards the leachate pipes. The drainage layer has a height of 40 cm and the used gravel has a diameter size between 16/32 mm.

To collect and channel the leachate out of the SLF unit, two 8 inch leachate pipes were embedded under the drainage layers which drain towards the lowest point in the cell. Figure 3 shows the cross-section of the Bayawan City landfill.

The most difficult aspect encountered during the installation of the protection and gravel liner was the logistics. The liner installation together with the installation of the protection layer, drainage layer and leachate pipes required accurate planning. In addition, the gravel delivered on site did not match the requested grain size distribution and diameters. Furthermore, it still contained a lot of silt and small grain sizes which could later clog up the drainage systems once in place. To avoid clogging, additional screening of the gravel was performed.

The set up of the BCWMEC aimed to avoid gas production and accumulation within the landfill site. To avoid accumulation of gas within the cell, an additional gas venting system will be installed. The system will consists of bottomless oil drums which are placed in the cell and filled with gravel. When the waste reaches the top of the drum, the drum will be pulled up and filled again with gravel until the waste reaches the maximum allowable level. To avoid unnecessary waste disposal and to avoid landfill gas production, the municipality applies two strategies namely: waste segregation at source and at the "end of the pipe" segregation of biodegradable and non biodegradable materials. The next paragraphs describe these strategies and needed processes in more detail.

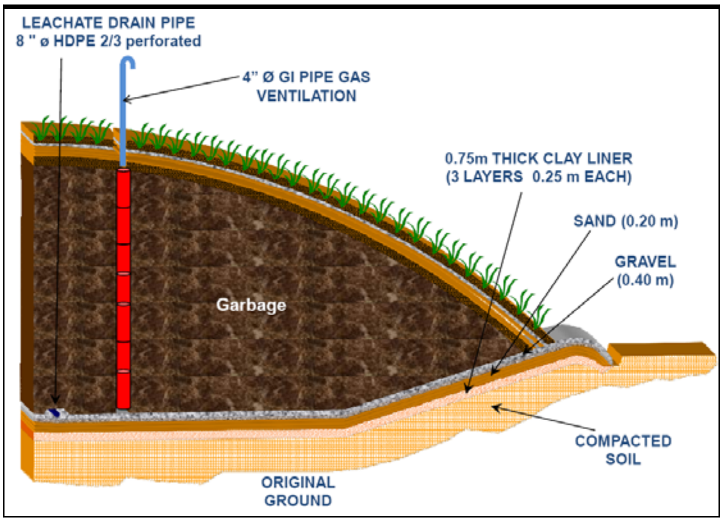

Figure 3 Cross section of the Bayawan landfill

Composting

Organic material decay is nature's way of bio-degeneration. As end product organic waste are being transformed and incorporated as solid matter in soils, floodplains, swamps, inland water or marine deposits or broken down into their end products carbon dioxide, methane and water and are released into the environment respectively the atmosphere (Paul et al., 2008). Therefore, by avoiding biodegradable matter within the landfill, a reduction in methane emission will be achieved.

According to the 2003 waste characterization, Biodegradables are the main portion of waste produced at household level. From the biodegradables collected, 56 percent of the total waste volume is biodegradable which results in 3,215 tons on a yearly base in the collection area. By intensive information and education campaigns, Bayawan City promoted for the past years segregation at household level in addition to the introduction of the sticker system. Initial results of the 2009 waste characterization show that the amount of collected biodegradables is lower if compared with the 2003 results. Unfortunately, during the time of writing the official outcomes of the new waste characterization are not yet finalized and released.

Presently, collected biodegradables are transported to the MRF where the City's Environmental and Natural Resources Office (CENRO) applied different types of composting. The first technology applied was drum composting. Using mechanized drum composter one can reduce the processing time but faces increased costs due to additional investments for mechanized equipment, electricity consumptions, maintenance of the drums and acquisition of process enhancer which needs to be added. The final product from the drum composter does not provide a significant advantage in terms of quality and marketability (Paul et al, 2008). Due to difficulties with the drum composters, it was decided to shift to windrow composting. This static technology provides a less costly way to process biodegradable waste.

Material Recovery Facility

In order to improve the segregation and to avoid mixing of organic materials, recyclables and residuals in both the landfill and for the compost process, the city developed a material recovery facility (MRF). The applied system uses slides and hence gravity force. The slides are guiding the waste down into separate boxes for each type of waste. The use of a gravity based system results in a more efficient operation and reduced maintainance. Following the 2003 waste characterization, a yearly amount of 1,054 tons of recyclables can be segregated out of the waste and sold to local junkshops by applying this end of pipe system. Figure 4 shows the principle and perspective of the proposed MRF.

Figure 4 Perspective of the Bayawan City material recovery facility

Wastewater Treatment

The wastewater treatment facility at the BCWMEC collects leachate which originates from the landfill and supernatant from the septage management system. The quality of leachate is highly dependent upon the waste composition, stage of fermentation in the landfill, procedures and operation. Many chemicals (e.g. metals, aliphatics, acyclics, terpenes, and aromatics) have been detected in landfill leachate from domestic, commercial, industrial, and co-disposal sites (El-Fadel et al., 1995). Unlike the leachate, the supernatant has a constant composition and its quantity can be controlled. The quantity depends on the collection rate of septage, this in contrary to the landfill leachate which depends on the precipitation, moisture content of the waste and operation practices.

The designed system consists of 4 different components without moving parts in order to avoid additional costs for electricity and maintenance. The leachate treatment uses a lagoon, aerobic ponds and a wetland. The septage treatment uses an anaerobic baffled reactor (ABR), aerobic ponds and a wetland. The lagoon was designed in order to catch large amounts of leachate during rainy days. It should be able to buffer at least a heavy rain event which is assumed to be 150 mm in 3 or 4 days. During normal operation, the lagoon will have a depth of not more than 1.0 meter. With this depth, the lagoon will, beside its role as buffer, serve as an aerobic treatment. The total volume of the system compromises 1,500 m^3. The lagoon is protected by a HDPE liner since concrete basins are subjected to cracks. To assure the quality of the liner, the city has chosen for a supplier which follows ASTM standards in their production and liner installation process.

The ABR is solely used for the septage treatment. The reactors main purpose is to reduce the waste load of the supernatant originating from the drying beds and the storage tanks. The ABR reaches high treatment rates due to its high solids retention time. According to a study performed by Foxon et al. the ABR reaches a 1 log reduction in pathogen indicator organisms (e-coli and total Coliforms) and a Chemical Oxygen Demand (COD) removal between 58 and 72 percent. After the ABR, the wastewater flows to the aerobic pond. The aerobic pond consists of 4 chambers in which filter materials can be placed if needed. The final treatment for both types of wastewater is the wetland.

The city of Bayawan has already good experiences with wetlands. Since 3 years the city is operating a wetland which treats the liquid waste from approximately 700 households. The system is able to reach 99 percent removal efficiency in terms of Biological Oxygen Demand (BOD). The wetland at the BCWMEC will receive a different type of wastewater compared to the existing wetland. Once in place, the wetland needs to be monitored on its performance. During the design, one of the key issues was that the system should be low cost and maintenance. Therefore, the whole system is able to flow on gravity without use of electricity.

Septage Treatment

Worldwide, many countries suffer from the effects of improper disposal of domestic liquid waste. The most-known effect is diarrhea that kills 2.2 million children every year and consumes scarce funds in health care costs, preventing families and nations from climbing the ladder of development (Khan, 1997). According to a study performed in a similar setting, liquid waste contributes significantly towards the total pollution load. In terms of BOD, the domestic liquid waste contributes approximately 65 percent to the total load (Boorsma, 2004). In order to reduce the pollution load of the domestic sector, Bayawan City has an ongoing project to empty all septic tanks on a regular base to prevent leakage into the groundwater aquifer, and minimize the incidence of waterborne diseases. Recently, the City acquired two vacuum trucks, which will be used to collect septage from households in the city, for this purpose.

The applied technology consists of two storage tanks connected to drying beds. Collected septage will be stored for approximately 30 days in the storage tanks and subsequently emptied into the drying beds. A waste water treatment facility is connected to the system. The multi-tiered project is another pioneering effort of Bayawan City to show the way in implementing environmental laws, by providing the needed infrastructure to perform its environmental duties, to attain the goal of sustainable local development. The treatment system is expected to be operational by August 2009 and is a step further for Bayawan City to make life better for everyone without sacrificing the environment.

COSTS AND RECOVERY MECHANISMS

For a project like the BCWMEC, cost estimate at every phase of work is indispensable, to determine which stage of the project the LGU can implement or initiate cost reduction measures, based on its funding capacity.

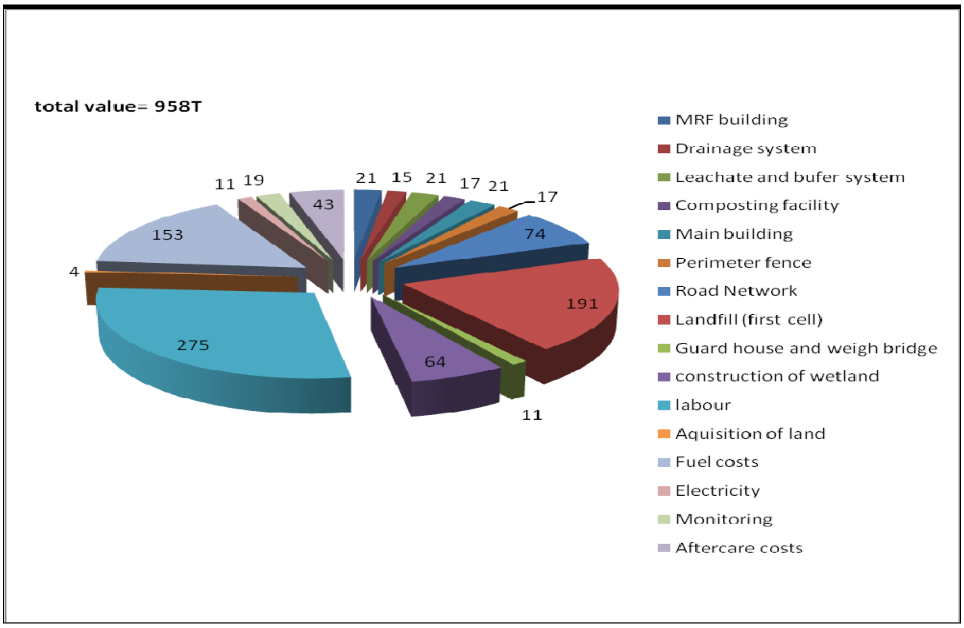

Figure 5 Breakdown of the BCWMEC costs (Dollars in Thousands)

Figure 5 shows the breakdown of both fixed investment and operational costs. Assuming a lifespan of 9 years, the total costs for the first cell within the BCWMEC reaches around one million US dollar.

In the Philippines, cost recovery mechanisms for waste are seldom in place due to the fact that the citizens expect that solid waste management service are provided by the government cost-free. Since waste management fees are hardly claimed so far, it seems difficult to propose and implement a "generator-pay's principle". However, without an efficient cost recovery mechanism, the sustainability of waste management services and enhancement projects is questionable. Nevertheless, Bayawan City has a strategy to recover expenses through the sticker system. The system makes it mandatory that a sticker worth 4 dollar cents should be attached to a cement sack container of solid waste from household and business establishments before the conduct of garbage collection. An extensive information, education campaign (IEC) of the target barangays preceded the implementation of the system. With this system the city is able to collect monthly fees of approximately 425 USD. e the costs for the collection.

Table 3 gives an overview of the tipping fees calculated from the total costs of the solid waste management component within the BCWMEC. It becomes clear that the municipality is sponsoring the largest amount for their citizens. With the implemented sticker system, the municipality is able to recover approximately 5 percent of the total amount spent for the disposal. It has to be mentioned that this number does not include the costs for the collection.

Table 3 Overview for the tipping fees (in USD)

	Per m^3 [1]	Per ton [5]	Per m^2 [2]	Per capita per year served within collection area[3]	Per household per year served within collection area[4]
Tipping fee[6]	21	53	96	2.7	12.2

Notes:

1. Based on a volume of 45,000 m^3; 2. Based on a surface area of 10,000 m^2; 3. Based on 39,256 served people within the collection area; 4 Based on a household size of 4.5; 5. Based on a compaction rate of 0.4 tons/m^3 6. Only costs for disposal are included

CONCLUSIONS

Although Republic Act 9003 was launched in 2001, many municipalities in the Philippines still lack a proper site for disposing their residual waste. With the constructing of the Bayawan City Waste Management and Ecology Center (BCWMEC), Bayawan City joins the few Local Governments that were able to implement the waste management law. By integrating a septage treatment facility into the BCWMEC, Bayawan City goes even one step further to utilize the project and to add initiatives to enhance local sanitation and to maintain a clean environment.

In terms of population, Bayawan City’s waste collection area covers approximately 35 percent. The most of collected solid waste comes from the city center and the adjacent rural barangays. Based on the waste characterization conducted in 2003 a total amount of 1,967 tons per year of residuals will be disposed to the newly constructed landfill.

Assuming that only residuals will be disposed and a proper waste compaction can be performed at the new landfill, it is expected that the lifespan of the first cell will be around 9 years. Furthermore, a scenario analysis shows that segregation of biodegradables, non biodegradables and recyclables significantly influence the lifespan of the cell.

In order to provide ground- and surface water protection, the first fill cell of the new landfill is equipped with an engineered base liner. The application of a Bentonite enhanced clay liner was chosen to utilize locally available materials and to lessen cost for material import. Because of its swelling capacity, bentonite clay was chosen as additive to construct the liner. By reducing the amount of bentonite to 10 percent instead of 20 percent, a significant reduction in construction cost could be reached. During the construction it was experienced that rainfall negatively influenced the construction works for the liner. Due to rainfall, heavy equipment could not enter the site and the targeted optimum moisture content could hardly be reached respectively became a time consuming process.

To ensure the proper protection and drainage of the cell, a protection layer, drainage layer and leachate pipes were installed. The different layers were installed on top of the liner which was engineered in such a way that the leachate flows by gravity towards the outlet of the cell. Due to the delay in the liner construction, difficulties were faced during the work planning and process coordination, especially with regards to the materials to be delivered on site.

In order to extend the lifespan of the first cell, Bayawan City implemented various measures to minimize the disposal of residual waste. Applied source reduction methods are backyard composting, source segregation and segregated collection. With this approach the amount of biodegradables collected and transported to the material recovery facility can be minimized whereas a further segregation is conducted at the MRF to reduce waste disposal as far as possible. At the material recovery facility the recyclables and biodegradables are removed from the delivered waste.

In the year 2008, the City of Bayawan started to implement a cost recovery mechanism. The used mechanism applies stickers as a medium to implement waste segregation at source combined with cost recovery. Currently, the municipality is able to recover around five percent of the costs for waste disposal. The five percent does not encompass the costs for collection.

In the future it is expected that neighboring municipalities will approach the Local Government Bayawan City and apply to dispose their waste at the BCWMEC as well. For this purpose a tipping fee was calculated. Assuming a lifespan of the 9 years, the calculation projected a per cubic meter tipping fee of 21 USD. Correspondingly, the tipping fee per ton was estimated with 53 USD based on 0.4 tons per cubic meter waste compaction.

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Role of R's in the Minimization of Solid Waste

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ABSTRACT

In Bangladesh, National 3R workshop was held in February 2007 emphasizing on reduce, reuse and recycle for minimizing Solid Waste (SW) whatever be the municipal waste, healthcare waste, industrial waste or hazardous waste in municipalities, district and divisional cities, metropolitan and mega-cities as 3R needs to be promoted for proper waste management. Apart of 3R, other Rs such as refuse, repair, replace, recovery, renew, recharge, are utilized in many urban centers partially or fully as much as possible minimize solid waste throughout the world. Among them, recycling is the predominant process of turning used products of a particular category into raw materials of that category which can be used to make new products of that category. Refuse indicates avoiding of buying anything that becomes waste. Reduce means decrease the amount of waste when mixed, of resources when sorted, and of materials when an action is applied. Reuse stands for anything that can be reused for any purpose for instance, toner cartridge backed from the customers can be disassembled and parts are reused in manufacturing new cartridges. Repair means minor renovation of the part or parts of any inactive plant to come into operation. Replace means replacing of non-working parts of a plant than purchasing new plant or new equipment. Recovery of resource is the method of resources from another resources or sources for instance valuable chromium is recovered from industrial chrome waste like tanning industry. Renew of the energy is the conversion of waste-to-energy as an alternative waste management option for example bio-gas is renewed from cow-dung. Recharge means revive or refresh of anything for example recharging of lead-storage battery, UPS, IPS etc. Refill denotes replenish or fill-up anything for example refilling of ink in ball-pen, graphite ink in the toners of photocopier and printer of computers etc. This paper will discuss the role of all such R's to minimize solid waste with proper recommendations.

INTRODUCTION

Waste management has become one of the major challenges confronting urban local authorities in cities and towns in a global scale as in recent years, with the amount of discharged waste remaining at a high level, problems have been incurred, including improper cyclical use and disposal, the shortage of landfill capacity of final disposal sites, frequent occurrence of illegal dumping, demand to establish methods for remediation, and so on. Obviously only collection of solid waste in time, treatment or dumping in the landfill can not give the proper solution to handle indiscriminately increasing amount of solid waste; needs the new dimension of solid waste minimization involving, 3R, 4R, 5R, recently more than 5R possibly 10 R. Relevant studies were conducted in Dhaka, the Capital City of Bangladesh, Sylhet, the most important Divisional City of Bangladesh, and Moulvibazar and Sunamgamg, two important district towns of North-eastern Bangladesh during 2007-2009 in order to evaluate the role of Rs in the solid waste management specially of recycling followed by the detailed investigation, a number of questionnaire surveys and extensive literature on other Rs added by adequate number of communication.

METHODOLOGY

The study included the extensive literature review, in-depth field survey in Dhaka, Chittagong and Sylhet city, and Moulvibazar & Sunamgamg, two important district towns of North-eastern

Bangladesh to collect the relevant information on 10Rs vis-à-vis *Refuse, Reduce, reuse, recycle, recovery, renew, recharge, refill, repair and, replace.* Besides interviews of staffs and executives of relevant industries like Pran Food Industry, Square Food industry, GQ Ball Pen, Matador Ball Pen, Janani Ball Pen, Writer Ball Pen industries, Rahim-afroj Limited as well as many engineering workshops of Dolaikhal and Tejgaon Industrial Areas, Computer and IT Shopping city of IDB Bhaban at Agargaon of Dhaka city; Bangladesh Steel Rolling Mill (BSRM) at Foujdarhat, Bangladesh Steel Re-rolling Mill and Billat Plant at Nasirabad, a number of engineering workshops in Chittagong City was undertaken. Moreover interviews of housewives, maid-servants, tokais (strangers), waste-pickers at landfill sites, municipal waste collection crews were taken in Dhaka, Chittagong and Sylhet City, and Moulvibazar & Sunamgamg towns. All survey and interview findings were gathered, accumulated, processed and analyzed successively.

RESULTS OF THE STUDY

The respondents of the study areas of urban areas of Bangladesh highly appreciated for planned wise Rs activities for all Rs specially for reuse and recycling, reduce, refuse, refill, repair, recovery, and renew and apprehend that all of 10 Rs should be practiced not only in the urban centers but also in peri-urban and built rural areas to minimize the gigantic sum of solid waste ensuring eco-friendly initiatives leading to sustainable development in order to save the green environment. Respondents apprehended that practice of all Rs will decrease the waste loads in the landfill, increase the financial saving, save the money in the eco-friendly way ensuring sustainable clean environment. However, majority of the respondents are not well aware of all Rs rather than 3R, or 4R or 5R and their role in the minimization of solid waste. Overall view of the respondents on 10Rs is presented in Table 1.

Table 1 Views of the respondents on 10R

Issues	Refuse	Reduction	Reuse	Recycle	Recovery	Replace	Repair	Refill	Renew	Recharge
Appreciation as a waste minimization process (%)	75	80	95	90	70	60	75	75	70	65
Decrease waste load in landfill	Yes	Yes	Yes	Yes	yes	Yes	yes	yes	yes	Yes
Opinion for first choice (%)	12	15	35	30	8	-	-	-	-	-
Waste minimization hierarchy	Ist	2nd	3rd	4th	5th	-	-	-	-	-
Financial saving from the option	yes	Yes	Yes	Yes	yes	Yes	yes	yes	yes	Yes
Eco-friendly way (%)	35	40	45	45	30	25	35	25	25	35
Sustainable process (%)	55	60	65	60	55	45	55	45	45	50

The findings of the conducted study in four urban areas analyze and review the nature of 13 Rs as much as possible as detailed below.

Refuse or Avoid Excess Waste

Refuse indicates avoiding of buying or using anything that becomes waste. Findings of the study reveals that change of food use and controlling the food purchase at home especially for a get-together or celebration decreases a significant amount (30 to 50%) of the waste. The respondents delivered the ideas on refuse of excess waste as follows

- ***First avoid excess food wastes in the family by :*** planning accordingly with the aim of avoiding left-overs; eating the left-over's, if exists; finishing up all foods what is bought; watching the selected portions keenly, purchasing only what is really needed; and making the meal plan efficiently

- ***Avoid the excess use of paper:*** Study shows that paper accounts for more than 50% of municipal solid waste which can be avoided by using the library to read newspapers, magazines and books, paying bills online, avoiding printing unnecessarily, printing on both sides of the paper, changing margins to “0.7” instead of “1” or more, using 100% post consumer recycled paper
- ***Why not Plastic, polythene, plastic/poly bags, plastic containers are avoided?:*** All over the world, more than 100 billions of plastic shopping bags made from petroleum and natural gas - nonrenewable resources are used annually that pollute land, water, air, animals and humans. The study shows that making a paper bag emits 70 percent less greenhouse gases than making a plastic bag and plastic bags never biodegrade in landfills. Plastics number out of zooplankton in 10 to 1 in bodies of water. From this point of view, Bangladesh Government has banned the manufacture and use of thin polythene shopping bags in 2002 which is a bold and land-marking environment friendly attempt to avoid the use of plastic/polythene bag in Bangladesh. Since then use of polythene shopping bag is being replaced by jute bags and paper bags in the markets of Bangladesh. The shopping bags made of cloth and jute can be used again and again instead of one time use of polythene bags.
- ***Be frugal, prudent and parsimonious in the festivals:*** In the national festivals like independence day, victory day, republic day etc., cultural festival like new years day, and the religious festivals like Ester day and Christmas of the Christian community, Eids days of the Muslim, Dewali and Durga Puja of the Hindu, Buddha Purnima of the Buddists, an abundant amount of flowers, foods, chicken, meats, cloths, cosmetics, both of ordinary and costly gifts (mostly packed with plastic paper or bags), toys (mainly made of plastic or non-renewable matter) bags (mainly plastic bags), baskets (plastic bags), plants, artificial grasses, chocolates and candy (packed in plastic paper), are widely utilized without any hesitation, restriction, frugalness or in an uncontrolled way. According to the view of the respondents, unrestrained and uncontrolled use of all these items degrade the environment seriously which can be restricted by judicious use, premeditated way and environment friendly intelligent thoughts through public awareness for instance buying sustainable green or organic toys, sharing of the ritual of beasts during Eidul Azha by number of families in the Muslim community, using shopping bags of jute and cloth instead of plastic bags and reuse the bags etc. In the festivals and congregation of the communities, a massive amount of foods and different commodities are also misused or spoiled due to the erroneous supposition of want, lack of proper planning or mismanagement that can be avoided by intellectual planning, careful quantification of demand and effectual management. The survey results shows that proper planning, cautious quantification of need and proper management made the public to be frugal for the use of commodities in different festivals by 20 to 30% in Dhaka, Sylhet, Moulavibazar and Sunamgang.

Reduce

Reduce means decrease the amount of waste when mixed, of resources when sorted, and of materials when an action is applied. Study in the urban centers of Bangladesh apparent the trend of reducing solid waste as follows:

(i) making compost from garden and food waste already being practiced in Dhaka, Chittagong, Khulna, and Sylhet city. In Dhaka Waste Concern, Noujuyan in Chittagong, Prism, Prodipan, Samadhan and Rastic in Khulna, EPCT & Sylhet partnersp in Sylhet are involved in composting. Prism, Prodipan, Samadhan and Rastic in Khulna are more successful than other NGOS in composting activities.

(ii) buying a newspaper if and only if there’s the time to go though it (rather than daily) not buying more than one newspaper just as a prestige commodities although have no time to go through. In Gulshan, Banani, Dhanmondi of Dhaka city, Kulshi of Chittagong city, Upashar of Sylhet, such a practice of buying more than one newspaper is being practiced for long since.

(iii) buying loose rather than pre-packed foods; Respondents commented that this practice may be successful through awareness program especially via media.

(iv) passing outgrown clothes to others; Such kind of practices are already under track in Bangladeshi cities especially during the occurrences of natural disasters that may be accelerated by prudent planning in accordance with the views of the respondents of the survey.

(v) using fragment paper for shopping lists and notes that can reduce paper waste significantly in the level of 10 to 15% according to the respondents.

(vi) avoiding the disposable versions of razors, pens, batteries, plates, cups, napkins, etc. for everyday use that can be popularized by effective motivations, telecasting awareness programs though electronic media, advertising in the print media in accordance with the view of the respondents;
(vii) reducing 'junk mail' by registering with the direct mail preference service or by asking that the name and address be removed from mailing lists;
(viii) when choosing between similar products, select the one with the least amount of packaging to avoid over-packaging.. Also, look for things that contain recycled content;
(ix) setting printer to print both sides of a sheet of paper and photocopiers to copy documents double-sided;
(x) buying whole fruits and vegetables to avoid the unnecessary trays and wraps that can be successfully practiced through motivation;
(xi) buying the large or economy size for less packaging and saving of the money;
(xii) reducing waste during shopping by using a reusable shopping bag or rucksack rather than plastic carrier bags and refuse carrier bags if you don't need them;
(xiii) storing food in re-sealable containers rather than using cling film or foil;
(xiv) packing a no-waste lunch for self and family members; use a reusable lunch box or bag and fill it with the lunch in reusable containers and; include a cloth napkin instead of paper one;
(xv) using rechargeable batteries that will help in reducing waste and saving money;
(xvi) using solar power to avoid inconvenience and cost of a system run on electricity, battery etc.

Reuse

Reuse stands for anything that can be reused for any purpose for instance, using a product for its original or a different purpose more than once. Many things like paper and cardboards, plastic and plastic bags, clothes, rubber and tires, envelopes, books, batteries, bicycles, bottles and jars, electrical and electronic goods etc. can re-sed effectively according to the study results.
Paper waste comprises 40% of municipal solid waste stream. The Food and Agriculture Organization of the United Nations (FAO) estimates that by 2010, worldwide paper and paperboard consumption will increase 90% from 1993 (FAO, 2006). This equates to a consumption level of 528 million tons. U.S. businesses throw away 21 million tons of paper every year, the equivalent of 175 pounds per office worker. On average, every American consumes over 730 pounds of paper a year, making the U.S. the world's greatest paper consumer. A 12-foot high wall stretching from New York City to Los Angeles could be built with our annual office and writing paper waste. The 300 million rolls of fax paper we use each year are enough to go from the Earth to the moon 26 times. These papers can be re-used in many ways according to the respondents of the study. Respondents in the study looked at avoiding thin plastic bag use at supermarkets as a waste reduction method. The use of plastic and plastic bags follows the table matrix. Some books are bought to be kept for many years, if not for ever. On the other hand other books may be finished with after once reading. Study revealed that books after once reading can be re-used by passing them to friends and families and finally to charity shop, jumble sale, education carnival or similar event. There are also charity organizations that collect educational and textbooks from developed countries to supply to schools and colleges in developing countries. Charity foundations like ASIA FOUNDATION, FORD FOUNDATION etc. collects the books from the western universities after once reading in the educational institutions of the USA, Canada, UK, Australia, Newzeland etc.; they donate these books into the schools, colleges, universities of developing countries like Afghanistan, Bangladesh, Bhutan, Cameroon, Djibouti, Ecuador, Ethiopia, Ghana, Haiti, India, Jamaica, Kenya, Laos, Maldives, Mauritius, Madagascar, Nepal, Niger, Nigeria, Pakistan, Ruanda, Rodesia, Swaziland, Tanzania, Uganda, Zimbabwe, etc. Respondents of the study praise such charity donations of the books to schools, colleges and universities of our country. Almost everyone even small children can be involved in clothing re-use. Passing the outgrown and worn out clothes of babies and toddlers through families and friends can get several uses out of a T-shirt or a pair of rompers. Clothing re-use can still happen with older children's and adult clothes, but to a lesser extent. In these cases re-use can still take place through charity shops and collections. Rubber and tires can be re-used in many ways. At the start of the part of the study we looked at ways of re-using jars in the kitchen and the garage. Everybody should try and come up with effective uses of old bottles or jars in possible various ways. In accordance with the respondents of the study, envelops can be re-used in a few ways as shown in the table matrix. The study infers that furniture rejected by riches can be re-used by poor people of the society. Rechargeable batteries are used again and again in the different types of devices. Bicycles and its different accessories can be re-used again and again in

accordance with the study results A variety of electrical and electronic goods can be re-used in different ways as shown table matrix of Table 2.

Table 2 Tabular matrix gives an eagle eye for reuse by households and manufacturers based on the study results

Re-usable Items	Re-use Activities
Paper and Cardboard	(i) Scrap paper can be used for making notes and shopping lists. (ii) In computer at home both sides of the paper can be used for printing; (iii) Some people even go to the extent of unwrapping presents very carefully and then re-use the wrapping paper for somebody else's present. (iv) Old papers and cardboards can also be collected by the agents and retailers of the manufacturers and re-used as raw materials. (iv)Scrap paper especially newspaper or thick papers can be used for making packets. (v)Cardboard boxes can be used to store things such as shoes, toys, papers etc.
Plastic and plastic bags	(i) Any plastic after one use can be tried to further use in the original form; (ii) When a thick bag has to be used the bag can still be re-used. If the large size thick bag is undamaged it can be used for future shopping trips, but it could also be used as a waste bin liner or in the car for wrapping muddy boots and shoes after an outdoor activity;
Cloths & Textile	(i)Cloths and textile can be re-used by passing the outgrown and worn out clothes of babies and toddlers through families and friends. (ii) Clothing re-use can still happen with older children's and adult clothes too especially in poor community like slum areas; (iii) During natural disaster re-use of textile and cloths can still take place through charity shops and CBOs collections.
Rubber & tires	(i) Rubber can be re-used in the original form or other purposes than previous one. (ii) Rubber and tires can be re-used for making shoes, sandals, sponges, toys and many other rubber goods and commodities.
Bottles and jars	(i)Bottles and jars in kitchen and households are re-used for filling with different type of liquid such drinks, oils; (ii) manufacturers of mineral waters, soft drinks, milk, medicine, oils, lubricates, mobil etc. should collect the empty bottles and jars from users by their agents and retailers with their own responsibility and refill with their products and send to the market again.
Books	Books after once reading can be re-used by passing to friends and families and finally to charity store, jumble sale, education festival or related occasion.
Envelopes	Envelopes can be re-used for sending the postage and mails, storage purposes and for keeping the things and articles safely. Larger envelopes and 'jiffy bags' can have sticky labels placed over their original address for the new address and be sealed with sticky tape. For smaller envelopes, several charities and other organizations provide re-use labels which provide space for the new address, cover up the old address and provide a means of sealing the envelope.
Furniture	(i)The old wood of the rejected furniture can be re-used in other various ways than furniture. (ii) Some charity shops take furniture while other charities operate schemes to refurbish and sell damaged furniture to be used in other ways. (iii) Many Civic Amenity (CA) waste disposal sites are pleased to take and sell usable furniture rather than see it enter the waste skips.
Bicycles	(i)Bicycles after minor repair, re-hauling or over-hauling or replacement of defected parts by newly manufactured one or the operable old parts can be re-used (ii) Charity organizations collect repairable bicycles donating them to charities overseas.
Batteries	Rechargeable batteries can be-used after charging in power tools, cellular and cordless phones, laptop, computers, camcorders, cameras, two-way radios, cars and other vehicles etc. Rechargeable batteries, as well as lithium, silver-oxide, and mercury batteries, should be brought to the designated waste sites from where these batteries will either be recycled or properly disposed.
Electrical & electronic goods	(i)Discs, CDs, DVDs, videos, audio taps, cell phones, toner cartridges, pagers and the effective operable parts of common electrical and electronic products such as computer, televisions, VCR, stereos, copier, and fax machine etc. used by

individuals, businesses and government offices can be reused by others like low income groups of the society for instance poor slum people. (ii) Gold, silver, copper, platinum etc. are valuable materials which recyclers recover from e-waste. (iii) Many charity shops accept electrical goods, as long as they have a way of testing that the items are safe. A number of charity shops and second-hand shops are now dedicated to household goods and they will almost certainly accept electrical items. (iv)Many organizations now request and collect electrical items from households. Even if the items no longer work they will often still be welcome as staffs are trained to refurbish and mend items. Even the electrical items are then usually used to pass onto those on low incomes or to re-housing schemes. These electrical waste schemes are often community projects and also create jobs for local people and provide skills and training to volunteers.

Tips for reuse

Conducted study reveals the following tips for reuse:

- Honestly evaluate the condition of the items you wish to donate - these organizations spend a lot of money disposing of items that should have probably been recycled or disposed of in the first place.
- Call or visit the organization's website for additional information on what they will or will not accept.
- Follow the specific instructions provided to ensure that the items you intend to donate will be reused, rather than discarded.
- Drop off items during normal business hours, or appointed time agreed upon.
- Contact a bulk hauler to recycle or dispose of your large items if they are not fit for reuse:
- Twist ties from produce or bread bags can be used to tie herbs in a bunch to be dried.
- Use the back of receipts, junk mailers, flyers, and “mess up” paper from the printer (something didn’t print right, use the back) to make lists.
- Glass jars, such as spaghetti or applesauce jars, peanut butter jars, mayo jars, olive or nut jars can be rinsed in soapy water, their labels removed can be used for other things. Uses we’ve found for glass jars include: storing bulk nuts, seeds, flours, and odds and ends. We even use the appropriately sized ones as drinking glasses. And Heather had the excellent suggestion of using peanut butter or mayo sized glass jars to take soup as a lunch to work. They also double as something to safely heat the soup in, as well as a bowl.
- Containers that starter plants come in or things like cut to size milk cartons make excellent places to start next year’s garden seeds.

Recycling

Recycling is the predominant process of turning used products of a particular category into raw materials of that category which can be used to make new products of that category. It involves the reprocessing/s of used materials of an item converting into new product/s or a new raw material/s for use in a new product/s through a number of conversion/s reaching to the original item flowing a or a number different or similar process/s to put off the waste of potentially functional materials declining the consumption of raw materials considerably in order to enhancing closing of the loop in a cyclic way. Recycling reduce the consumption of fresh raw materials, reduce energy usage, reduce air pollution (from incineration) and water pollution (from landfilling) by reducing the need for "conventional" waste disposal, and lower greenhouse gas emissions as compared to virgin production (LWV. 1993; Vigso,2004; Economist, 2007*)*. Another form of recycling is the salvage of certain materials from complex products, either due to their intrinsic value (e.g., lead from car batteries, or gold from computer components), or due to their hazardous nature (e.g., removal and reuse of mercury from various items). Arguably, there are many more items that are recyclable, though, strictly, recycling involves the re-manufacture or manufacture of goods/packaging, using some or all of the elements found in the waste from existing goods. Materials to be recycled are either brought to a collection center or picked up from the curbside, then sorted, cleaned, and reprocessed into new materials bound for manufacturing. In a strict sense, recycling of a material would produce a fresh supply of the same material, for example used office paper to more office paper, or used foamed polystyrene to more polystyrene.

Conducted study shows that in old city area like Lalbag, Islambag, Sadarghat, Mitford etc. and slums of Mega city Dhaka, majority of the people being illiterate or ill-educated (mostly businessmen) are completely unaware of recycling, pollution and spreading of diseases and they are not ready to pay extra cost for recycling although recycling interest is grown to them. Table 3 shows the response of the householders of old Dhaka (20 householders from each area) about recycling in household level.

Table 3 Results of Household Interview for SWM in Old Dhaka

AREA	EDUCATION OF HH (HW)			PROFESSION OF HH (HW)			AHR	APDS	SCIHR	RI	WTPHRF
	Illiterate	Below SSC	Above SSC	Business	Service	Unemployed					
Lalbag	14(16)	4(3)	2(1)	12(0)	6(2)	2(18)	0	0	11	13	5
Islambag	19(20)	1(0)	0(0)	9(0)	6(0)	5(20)	0	0	7	12	0
Mitford	13(5)	5(5)	2(0)	11(0)	5(2)	4(18)	0	0	13	14	4
Sadarghat	17(19)	3(1)	0(0)	13(0)	4(0)	3(20)	0	0	10	11	1
Swarighat	18(20)	2(0)	0(0)	14(0)	4(0)	2(20)	0	0	8	10	0

Note: *HH stands for householders, HW for housewives, AHR for Awareness about household recycling, APDS for awareness about pollution and disease spreading, SCIHR for seeking community involvement for household recycling, RI for recycling interest and WTPHRF for willingness to pay for household recycling facilities.*

Sylhet city corporation (SCC) is not at all concerned about recycling of solid waste. There are about 225 private shops in SCC; they all buy the recyclable waste from hawkers. There are many types of waste including scraps, tin, plastic etc. There are 195 retail seller and 30 whole seller involved in recycling. Table 4 shows the type and amount of recyclable waste is buying by the retail seller per day toping up iron in the level of 256 kg/day followed by tin 102 kg/day and paper 15.25 kg/day.

Table 4 Amount of recyclable waste is buying by the retail seller per day in SCC

Recyclable Material Collected	Amount (kg/day)
Iron	256
Tin	102
Paper	15.25
Plastic	3.5
Cu, Pb, Al, Zn, Gun metal.	5

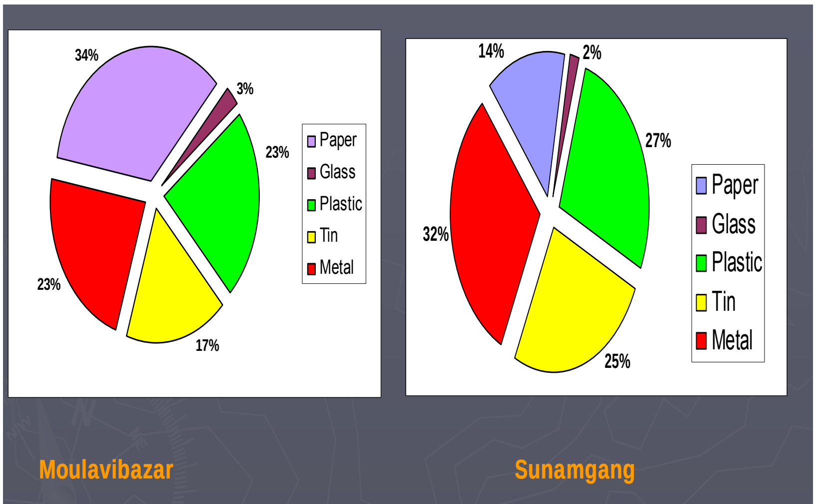

Figure 1: Comparative percentile presentation of Recycled items per day in terms of taka of two Pouroshova

Figure a: Shops handling recyclable items in Moulavibazar

Figure b: Recycling Shop in Sunamgang

Figure c: A Hawker is carrying recyclable commodities

Figure d: Recyclable materials ready for transportation

Figure 2 Recycling scenarios in Maulavibazar and Sunamganj

In spite of no effective attempts of municipal authority, recycling of solid wastes mainly paper, plastic, glass, tin, and other metal is locally available in the recent times which are collected by households and tokais in Moulavibazar and Sunamganj Paurashava. Retailer picked up the waste from them and sold to the whole-sellers that mainly goes to Dhaka. In Moulavibazar, around a turn over of 12 millions taka per year is completed from recycling and in Sunamganj, the amount dealing with recycling is almost 6.7 millions taka per year. In Maulvi Bazar Pouroshova, paper (34%) has the most economical value of recycling followed by metals (23%) and plastics (23$) while in Sunamganj, metal (32%) has the most economical value of recycling followed by plastic (27%) and tin (25%) as shown in Figure 1. Diversified scenario of recycling is Maulavibazar and Sunmamganj is depicted in Figure 2.

Additionally conducted study merged with in depth literature review reveals a number of interesting findings on recycling:

- All non-special packaging should be recycled, recyclable, and taxed to cover the cost of it's lifecycle. All special packaging anti-static packaging for electronics, sensitive food containers - should be recyclable and taxed to cover their lifecycle. And all packaging that can be made of food starch instead of oil based plastic should be required to be made out of food starch (same with other short use plastics; disposable forks).
- Virtually all materials generated on a construction site can be recycled, subject to local opportunities. Wastes must be kept clean and separated to ensure opportunities for reuse or recycling as follows:
    - Cardboard packaging can be broken down and recycled;
    - Top soil can be saved and reused on site for landscaping or sold to nurseries;
    - Metals can be recycled;
    - Carpeting can be recycled;
    - Paper from trailers and offices can be easily recycled into a fine paper bin.
- Concrete aggregate collected from demolition sites is put through a crushing machine, often along with asphalt, bricks, dirt, and rocks. Smaller pieces of concrete are used as gravel for new construction projects. Crushed recycled concrete can also be used as the dry aggregate for brand new concrete if it is free of contaminants. This reduces the need for other rocks to be dug up, which in turn saves trees and habitats (ACP, 2008).
- The arrival of recycled timber as a construction product has been important in both raising industry and consumer awareness towards deforestation and promoting timber mills to adopt more environmentally friendly practices (Rainforestinfo, 2006). Wood and timber are being popularly recycled throughout the world. In Bangladeshi cities and towns wood and timber recycling are is of very significant order.
- Lead-acid batteries, like those used in automobiles, are relatively easy to recycle and many regions have legislation requiring vendors to accept used products. In the United States, the recycling rate is 90%, with new batteries containing up to 80% recycled material (EPA, 2008).

- Kitchen, garden, and other green waste can be recycled into useful soil reconditioning materials by composting. This process allows natural aerobic bacteria to break down the waste into fertile topsoil. Much composting is done on a household scale, but municipal green-waste collection programs also exist. These programs can supplement their funding by selling the topsoil produced.
- Recycling clothes via consignment or swapping has become increasingly popular. In a clothing swap, a group of people gather at a venue to exchange clothes amongst each other. In organizations like Clothing Swap, Inc., unclaimed clothing is donated to a local charity.
- Workers sort and separate collected textiles into good quality clothing and shoes which can be reused or worn. There is a trend of moving these facilities from developed countries to developing countries either for charity or sold at a cheaper price. Many international organisations collect used textiles from developed countries as a donation to those third world countries. This recycling practise is encouraged because it helps to reduce unwanted waste while providing clothing to those in need (Salvationarmy, 2008)
- The direct disposal of electrical equipment—such as old computers and mobile phones—is banned in many areas due to the toxic contents of certain components. The recycling process works by mechanically separating the metals, plastics, and circuit boards contained in the appliance. When this is done on a large scale at an electronic waste recycling plant, component recovery can be achieved in a cost-effective manner.
- Every ton of recycled paper saves 17 forty foot high Douglas Fire trees.
- Paper takes up as much as 50% of all landfill space. The paper can be recycled by reducing it to pulp and combining it with pulp from newly harvested wood. As the recycling process causes the paper fibres to break down, each time paper is recycled its quality decreases. This means that either a higher percentage of new fibres must be added, or the paper downcycled into lower quality products. Any writing or coloration of the paper must first be removed by deinking, which also removes fillers, clays, and fibre fragments. Almost all paper can be recycled today, but some types are harder to recycle than others. Papers coated with plastic or aluminium foil, and papers that are waxed, pasted, or gummed are usually not recycled because the process is too expensive. Gift-wrap paper also cannot be recycled due to its already poor quality. Less than 1/3 of used paper is manufactured from recycled sources, and in the U.S., 99% of the virgin fiber used for paper manufacturing comes from trees(Tappi, 2008).
- Up to 90% of recycled glass can be reused to make new glass items, such as bottles and jars.
- Every glass bottle recycled saves enough energy for a 100 watt light bulb to be lit for 4 hours.
- Most bottles and jars contain at least 25% recycled glass. Glass never wears out; it can be recycled forever. We save over a ton of resources for every ton of glass recycled :1,330 pounds of sand, 433 pounds of soda ash, 433 pounds of limestone, and 151 pounds of feldspar.
- Aluminium is one of the most efficient and widely-recycled materials (Letsrecycle, 2006). Aluminium is shredded and ground into small pieces or crushed into bales. These pieces or bales are melted in an aluminium smelter to produce molten aluminium. By this stage the recycled aluminium is indistinguishable from virgin aluminium and further processing is identical for both. This process does not produce any change in the metal, so aluminium can be recycled indefinitely. Recycling aluminium saves 95% of the energy cost of processing new aluminium from raw materials. This is because the temperature necessary for melting recycled, nearly pure, aluminium is 600 °C, while to extract mined aluminium from its ore requires 900 °C. To reach this higher temperature, much more energy is needed, leading to the high environmental benefits of aluminium recycling. Energy saved from recycling one ton of aluminum is equal to the amount of electricity the average home uses over 10 years. (Economist, 2007). Americans throw away enough aluminum every year to rebuild their entire commercial air fleet. Also, the energy saved by recycling one aluminum can is enough to run a television for three hours (Waste-online, 2007).
- Recycling one aluminum can saves enough energy to run a 100-watt bulb for 20 hours, a computer for 3 hours, or a TV for 2 to 3 hours (EPA, 2008).
- Around 50% of a new aluminum can is made from recycled aluminum recently in a few Bangladeshi Aluminum industries of Dhaka and Chittagong .
- Thirty-six plastic recycled bottles can make one square yard of carpet

- 26 recycled PET bottles equals a polyester suit. 5 recycled PET bottles make enough fiberfill to stuff a ski jacket.
- In 1988, 2 billion pounds of HDPE were used just to make bottles for household products by plastic companies of UK that's about the weight of 90,000 Honda Civics (Letsrecycle, 2006).
- Recycling steel and tin cans saves 74% of the energy used to produce them. A steel mill using recycled scrap reduces related water pollution, air pollution and mining wastes by about 70%.
- Iron and steel are the world's most recycled materials, and among the easiest materials to reprocess, as they can be separated magnetically from the waste stream. Recycling is via a steelworks: scrap is either remelted in an electric arc furnace (90-100% scrap), or used as part of the charge in a Basic Oxygen Furnace (around 25% scrap) (CISC, 2006). Any grade of steel can be recycled to top quality new metal, with no 'downgrading' from prime to lower quality materials as steel is recycled repeatedly. 42% of crude steel produced is recycled material (World-Steel, 2006).
- A steel mill using recycled scrap reduces related water pollution, air pollution and mining wastes by about 70%.
- It takes half a barrel of crude oil to produce the rubber for just one truck tire. Producing one pound of recycled rubber versus one pound of new rubber requires only 29% of the energy that means saves 71% energy.
- Tire recycling is also common. Used tires can be added to asphalt for producing road surfaces or to make rubber mulch used on playgrounds for safety. They are also often used as the insulation and heat absorbing/releasing material in specially constructed homes known as earthships.
- Recycling a 1-gallon plastic milk jug will save enough energy to keep a 100-watt bulb burning for 11 hours.

Recycling instructions based on the study concentrates to:
Do

- Put all your recyclables in one container
- Wheel your recycling container out on the same days as your garbage collection before 7 a.m.
- Place your recycling container at least three feet from your garbage container and other obstructions
- Set your recycling container out only when it is at least 3/4 full

Please do not

- Do not put the following items in your curbside recycling container:
    - Glass and clothing
    - Napkins, paper towels, toilet paper
    - Food and food wrappings
    - Small appliances and yard waste
    - Hazardous waste (paint, pesticides, other chemicals)
- Do not set recyclables on the side of the recycling container or use any container other than the 90-gallon, City-issued, blue recycling container.

Home recycling tips

A significant number of respondents emphasize for home recycling as the first step of recycling activities suggesting a number of tips as follows:

- visit local recycling center & find out what materials they accept for recycling. Then set up your bins accordingly.
- put storage bins in a suitable place like garage to make a successful home recycling program.
- use plastic bags or totes to store materials for recycling. Paper bags can be leaky, and rip easily. Try to use smaller containers, as they will be easier to lift when full.
- label recycling bins to ensure materials are separated correctly.
- choose products with the highest percentage of "post-consumer" recycled content among pre-consumer (often referred to as mill scraps recycled internally at manufacturing plants) and post-consumer (returned by consumers, through recycling programs, to the manufacturing process).

- clean bottles and tins before putting in recycling bin. This prevents flies both at home and the recycling station.
- put a 'no junk mail' sticker on letter box. You'll be amazed at how much this reduces the rubbish.
- join the free-cycle movement: you give away and receive for free what you need or have but don't need and don't have. Free cycle of goods keeps lots of stuff out of landfill sites and is thinking globally and recycling locally.
- close the loop: Buy recycled materials.

Repair

Repair means minor renovation of the part or parts of any inactive plant to come into operation. The people have a tendency of throwing out goods and commodities as they break or become damaged; however there are many cases of repairing of broken goods. Study results states a lot of cases of repair of faulty and defective goods, machines, or equipments in Dolaikhal, Tongi and old town of Dhaka city, Kalurghat, Bibirhat, Pahartali of Chittagong city. Repair of machine without major cost make functional the machine in stead of sending the faulty machine to the landfill leading to the minimization of a gigantic amount of heavy solid waste. Majority of the respondents (63%) emphasizes on repair to avoid SW.

Replace

Replace means replacing of non-working parts of a plant than purchasing new plant or new equipment. Replacement of faulty or defective parts of a plant, machine or equipment with a minor cost make workable the plant, machine or equipment instead of sending the faulty or defective plant, machine or equipment to the landfill leading to the minimizing of a massive quantity of profound solid waste. Study shows that replacement is more than a financial decision which must be integrated into an organization's business planning and requires the integration of operational, mechanical and financial aspects of the decision. Replacement is also appreciated by the respondents of the study with some sort of limitations of the skill of operatives and executives to be involved in the replacement activities.

Recovery

Recovery of resource is the method of resources from another resources or sources for instance valuable chromium is recovered from industrial chrome waste like tanning industry. Heavy metals like chromium, cadmium, manganese, cobalt etc. may be recovered from industrial wastes allowing the removal of the metals from the effluents to residual concentrations as low as several ppm minimizing the risks of polluted wastes to the landfill leading to the diminution of a major amount of solid waste. Vegetable and animal oils can be often recovered and recycled to evade pollution, set aside remnant fuels and trim down greenhouse gas emissions. Major respondents (70%) of the study areas emphasized on the heavy metal recovery especially chromium from tannery waste and gold and cobalt recovery from electrical and electronic waste.

Renew

Renew of the energy is the conversion of waste-to-energy as an alternative waste management option for example bio-gas is renewed from cow-dung. Renewed biogas is used as a strong fuel for cooking as a well for lighting in the household. In the peripheral area of Chittagong cow-dung of 15 cows from family dairy are being successfully used to get cooking fuel and to generate electricity for lighting in the household in a very small or mini-scale. Landfill gas such as methane, one of the cheapest sources of non-fossil energy can be renewed to electricity by waste combustion. USA has set-up its target of getting 10% of its electricity from renewable sources by 2010. A case study conducted in the USA shows that 'any risk associated with the process of incinerating Meat and Bone Meal (MBM) for renewing energy at Glanford is less than one in 100 billion' (SWMC, 2008) .

Recharge

Recharge means revive of anything for example recharging of lead-storage battery, UPS, IPS etc. Ultra-capacitors, batteries, fuel cells, solar power, hydraulic energy, regenerators are used to recharge mobile, lights, digital camera, music players, automobile car recharger batteries, AC, UPS, IPS, and many other electronic goods that were observed during study. The transformation of an

Uninterruptible Power Supply (UPS), commonly used as low cost power backup for desktop computers into a solar rechargeable portable mains supply, almost any commercially available UPS, can be used and conversion can be made without having detailed knowledge about electronic circuits inside. Such system can be used wherever there is need for AC power with low consumption, like lighting in small isolated houses, camping, powering of small electronic devices like TV or radio transmitters etc.

Refill

Refill denotes replenish or fill-up anything for example refilling of ink in ball-pen, graphite ink in the toners of photocopier and printer of computers etc. Case study exchanges the views with a number of Ball Pen company of Dhaka like GQ Ball Pen, Matador Ball Pen, Janani Ball Pen, Writer Ball Pen etc. Findings of the exchange of view points out that pen can be refilled as follows:

- gel pen refills with good ink and ball pen with rechangeable refill ink,
- cross authentic ball point pen refills with parker type metal refill & cross type metal refill,
- ball pens made of metal, with metal refill and plastic click pen with a ball point ink refill,
- metallic ball pen with blue / black refill,
- brass made twist type ball point pen, twist part changeable, with a ball point ink refill.

One can save important raw materials, waste and energy by using laser cartridges again. A decision to reuse or refill toner rather than replace them can definitely cut down on toner cost. This is especially true once cut down on toner refills. Using a bottle of refill toner can fill cartridge as well as will save up to 87% of cost of replacing laser cartridge. It can be used often as well. It will be able to save more because of these toner refills. Normally, customers can save around 50% on the price of their printer cartridges.

One can refill fax and photocopier toner cartridges also. Just don't scrap it, restore it with fresh toner powder and it becomes easy to refill. By the recent times refilling of the ribbons of computers' printer cartridges, photo-copiers, fax machines, Xerox machines, ammonia printers, type-writers etc. are being widely used in Computer markets of Dhaka and Chittagong city.

DISCUSSIONS

Detailed study and extensive literature survey emphasizes on 10 R especially universal 4Rs refuse, reduce, reuse and recycle added by recharge, recovery and refill. Apart of refuse other 9Rs reduce, reuse, recycling, repair, replace, recovery, renew, and recharge will be predominantly influenced by garbage segregation or separation at source as follows.

Why Garbage Segregation? – There are Many, Many, Benefits

- To reduce the amount of garbage that is dumped into land fills or burned because 40 per cent of household waste is reusable or recyclable – consisting of containers and wrappers. By promoting waste segregation, we can help reduce the amount of these 40% garbage and, hence, the area of land required for their disposal.
- To help improve health and hygiene and reducing global warming since most of the garbage collected from us gets transported to landfills. While the garbage collectors themselves do some amount of segregation, a large proportion of recyclable waste to be dumped gets reduced. Subsequently source segregation prevents recyclable waste from being put into land fills.
- To save money as if the recyclable dry waste is kept separately, it means 40 per cent less garbage. Obviously about 40 per cent of the municipal budget would come down and these funds can be utilized in other ways.
- To earn money for the reason that recyclable dry waste can be sold.
- To promote Rs when we segregate garbage, we sometimes find things we would have thrown away. By using such goods repeatedly and carefully through the practice of any of Rs we tend to avoid buying unnecessary goods.

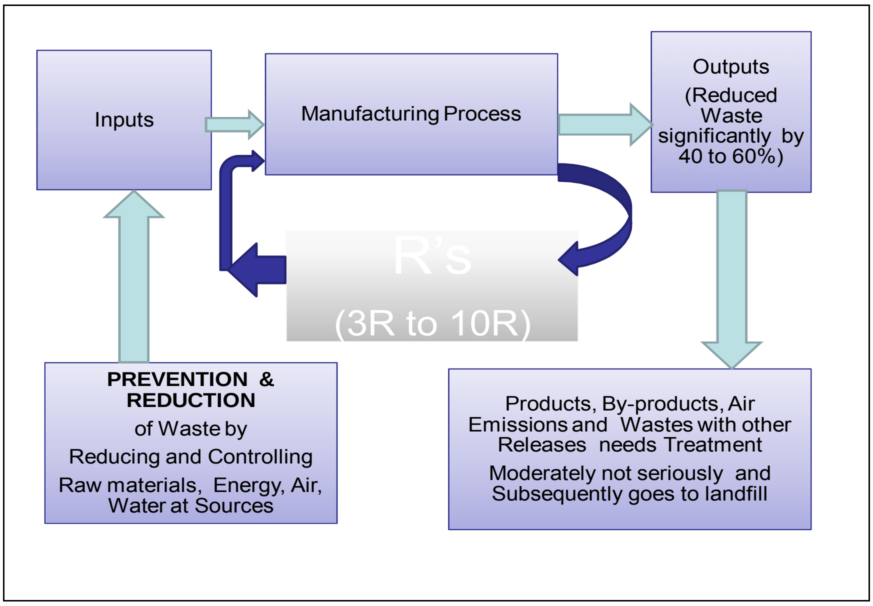

Figure 3 Roles of Rs in Waste Cycle

A manufacturing chain dominated by 10 Rs agglomerated with prevention and reduction of raw materials at source converts input to planned output by reducing waste significantly by 40 to 60% and generates products, by-products, air emissions, wastes with other releases that needs moderate treatment although not seriously leads to turn down to landfills that depicts the role of Rs in waste cycle as shown in Figure 3.

CONCLUSIONS

Conducted detailed study in Dhaka, the Capital City of Bangladesh, Sylhet, the most important Divisional City of Bangladesh, Moulvibazar and Sunamgamg, two important district towns of North-eastern Bangladesh added by the wide-ranging literature appraisal on 10 Rs such as refuse, reduce, reuse, recycling, recovery, renew, recharge, refill, repair, etc. concludes that Rs can play an imperative and essential function to trim down the solid waste intensity in the urban and semi-urban centers as well as the rural agglomeration of not only the developing countries but also the developed world. Evidently solid waste management utilities should give due considerations on the effective uses of Rs that will not drop off the titanic size of solid waste in the landfill alone, will also save the cash and kinds of the utility and publics considerably, guarantee the eco-friendly environment, sustainable community life as well as will contribute significantly to back to natural green earth once more.

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Socio-Economic Aspects of Solid Waste Management

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ABSTRACT

Now-a-days, a number of hardware and software techniques in the form of scientific technology for collection and transfer of solid waste by utilities, treatment and final disposal as well as source separation by housewives, maid-servants, householders as well as a number of R's such as refuse, reduction, return, repair, replacement, recycling, reuse, renewal of energy and resource recovery, recharge, refill are available to mitigate solid waste problems throughout the world. Unfortunately practice of technology and scientific knowledge are not able to show the fruit ripen rather leads to failure if the society does not accept it cordially; obviously social approaches and traditional social customs such as community participation/equi-community participation from gender perspectives, social mobilization, motivation, proper monitoring of solid waste activities, public awareness, solid waste education to publics, good public relationship, change of behaviors attitudes regarding SW and SWM and advocacy on SWM should be kept in mind seriously to achieve the success of ISWM. Side by side solid waste management utilities and institutions by streamlining management functions and strengthening of the institutional capacity have to be keen to their commitments through proper legislation and timely enforcement, harmonious relation with all kind of stakeholders, policy-makers and financers, donors etc. otherwise all efforts leading to ISWM will not be succeeded. In this regard, proper and adequate SWM training to staffs and executives of the utilities and institutions in a regular basis at a fixed time of interval should be kept in mind. Besides the adequate financial policies such as incentives for environment friendly measures, imposing taxes for pollution enhancing incineration and land disposal whatever the sanitary landfilling or crude dumping, subsidy for environment friendly measures like R's as well as steps for creating willingness to pay for solid disposal to the urban citizens through public-public/private-public/ private-private partnership should be taken into consideration in order to implement effective SWM. Rather proper evaluation of all kinds of measures regarding solid waste management, economic feasibility of the utilities, financial viability of the publics as well as the prototype actions by symbolic clean force or green force like scouts, rovers, girl-guides, etc. to exercise the solid waste management activities in black and white are essential for efficient SWM. Solid waste management program can not be satisfactorily completed until all sorts of necessary measures related to integrated solid waste management have been taken to ensure the in-offensive disposal of the wastes. Such kind of all socio-economic activities will be discussed in detail as much as possible in this paper.

INTRODUCTION

Life is not stationary in the personal, individual, social, national, regional and international arena, rather changes with time, with respect to social, cultural, economic, urban and industrial development altering the life style, values, norms, attitudes, behavior etc. to cope with the effects of changes of natural as well man-made activities. Human interventions degrade the natural green environment generating various types of emissions, pollutants, wastes especially solid wastes as a result of modern urbanization and industrialization leading to causal activities mostly adverse performed by both of upstream and downstream technical systems added by transport, housing etc. changing green belt to brown blocks losing the sustainability in each sectoral domain as shown in figure 1.

With the growing civilization men try to turn back to original green of nature minimizing waste as much as possible and recently to zero waste with no garbage! no throwing anything away in a pit in the ground! no burning things just to "get rid of them" (Palmer, 1966).

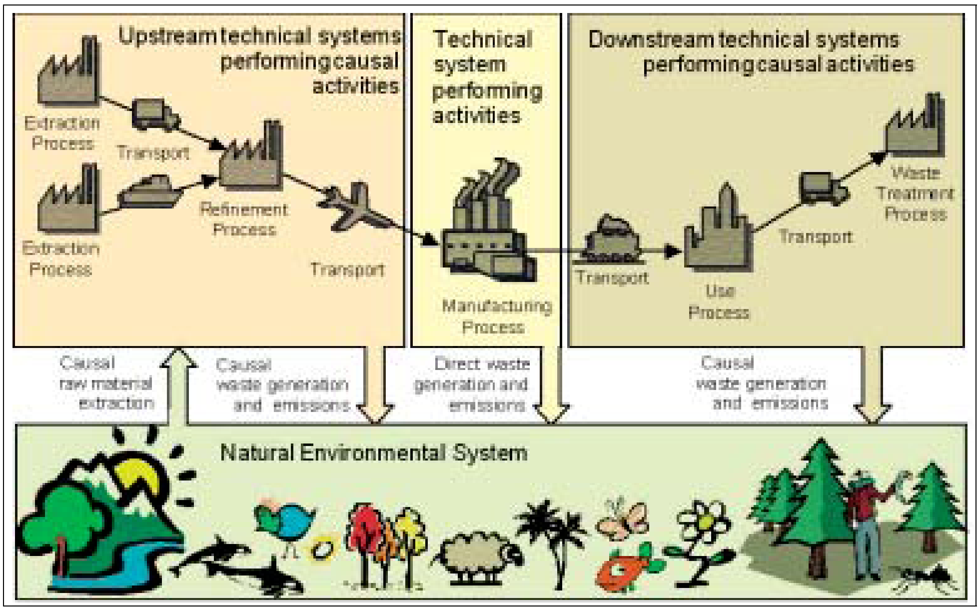

Figure 1 Modern Urbanization and Industrialization degrade natural environment

Utilities are trying to no stone unturned to minimize solid waste in the urban centers utilizing all sorts of technical measures but in vain for not taking related socio-economic factors into proper consideration. In order to assess the role of such socio-economic factors involved in solid waste management, a study has been conducted socio-economic study, questionnaire surveys, home interviews, group discussions etc.

STUDY OBSERVATIONS AND DISCUSSION

Concerned utilities of all the urban centers from small towns to mega-city tries no stone unturned to keep their jurisdiction neat and clean from garbage menace to trim down the environmental threats of civic people. They take various types of remedial measures to sort, separate, collect, store, transport, treat, and dispose the solid waste from source to final disposal site using traditional as well as improved techniques blended with modern latest technology in all functional elements (as shown in figure 2) and procedures to cope with the material society. Unfortunately peoples of the society are not always well aware of or completely ignorant about the solid waste management scenario and do not accept it cordially because of the lack of practice of advocacy, community participation/equi-community participation from gender perspectives, social mobilization, motivation, proper monitoring of solid waste management activities, public awareness, solid waste education to publics, good public relationship, change of behaviors attitudes regarding SW and SWM. Study shows that majority of the respondents have no ideas and feelings on such sort of lacking but introducing by the interviewers and surveyors of the study they are convinced that such sorts of social discrepancies should be get rid of and social commitment of the public should be established in all walks of life for effective solid waste management. Besides streamlining, reformation and restructuring of management functions as well as intensification and strengthening of the institutional capability of solid waste management utility organizations and institutions is a must that to be wholehearted and devoted to their commitments through appropriate legislation and well-timed enforcement, pleasant relation with all sort of stakeholders, policy-makers and financers, donors etc. to make successful and fruitful the overall SWM otherwise all type of attempts and efforts be in vain. In addition, the satisfactory financial and economic policies such as financial incentives in the form of grant or aid for environment friendly actions, imposing taxes for pollution creating incineration and land disposal whatever the sanitary land-filling or crude dumping, subsidy for pollution free measures like R's tending to zero waste will keep vital contributions to trim down pollution causing treatment options. Several steps for instance public-public/private-public/ private-private partnership for creating willingness to pay for solid disposal in urban citizens is a requisite to implement effective SWM. Proper evaluation of all kinds of measures regarding solid waste management, economic feasibility of the utilities, financial viability of the publics as well as the prototype actions by symbolic clean force or green force like scouts, rovers, girl-guides, etc. to exercise the solid waste management activities in black and white are indispensable for efficient SWM. Solid waste management program can not be satisfactorily completed until all sorts of such socio-economic aspects are integrated to traditional solid waste management to ensure the in-offensive disposal of the wastes. Let us give the attention to such socio-economic factors how they influence and affect the functional elements of solid waste management in the urban centers enhancing the significant minimization of solid waste reducing environmental degradation leading to sustainable SWM.

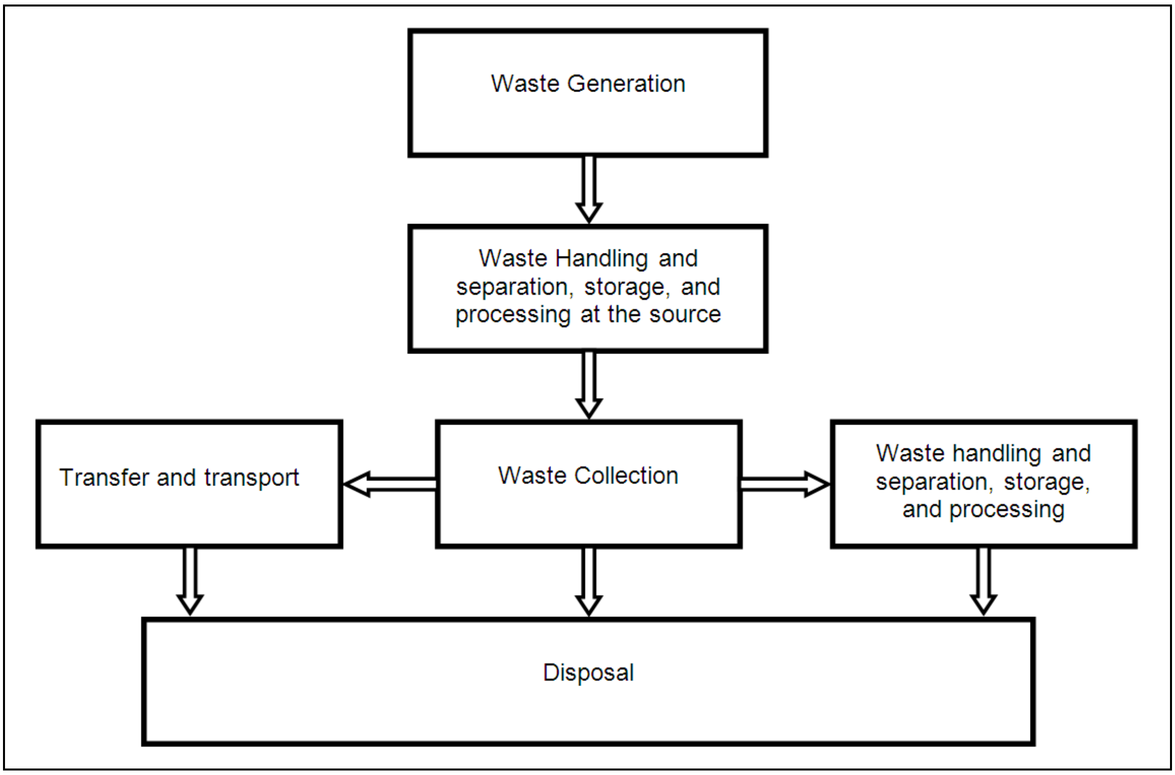

Figure 2 Functional Elements Comprising a Solid Waste Management

Advocacy on SW and SWM

Advocacy is a process of gathering, organizing and formulating information into argument, to be communicated through various interpersonal and media channels to political and social leaders with a view to gaining their commitment to and active support of a development programmed; it is the main tool to mobilize politicians and other partners. Advocacy is speaking up, drawing attention to an issue, winning the support of key constituencies in order to influence policies and spending, and bring about change success. Advocacy usually starts by identifying the people they need to influence and planning the best ways to communicate with them. An advocate plays a vital role to organize and formulate information into argument in the law court in favor of his client and establishes his right from the view point of legal aspects complying with existing laws, rules and regulations as well as they works to mobilize politicians and other partners. They do their homework on an issue and build a persuasive case. They organize networks and coalitions to create a groundswell support that can influence key decision-makers. They work with the media to help communicate the message. The objective of an advocacy is to raise awareness and convince others of the need to take action.

In the same way advocacy program on SW and SWM reflecting its various aspects including ABC of SW will make aware of the general publics of the urban centers and they will be accustomed of the practice of the functional elements of the SWM properly by the course of time.

Community Participation/Equi-Community Participation from Gender Perspectives

Participation refers to the process through which stakeholders (consumers, beneficiaries, users etc.) influence and share the control over of development initiatives, decisions and resources involved in development activities etc. that affect them which is nothing but a voluntary process by which people, including the deprived (in income, gender/sex, social status, age, ethnicity, or education), influence or control the decisions that affect them. The fundamental nature of participation is exercising respective voice and choice. Community participation can be loosely defined as the involvement of people in a community in projects to solve their own problems. People cannot be forced to participate in which affect their lives but should be given the opportunity where possible. Equi-community participation refers to the equal participation and involvement of people from all walks of life in the community ranging from men, women, children, boys, girls, youths, elderly, disabled etc. living in the society irrespective of cast, race and gender in all kind of activities, actions and works. Community participation is especially important in emergency programs where people may be unaccustomed to their surroundings and new facilities. Beneficiary equi-community participation can be brought about in several ways:

- directly,
- through participation in decision making;
- indirectly,
- through leaders; or
- through representation of committees or boards.

Since equitable share of benefits is essential, equi-community participation can be presented by involvement of the local population actively in the decision-making concerning of development activities, projects or in their implementation.

The evaluation of the study reveals that equi-community participation is necessary for performing the development activities and managing the utility services especially in the SWM for:

- accomplishing more actions;
- providing services more cheaply;
- achieving an intrinsic value for participants;
- enhancing further development;
- encouraging a sense of responsibility to all father, mother, children, daughter, daughter in-law, son, grand parents, grand sons, servants and servants of a family;
- guaranty that a felt need is involved;
- ensuring that things are done the right way;
- using valuable indigenous knowledge;
- making people free from dependence on other's skills;
- making people more conscious of the cause of their poverty and what they can do.

The study conducted in Gulshan-Baridhara, Dhanmandi-Kalabagan, Azimpur-Palashy, Lalbag-Chawakbazar, slum areas of Kamrangichar of Dhaka city; Kulshi, Jamal Khan, Pahartali and slum areas of Kalurghat of Chittagong city, Shahjalal Upashar, Housing estate, Akhali and slum areas of South Surma of Sylhet city justified the role of equi-participation in SWM. In Gulshan-Baridhara of Dhaka city and Kulshi area of Chittagong city, where all family members are well-educated, equally conscious about the adverse impacts of solid waste and responsible, solid waste management is more systematic in the available functional elements such as sorting and separation through different colored bag or container for different wastes like food waste, paper, containers etc., streets are comparatively more cleaner than other areas of Dhaka city, utility crews of SWM wing of DCC are also regular and paying special attention to SWM locally. In Dhanmandhi-Kalabagan of Dhaka city, Jamal Khan of Chittagong city and Shahjalal Upashahar and Hosing estate of Sylhet city where local people from all walks of life are well aware of SW and equally participate in SWM activities specially by the initiatives of local community based organization to collect solid waste through community vans and tri-cyclers from door to door, solid waste collection intensity is the highest in the level of 95 to 100% in Dhaka city. Utilization of Rs specially refuse, reduce, reuse and recycle is very impressive. In Azimpur-Palashy area of Dhaka city, Pahatali of Chittagong city, Akhali of Sylhet city where the participation in the functional elements of SWM of all family members and people from all walks of life working hard for better life is not so intense due to ordinary economic status, and solid waste collection efficiency is in moderate level of 40 to 60% due to non involvement of local initiatives of CBOs. In slum areas of three cities, SWM status is very poor due to lack of community participation and local initiatives of CBOs.

The study also reveals that equi-community participation regarding SWM can be successfully and effectively happened through

- consultation with the community,
- financial contribution of the community,
- self-help activities by beneficiary groups,
- involvement of the whole community in self-help projects, programs and activities,
- community based specialized working groups,
- mass action,
- collective commitment to change the customs and behavior,
- endogenous development,
- autonomous community projects and programs,
- self-sufficiency approaches etc.

According to the view of the respondents people are usually willing to participate in SWM program for the following reasons:

- community participation motivates people to work together;
- people feel a sense community and recognize the benefits of their involvement;
- social, religious or traditional obligations for mutual help;
- people see a genuine opportunity to better their own lives and for the community as a whole;
- remuneration in cash or kind

Community participation can contribute greatly to the effectiveness and efficiency of a SWM program; the crucial factor in its success is the attitude of agency and utility staff in the field. If the staff do not treat people with respect or are seen to favor particular individuals or groups within a community, this can have a highly destructive effect on participation. For this reason, it is important to identify key representatives and groups to be involved in all of the functional elements of SWM within the affected population early to ensure the SWM properly.

Social Mobilization

- In order to improve any utility system of a community such as SWM whatever in urban or rural areas mobilization is felt essential and fruitful especially in developing countries where majority of the people are illiterate or not highly educated. For strengthening mobilization advocacy for SWM can be play a vital role.
- Members of the community who are the users of any utility services are not always well aware of the facilities due to the ignorance. As a result, facilities are not used, maintained and operated properly or misused and they are not ready to pay for the facilities. Even they are not ready to use such facilities in spite of distributing to them with subsidy or free cost. As a result health safety of the community is in the verge of serious risk. To change the situation, mobilization to all walks of life has to be initiated in a planned way. Social mobilization for SWM improvement can be performed to:
- users of the facility,
- housewives,
- the children,
- the teachers as they can motivate their students,
- the elites of the society to motivate general publics,
- the community leaders to motivate to their dependants,
- the Imam and other religious leaders,
- union Council members to motivate the inhabitants of their jurisdiction,
- scouts, girl guides etc. to motivate the young forces of the society,
- ansars and Village defense party members etc.
- As a result of the social mobilization to all wings of the society the following positive results on SWM system of urban areas are obvious:
- a remarkable increase of sorting and separation practices of SW in the household in the social mobilization intervention areas,
- a marked improvement of proper SW storage practice and collection specially by CBOs in the in the urban areas,
- a significant increase of practice of Rs specially refuse, reduce, reuse, recycle, recovery and renew leading to considerable improvement of SWM to all walks of life in the urban centers,

- growing awareness about SWM to the householders as well as housewives,
- growing willingness to pay to all to improve SWM status in the urban areas,
- a substantial improvement in the health awareness of people regarding SW and SWM at community level.

Motivation

- Motivation program on SW and SWM to improve of SWM status in a few selected areas of old Dhaka involving NGOs and CBOs through JICA project resulted in a few positive impacts
- an amazing change in sorting and separation of SW in the household level,
- a noticeable progress in storage and collection system of SW specially by the efforts of CBOs and NGOs,
- a major increase in practice of Rs such as refuse, reduce, reuse, recycle, recovery, recharge, replacement, repair and renew leading to substantial advance of SWM to all walks of life specially increasing the recycle, recovery, replacement and repair of faulty and defective machines, equipments and industrial components,
- increasing awareness about adverse impacts of SW and SWM practices to the housewives, servants, maid-servants etc.,
- rising willingness to pay to the urban publics to recover SWM expenditure of the utility from own source without depending on the donors,
- an ample enhancement in public health awareness of people regarding SW and SWM at the public level.

Enhancing Public Awareness

Public awareness will effectively enhance the publics to the best use of SWM activities. While public awareness about Rs for instance recycling is improving, many people attending special events tend to toss trash in the nearest container or on the ground. One can create opportunities for participants to recycle at the event by providing containers that are:

- Colorful and eye-catching or markedly different from trash containers
- Clearly labeled for recycling
- Placed near trash containers to avoid trash being deposited in recycling container
- Made with a small opening for recyclables only
- Anchored and locked securely
- Monitored and serviced frequently to prevent contamination and scavenging
- Closed the loop! Remembering not truly completing the recycling process until one bought products made from recycled material and used products that could be recycled
- Purchasing recycling containers made with recycled materials
- Printing event letters, brochures, posters and other advertising materials on recycled paper
- Using paper products such as napkins and bags made from recycled material.

Monitoring of Solid Waste Activities

Solid waste management activities of a utility comprising the functional elements need the continuous monitoring to assess SWM status. Proper monitoring improves the status of the functional elements of SWM as shown in figure 2. Waste generation at source is closely looked for sorting into different component to separate the waste distinctly at the household by housewives, servants and maid-servants. Housewives sell the waste of market values like paper, can, bottles, cloths, shoes, aluminum etc. to the retailers who are out of the utility statistics. If such activities of Rs are not monitored properly, solid waste collection rate will not be counted properly. Conducted study emphasized on regular monitoring of SWM status in each of the functional elements of SWM.

Solid Waste Education to Publics and Adequate Training to Utility People

In urban centers, especially in the slum areas and old part of the cities, publics are not properly aware of SW and SWM. To handle the solid waste accurately, there is no alternative than providing proper education to the public and to train up the utility peoples who handle SWM. Solid waste management should be included in the course curricula of the school education as to deliver the fundamental and preliminary knowledge of SWM to the publics of all walks of life of the society. Proper and adequate SWM training to staffs and executives of the utilities and institutions in a regular basis at a fixed time of interval will be helpful to increase their capability and work efficiency. Short term to long term training on SWM should be organized for utility people to train up them properly on SWM as they can handle the emerging SWM of the urban centers successfully and efficiently.

Harmonious Public Relationship

For the improvement of the services of any utility, good and harmonious public relation is essential and most significant. If the people does not have idea about the services of the utility, characteristics and quality of the services, input and output of the services, economic and financial benefits of the services, positive environmental impacts of the services, health impact of the services wishing to be better than past, they will not show their interest to the services; to do this, utility present their services to the publics with a good public relation in such a way that community gets a clear overview of the services, always takes service mechanism of the utility very positively. Specially well-managed collection facilities with designated collection route of the utility, well planned storage facilities in the form of dustbins or transfer stations whatever be the on-site or off-site and transport services whatever be the motorized or non-motorized if prompt and in the reach of the publics with routinely time-schedule with harmonious public relation attracts the attention of the publics and influences them positively to come forward and contribute significantly in the SWM activities of the utility leading to considerable minimization of solid waste pollution impact at urban centers.

Streamlining Management Functions

Management function of any utility is the main backbone to implement its utility functions to achieve its objectives and goals. Effective management functions when streamlined by the special care and firm concern of the executives and higher hierarchy of the top authority accelerates the utility organizations sharply and stridently to pull off the best fruits and attain the highest efficacy to ripen the wishes of the consumers and publics. In study areas, streamlining management functions of DCC and CCC significantly improves the efficiency and work competence significantly specially in collection system and composting to some extent that opens a new door of involving CBOs and NGOs through diversified local initiatives of Public-Private partnership. In DCC, Matuail sanitary landfill is an ideal example of streamlining management function through proper engineering knowledge, intellect and intelligence of the technical executives of DCC that establishes that streamlining management is one of the main catalysts for effectual and competent SWM.

Legislation and enforcement

Laws and legislation gives the opportunity to keep the publics and utility workforce in the right track for implementing the utility functions and to make the beneficent for getting the best output. Without laws and proper legislation, publics especially rowdy ones are not always complying with the compliances of the utility and services. Every utility has the byelaws, standards, regulations and directives related to the utility services that must be maintained by the utility to ensure the quality of the services. Legal authority like Department of Environment monitors the activities and prevailing standard of the services of the utilities time to time; if finds any discrepancy with the standard, takes legal action by the help of law enforcing agency.

Pleasant Relation with Stakeholders

Pleasant relation with all kind of stakeholders related to the utility services, policy-makers and financers, donors etc. are essential to make the utility services progressive, up-to-date, uninterrupted, continuous, incessant, and a developed one. Without proper policy and lack of decision making hampers the growing movement, suppress the constant motion of the utility services and even stop the slow motion of the utility services. If the policy maker denies the decision of the utility, nothing can be implemented. In the same way without funding, no development projects of the utility can be implemented. If utility fails to maintain good relation with the funding agencies, on going projects can be interrupted or totally stopped at any time without any reason.

Financial and Economic Policies

Proper financial and economic policy of the government department is a lead agent to any kind of utility services facilitated for the wellbeing of the publics. Government takes either positive or encouraging economic policy to accelerate the utility services in the form of financial contribution to the utility; in the same way government may take restricted economic policy to some extent by imposing levies and dues.

Grant/aid/incentives/tax deduction

Grant or aid is supported to the development projects of the utility by donors and international financers to improve the utility services. Donors are basically interested in solid waste collection projects mainly run by CBOs, NGOs etc., in the treatment projects or waste disposal projects like sanitary land-filling are not always in the Rs projects, organic composting project; animal feeding, vermiculture etc.; in that case government might allocate the adequate fund to naturally oriented waste disposal projects and provide incentives to the recyclers and Rs project. Incentives may be provided for both waste consumers and waste producers to change their behavior leading to the waste minimization significantly. Many countries have some sort of incentives for both waste consumers and waste producers to change their behavior to offset the cost of waste disposal and to encourage waste prevention, re-use and recycling. One country that has such incentives is the Netherlands (VROM[1], 1998). A standard mechanism uses tax deductions to stimulate solid waste management granted to companies using recycled materials; for example In Poland, income tax is reduced by 5% for companies buying glass packaging and recycled materials (except precious metals), and the sale of products regenerated or manufactured from recycled materials is exempted from turnover tax (Jurasz, 1998, 1999).

Imposing taxes

To change the status of SWM positively different type of taxes such as green tax, waste tax, landfill fees etc. are imposed by the government.

Green Taxes

"Green taxes" are market-based instruments that aim to encourage environmentally responsible behavior. Green taxes are particularly effective instruments for:

- correcting false pricing signals in the market by internalizing externalities—that is, the incorporation of the social and environmental costs into the price of a product;
- raising revenue which may be used for environmental expenditures and/or to reduce taxes on labor, capital and savings;
- tackling "diffuse" pollution sources, such as waste.

Green taxes can be classified into three categories according to their main policy objectives:

- ❖ Cost covering charges are designed to cover the cost of environmental services and abatement measures, such as waste collection and recycling.
- ❖ Incentive taxes are designed to change the behaviour of producers and/or consumers.
- ❖ Fiscal environmental taxes are designed primarily to raise revenue.

There are examples of both cost covering charges (waste taxes and disposal fees) and incentive taxes (product taxes and material taxes) that have been applied to major appliances.

Waste Taxes

Many countries have some sort of waste tax to offset the cost of waste disposal and to encourage waste prevention, re-use and recycling. One country that has such a tax is the Netherlands. The Dutch Waste Tax entered into force on January 1, 1995 as a part of the *Act on Taxes with an Environmental Base*. It was expected that the increase in the costs of landfilling would make waste prevention, recycling and incineration more preferable. The waste tax is levied on waste that is delivered to landfills and is calculated on the basis of the weight of the waste. The tariff for landfilling is approximately 30 guilders (NLG) (AUD 22) for noncombustible waste, and NLG 60 (AUD 45) for combustible waste. The proprietor of an establishment where waste matter is delivered for processing is liable forthe waste tax. Normally, they will pass the tax on to the suppliers of the waste. In some cases the waste delivered consists of refuse collected by the municipalities. These municipalities can pass the cost increase on to their citizens by raising the local waste disposal charge. The waste tax does generally not distinguish between different kinds of waste. Whilst there may be environmental reasons to use a differentiated tariff for different waste streams, it was decided not to do that for practical reasons. For some waste streams, however, there are special provisions in the Act. For example, vegetable, fruit and garden waste, which is delivered separately to a landfill, is not taxed. Additionally, non-purifiable polluted dredging sludge and soil, de-inking residue (taxing this would make paper recycling more expensive than the alternative, thus stimulating the use of primary material), and asbestos are not taxed. In June 1997, the government sent an evaluation report on taxes with an environmental basis to the parliament. Although it was not possible to give quantitative data about the environmental effects of the waste tax because of the short period of experience, it was found that the waste tax has contributed to the desired shift from dumping to prevention, recycling and incineration. Important negative effects or economic problems were not found (VROM[2], 1998; VROM, 1999). The use of waste taxes is already widespread in Australia, although not in areas that have unmanned landfills. This may contribute to the relatively high proportion of appliances that are recovered and recycled. However, these taxes are not always high enough to discourage landfilling (such as in Tasmania), and greater harmonization at a regional, state or even national level may reduce the incidence of appliances being transferred to places where it is cheaper to discard them (Umweltforum, 2001). Waste taxes have some constraints too. General disadvantages of waste taxes include:

- they can encourage illegal dumping.
- they focus on what happens to waste after it has been created, rather than directly promoting waste avoidance.

Disposal Fees

Disposal fees are similar to waste taxes, but they are imposed on discrete products rather than on the general waste stream. Disposal fees are designed to cover the cost of treating and disposing end-of-life products. Disposal fees are usually imposed on consumers. They may also be imposed "upstream" (on manufacturers, importers or distributors) and then passed on to consumers.
There are two types of disposal fees:

- direct disposal fees and
- advance disposal fees.

Direct disposal fees are fees charged at the time of disposal. If the fee is too high, it can deter consumers from returning products to allocated collection points or waste handlers.
Advance disposal fees are disposal fees that are paid at the time of product purchase (or earlier if the fee is imposed on producers and then passed on to consumers). Advance disposal fees are based on estimates of how much it will cost to collect, treat and dispose of a product when it reaches the end of its useful life. The fee may be fully or partially refunded when the product is "appropriately" disposed of. In Austria, an advance disposal fee for refrigerators, washing machines, clothes dryers, dishwashers, stoves and other major appliances, has been voluntarily adopted by the private sector to assist in covering the cost of end-of-life treatment. The fee is ATS 100 (AUD 12) and is not refunded at the time of disposal (OECD, 1999).

The main disadvantage of an advance disposal fee is that it can be difficult to estimate end of-life treatment costs when a product is produced or sold, particularly for products such as appliances that have a relatively long life span. In addition, the administration requirements for take-back systems with advance disposal fees (particularly deposit-refund systems) can be onerous. Nevertheless, when refunded at the time of disposal, advance disposal fees can provide a strong incentive for consumers to return used appliances.

Charges for waste landfilling should be left at the disposal of the local authorities (rural or urban municipalities) responsible for the system of collection and disposal of municipal waste. The system's users should finance enterprises dealing with waste collection and landfill maintenance. It is a welcome fact that in many Polish cities, private enterprises of this type are being established offering services at a lower cost and higher standard, thus breaking the monopoly that municipal waste collection enterprises have had so far (Jurasz, 1998, 1999).

Willingness to Pay (WTP)

According to European Environment Agency (EEA) Willingness to pay (WTP) is defined as "the amount an individual is willing to pay to acquire some good or services; this may be elicited from stated or revealed preference approaches". According to Wikipedia Willingness to pay (WTP) generally refers to the value of a good to a person as what they are willing to pay, sacrifice or exchange for it (Tsi et al., 2008). WTP is the maximum monetary amount that an individual would pay to obtain a good or services. The willingness to pay is influenced by different factors as cited below.

Perceived benefits of a new facility. Where the users perceive that new facilities provide a service level that is much higher than the existing supply they will be more enthused to pay a higher contribution. This is particularly the case if they are not satisfied with their present service level. The preparedness to pay will also be higher if the users feel that the possible cost are low in comparison with other communal services such as electricity supply or education. Agencies and communities may not share the same perception of benefits. The same differences may also exist within communities.

Level of income. Communities with low incomes and low ability to pay are less willing to pay for improved services because they need their financial resources for other basic needs such as food, health care, education and shelter.

Perception of ownership and understanding. Involving the users from the start of a project in a transparent way helps to increase their willingness to pay. It will clarify for them the contributions that are being provided by different actors including the government and the expected contribution of the users. A higher degree of community autonomy over services may also be positive as a sense of ownership often encourages responsibility and pride.

Conducted study emphasizes on enhancement of effective motivation on WTP to be SWM more fruitful in urban centers

Clean force/ green force

Like boy-scout, girls-guide, rover-scout, red-cross, red-crescent, clean force or green force can be formed in urban centers to motivate, mobilizes and practically show the practice of solid waste collection from the roads, streets, footpaths, markets, open space etc. They can also set the good examples in favor of SWM being dedicated to the clean world and green environment.

Apart of all these elaborated socioeconomic factors, behaviors, attitudes etc. also affect on SWM practices significantly.

Thus all kind of such socio-economic aspects are the predominant organs of the SWM to minimize SW waste significantly, effectively and efficiently as shown in figure 3 lead to sustainable development in order to the ultimate target of zero waste to back to green nature again.

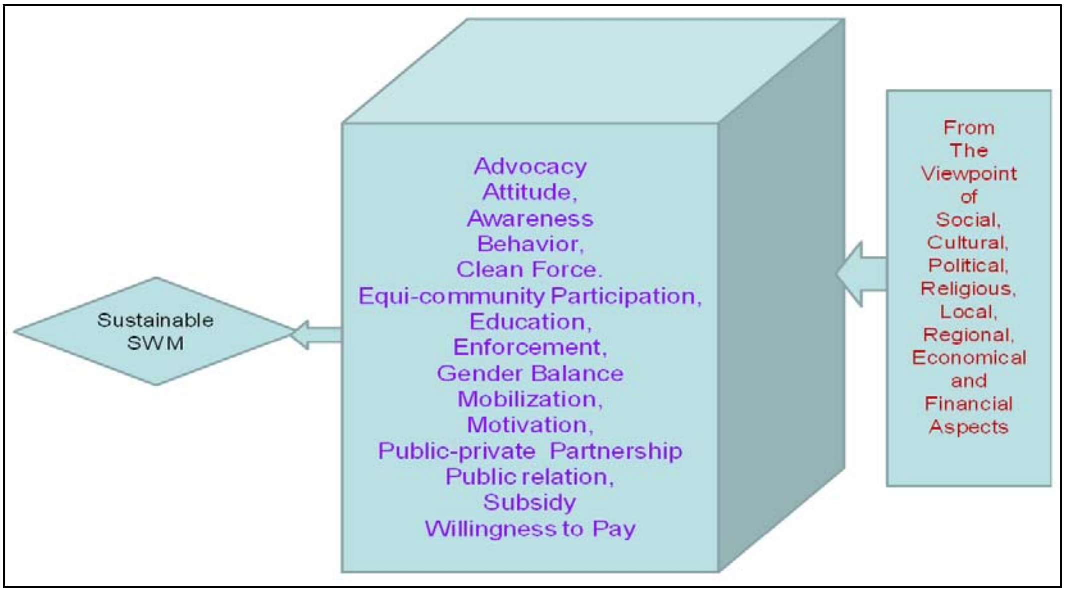

Figure 3 Socio-economic and cultural factors to sustainable SWM

CONCLUSIONS

Hereafter, efforts will be promoted to expand the traditional solid waste management system based on the discharging person's responsibility and extended producer responsibility (EPR), prevent illegal dumping, establish a system to regulate it and restore the original state, appropriately utilize economic instruments to encourage self-managed actions of each entity, rationalize procedures of all sorts, and so on. In such businesses, citizens, nonprofit organizations (NPOs), nongovernmental organizations (NGOs), business organizations and the like will work in cooperation with each other and play their respective roles, aiming high and actively making an effort to establish a sound material-cycle society. With activities of these various entities being well conducted, by around a fixed frame of year span, a sound material-cycle society represented by the pollution free zero waste image will be established, and the public at the present time and in the future will be able to enjoy healthy and cultured lifestyles.

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Solid Waste Management Situation in Sylhet City

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ABSTRACT

Bangladesh is now faced a huge number of growing unmanageable population bomb and a significant number of the population is migrated from rural to urban cities each year. This migration is creating unplanned urbanization and slum development that produces a lot of unmanageable quantities of solid waste in all major cities of Bangladesh and Sylhet is one of them. Municipal solid waste management is a serious environmental hazard and social problem in Sylhet. Currently a gigantic volume of solid waste (336 tones in 2006 and estimated 420 ton in 2008) is generated every day in Sylhet city and unfortunately solid waste management is being deteriorated day by day due to the limited resources to handle the increasing rate of generated waste. In order to assess the deteriorated waste management situation a detailed survey in SCC has been done in this study. The major lacking as identified by the study is awareness programs and programs simulating attitudinal and behavioral changes regarding solid waste management among the public that were never been practiced in the past year. The conducted study showed the deteriorated situation of SWM in Sylhet City Corporation. Waste generation rate is being increased due to the lack of public awareness, haphazard urbanization, introduction of environmentally unfriendly materials, and changing consumption patterns of people. Solid waste of SCC dumping sites contains adequate organic matter (82.36%) showing the potentiality for organic composting. The waste generation rate of SCC in the year 2006 is 0.48 (kg/cap/day) producing around 336 tones of wastes of which only 42% (140 tones) of wastes are disposed to the dumping site while about 58% (196 tones) of total wastes generated are put and thrown to roadsides, footpaths, open drains, open spaces and low lying areas etc. Clogs and encroachment of the drainage system with garbage and gigantic volume of solid refuse cause sever environmental degradation.

INTRODUCTION

The major sources of solid waste pollution in Sylhet City are the residences, streets, market places, commercial establishments, hotels, restaurants, hospital, clinics, outdoor clinics, diagnostic center etc. Currently around 400 tons of solid wastes are generated in every day within the Sylhet City Corporation area. Traditional concepts and technologies to collect waste is becoming insufficient and ineffective causing more than half of the generated wastes (44%) remain uncollected and disposed of locally. Unregulated and unhygienic management of solid waste results in adverse impacts like air pollution, surface and ground water contamination, drainage congestion, attraction of disease-carrying insects and finally, the degradation of the overall urban environment of Sylhet City. In order to assess the deteriorating status of solid waste management in Sylhet city a study based on the detailed survey and investigation work was conducted municipal wards 01, 02, 07, 09 and 14 of SCC during 2006-2007 by Civil and Environmental Engineering Department of Shahjalal University of Science and Technology, Sylhet (Saleem and Hossaen 2007).

RESULTS OF THE STUDY

Study results of solid waste management situation of Sylhet city are summed in the following sections.

Waste Generation

Waste generation in Sylhet city is being increased continuously from 1991 with a waste generation rate of 0.4 kg/capita/day to 0.5 kg/capita/day in 2008 due to the lack of public awareness, haphazard urbanization, introduction of environmentally unfriendly materials, and changing consumption patterns of city people. Waste generation of Sylhet City Corporation area with respect to population is given in the Table 1.

Table1 Population and waste generation in different year

Year	Source	Population	Waste generation rate (kg/capita/day)	Waste Generated (ton/day)	Waste Generated (ton/year)
1991	Regional Statistical Office (2007)	95261	0.4	38	13870
1993	Final report, Water System Leak Detection, LGED, (1993)	110000	0.4	53	19345
2005	Regional Statistical Office (2007)	263197	0.48	127	46173
2002	Haque & Hasan. (2002)	500000	0.48	240	87600
2005	Jubaer & Jahan. (2005)	600000	0.48	288	105120
2006	Islam & Muntaha. (2006)	700000	0.48	336	122640
2008	Estimated by Authors (2008)	840000	0.5	420	1533000

Based on the above population and waste generation facts from 1991 to 2006, population and waste generation of Sylhet city were estimated and predicted by best fitting curve assuming domestic waste generation rate of 10% per year as shown in Figure 1.

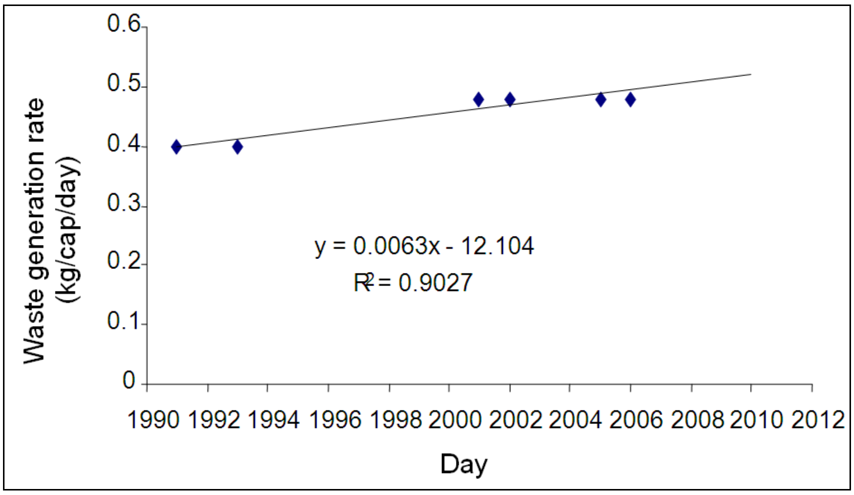

Figure 1 Population vs. waste generation of SCC

Based on the above best fitting curve, the estimated population, average daily waste generation rate, estimated amount of domestic waste generation, commercial waste generation, institutional waste generation, street waste generation, total waste generation per day of Sylhet city for the year 2007, 2008 and 2010 is summarized in Table 2.Based on the generated waste of 336 ton/day as estimated for 2006, the study was being majorly concentrated.

Waste Composition

Solid waste generated in urban areas like Sylhet city is mainly classified to organic and inorganic waste. Inorganic waste includes both of hazardous and non-hazardous waste. Composition statistics of solid waste collected from households of municipal wards 01, 02, 07, 09 and 14 of SCC is cited in table 3. On the basis of the waste collected from these five administrative wards of SCC, on average 84.5% collected waste is organic and 15.5% is in-organic of which 13.47% is non hazardous and 2.08 % is hazardous that are mainly comes from hospitals, clinics and diagnostic centers (Faroque, 2005).

Table 2 Waste generation estimation for SCC

YEAR	2007	2008	2010	UNITS
Estimated Population[1]	790000	840000	1191000	Lacks
Average daily waste generation rate[2]	0.49	0.50	0.52	Kg/cap/day
Estimated total domestic waste generation	387	420	619	Ton/day
Commercial waste[3]	38.7	42	61.9	Ton/day
Institutional Waste[3]	38.7	42	61.9	Ton/day
Street waste[3]	38.7	42	61.9	Ton/day
Estimated total waste generation	503	546	895	Ton/day

Notes: 1 & 2: Prediction from the best-fitted curve of the previous yearly population and previous yearly waste generation. 3. Assumed 10% of Domestic Waste Generation.

Table 3 Household waste composition of different Wards of SCC.

Serial no	Waste type		% of different types of waste within the selected wards.					Avg. %
			Ward-01	Ward-02	Ward-07	Ward-09	Ward-14	
01	Organic		89.24	75.70	80.46	89.33	87.59	84.46
02	Inorganic	Non-hazardous	9.00	22.89	15.73	9.10	10.60	13.47
		Hazardous	1.76	1.41	3.81	1.57	1.81	2.07

But the waste composition figure of SCC for the year 2006 based on the analysis of waste of the SCC dumping site indicates that almost 82.36% (food & nutrient) of the waste generated in Sylhet City Corporation is organic (food & nutrient) which is slightly varied from 84.46% (2.10% less) ward-wise composition of 5 wards. Paper (5.98%) and plastic (5.27%) is other two important constituent of the municipal solid waste stream of SCC as shown in Figure 2.

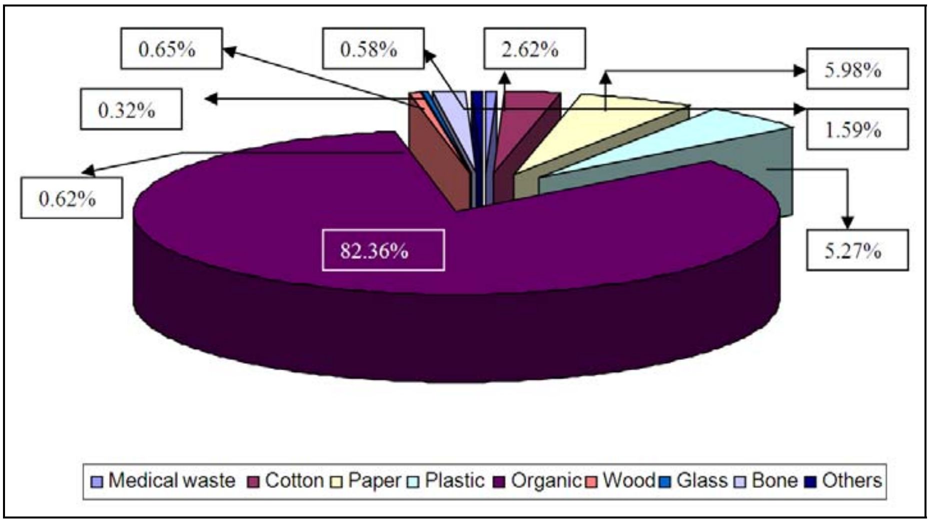

Figure 2 Waste composition of SCC 2006 of dumping site

Waste Collection

Both of the primary and secondary collection systems are practiced in Sylhet City Corporation area. City Corporation as well as CBOs and NGOs are involved in the collection of waste generated in the City using handcarts, tri-cycles, tractor and trucks for different activities. The most prominent organization is the SCC. The Table 4 summarizes different bodies involved in the collection process.

Table 4 Actors involved in waste collection process

Activity	Equipment in use	Implementation Body		
		CBOs	City Corporation	NGO's
Primary Collection	Handcart		√	
	Tri-Cycle	√	√	√
Secondary Collection	Tractor		√	
	Truck		√	

Table 5 Participation of different NGOs is in solid waste's primary collection of SCC

Parameters	Name of the ngo's		
	SP	SSK	AYA
No. of van	15	5	9
No. of wards covered	9	3	6
No. of households covered by each van	120 to 150	50	33
Collection areas and storage point	Rikabi bazaar, Upashahar.	Rikabi bazaar	Rikabi bazaar, Shibganj point, Mirabazar, Near 19 no. wards commissioner's office.
Total no. of workers for waste collection	10	4	9
Size of each van	4.5*2.5*3.25	4.5*2.5*3.25	4.5*2.5*3.25
Amount of waste collected (Tons)	10.22	3.41	6.21
Total amount of waste collected by NGO's (Tons)		19.75	

Apart of SCC, several organizations are involved in the collection of waste generated in the Sylhet City Corporation (SCC). In the last decade, there has been a substantial increase in the number of solid waste management organization, other than SCC. These organizations are Community Based Organization (Youth Clubs) and NGOs (Non-governmental organization) who are involved in small quantity of primary collection. Three major NGOs Sylhet Partnership (SP), SSK and AYA are active in collection of solid waste in SCC area collecting 19.75 tons of waste per day. Participation of NGOs in solid waste collection of SCC areas is shown in Table 5.

In Sylhet city, 60 to 70 CBOs (Youth Organizations) such as Vatalia jubo Shongho, Modhushohid shomaj kollan shongstha, Nurani, Dishari, Kajitula shomaj kollan shongstha etc. collect some parts of solid waste of SCC. They collect the waste with van as the others do. They collect about around 11 tons waste per day in SCC areas.

SCC collects about 170 to 180 tons of solid waste with their 17 trucks by 30 to 40 trips per day that carries to dumping site by SCC crews that include 157 sweeper, 14 supervisors and 28 drivers. About 200 to 210 tons waste remain collected every day in SCC areas. Totally 21 dustbins are used to store solid wastes by households and other users from where SCC fleets collect the waste daily. Percentile statistics of solid waste collection by different agencies is given in Figure 2.

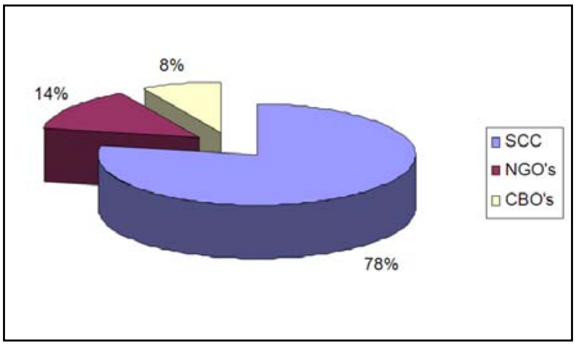

Figure 2 Solid waste collection of SCC by different agency

The wastes from the SCC dustbins and roadsides are swept and piled up into heaps in a specific place and from primary collection that are then loaded into the transportation truck. Then loaded wastes are transported to the final dumping site (Lalmatia) following the designated collection route of SCC as shown in figure 3 within 6 to 7AM and 8 to 10 PM. In this time, about 17 trucks are involved in transportation and 30 – 40 no. of trips per day.

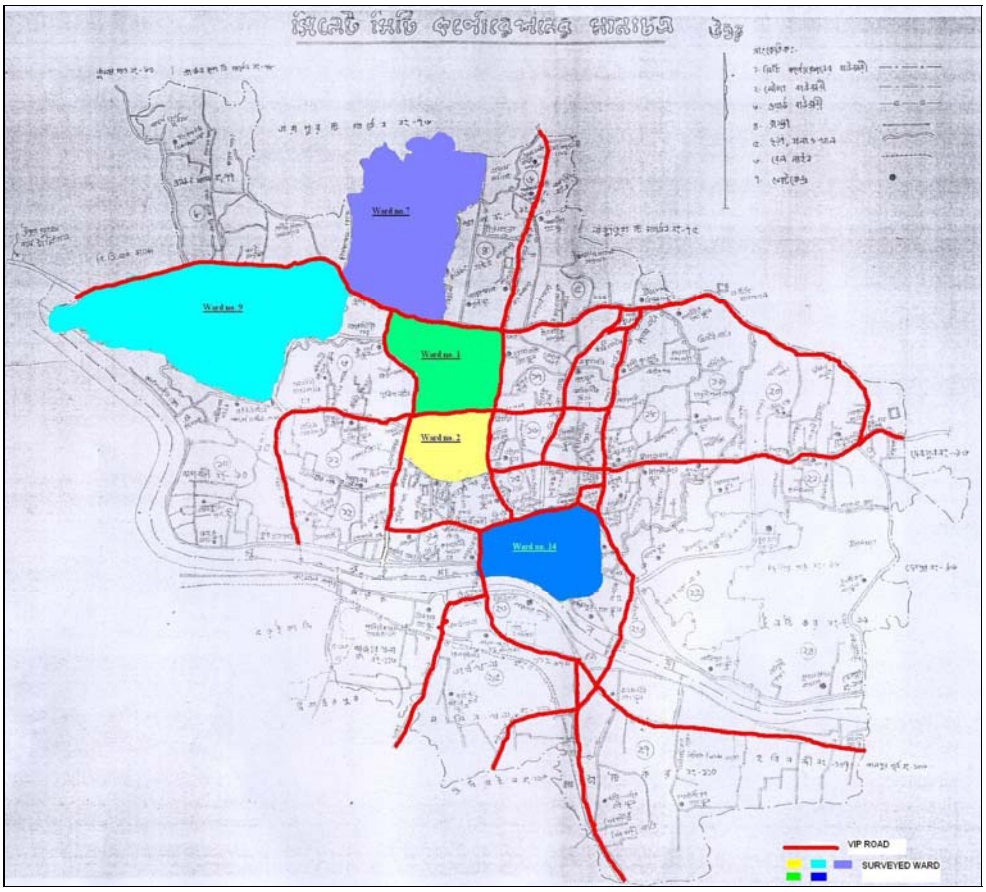

Figure 3 Sylhet City Corporation's waste collection route map

Disposal

Due to financial and institutional constraints, no engineered landfill is available in SCC areas; open dumping is used for final disposal of solid waste by SCC. This open dumping system of Sylhet has no precautions being taken. As a result, such crude dumping already creates potential environmental risk to both human and nature. The existing dumping site, named 'Lalmatia dumping site' is 5 km away from Sylhet Sadar or SCC area, belongs to the area named Lalmatia. The present dumping site is situated in a low-lying area and the first dumping was being started about 17 years ago. However, planning for environmentally safe landfill, monitoring of its future impacts, and site remediation are not yet undertaken. Figure 4 shows the present scenerio of Lalmatia dumping site.

(a) Most unsanitary dumping site. (b) Most unsanitary dumping site.

Figure 4 Present scenery of Lalmatia dumping site

Composting

Since the physical and chemical characteristic of waste of Sylhet city is appropriate for composting and there is a demand for compost two existing composting plants ran by Sylhet partnership and EPCT were sustaining and getting well response from consumer (Karanjit and Shrestha, 2005). A network of soil and composting specialists helped to develop a system of composting for the Sylhet partnership composting plant, which was producing one of best quality local compost.

Recycling

In urban areas of Bangladesh, wastes are recycled in a few ways. In the first stage the housewives, servants, and maidservants separate the refuse of higher market value such as old newspaper, used writing paper, empty bottle, old container etc. and sell them to the street hawkers. Such salvage activities are in practice in all households of low to average income. Used cloth, shoes and old utensils are bartered for new crockery and utensils.

The next stage of salvaging is carried out by children of slum dwellers popularly known as “Tokai” who separate, sort and collect the waste of low market value such as broken glass, cans, paper, cardboard, plastic, rubber, rag, metal etc. from trashcans, street sweeping accumulation points and open dumps to make a little money.

Refuse pickers do the third stage of salvaging when garbage vehicles at the final disposal sites unload the refuse. Moreover, the recycled materials reach scrap-stores, refuse dealers via street hawkers, and refuse collectors. Refuse dealers ramify them, sell them to the market, and supply them to the appropriate processing/remolding mills and factories. Figure 5 shows the significant activities of recycling process in Sylhet.

SCC is not concerned about recycling of solid waste. There are about 225 private shops in SCC who handles recycling activities. They all buy the recyclable waste from hawkers. There are many types of waste including scraps, tin, plastic etc. There are 195 retail seller and 30 whole seller involved in recycling activities of Sylhet city.

Fig. a: Tokais are collecting waste from dumping site.

Fig. b: Street hawker is collecting recyclable waste.

Fig. d: Haphazard condition of recyclable shop.

Fig. c: Recyclable wastes are stored at recyclable shop.

Figure 5 Recycling activities

Awareness among publics, laborers, utility people

The major lacking as identified by the study is awareness programs and programs simulating attitudinal and behavioral changes regarding solid waste management among the public that were never been practiced in the past year by SCC or NGOs or CBOs. General publics are not at all aware of the adverse impacts (whatever be the environmental, socio-economic, health impact) of the solid waste, throwing of solid waste here and there, encroachment of drains, charas and canals with gigantic volume of solid waste thrown to them, improper and indiscriminate dumping of polythene bags, application of Rs (Refuse, Reduce, Reuse, Replace, Return, Recycle, Recovery, Renew, Recharge, Refill, Repair, Remanufacture etc.) in the solid waste management. Labors who are handling solid waste continuously from source to disposal are not aware of the cleanliness, uniforms, saving gloves, masks etc. to protect themselves from running environmental pollution during their activities and health hazards of uncontrolled handling of solid waste. Also utility persons like Mayor, officers, supervisory persons to labors are not aware of and quite responsible about their duties to others regarding solid waste management. Obviously utility uses unfriendly materials in solid waste management activities, permits unplanned and haphazard urbanization to the developers who does not care about the use of eco-friendly construction materials minimizing construction and demolition waste. Also publics are not aware of the consumption materials which are most helpful to minimize waste and that are not; as a result, they are not ready to change the old consumption behavior and attitude and to accept the new ones instead, to minimize the waste and garbage in all tires of the daily life. Consequently waste generation rate is being increased due to the lack of awareness among publics, utility peoples, waste handlers etc., haphazard urbanization, introduction of environmentally unfriendly materials, and changing consumption patterns of people in SCC area.

ENVIRONMENTAL IMPACTS OF SOLID WASTE OF SCC

There are potential risks to health and the environment from improper handling such as collection, storage, recycling and disposal of solid waste (Chowdhury et al. 2001). In addition, due to heavy traffic and pedestrian congestion in the roads of Sylhet city, narrow road width, in absence of traffic signals and up-to-date signaling system causes traffic accidents that can result to toxic spilled waste, which causes death and injury to people in the vicinity of the city roads. Improper disposal of such wastes has resulted in the death of men and animals through contamination of crops or water supplies.

Accumulation of large amount of uncollected wastes (mainly organic) (about 58%) produces strong offensive odor and pollutes air. It also acts as a breeding ground for mosquitoes, flies, and other insects. Moreover, it helps producing and spreading of pathogenic microorganism.

Throwing of solid waste here and there clogs sewers and open drains, encroaches roadways, diminishes aesthetic quality and causes unpleasant odor and irritating dust cause public nuisance by clogging sewers and open drains.

Most of the garbage collection trucks of SCC being open flat-bedded spreads waste here and there without taking proper care that causes severe air pollution by foul smell and odor during the movement of trucks on the streets.

Waste collectors and scavengers involved in manual sorting, recycling and resource recovery and employers with no medical facilities are exposed to environmental hazards and become prey to many pathogens and diseases. Their poor health condition reduces labor productivity as well as poses threat to other employees and larger community (Ahmed and Jahan 2005).

Markets' slaughter house waste as well as the Muslim ritual Eid-ul-Azha waste not disposed properly is another health hazard and environmental threat in SCC area.

Due to unawareness and lack of knowledge on health hazard from unmanaged littering of solid waste, the slum people suffers from severe environmental pollution and water logging by encroached drains' piled up solid waste.

Lalmai landfill site situated in the vicinity of a small haor, which dried out during dry season, is filled with water into the brim and becomes the part of the biggest haor of Sylhet named 'Hakaluki Haor' in the rainy season. Since Hakaluki haor originating from the 'Golapgonj Thana' extends towards Lalmatia landfill site area, there is a huge probability of serious contamination of the surface water of haor area due to leachate propagation, which is in direct contact with the dumping site.

CONCLUSIONS

Solid waste management scenario in Sylhet City Corporation area is being deteriorated day by day as the situation is very difficult to handle the colossal volume of waste in SCC due to the uncontrollable migration of rural people to urban areas for better life. Solid waste generation rate in SCC is being increased due to the lack of awareness among publics, utility and work forces involved with solid waste management operation as well as unplanned and haphazard urbanization, introduction of environmentally unfriendly systems and materials involved, and changing consumption patterns of the city people. Solid waste available in the SCC containing adequate amount of organic matter (82.36%) provides the good scope of composting and biogas production as a renewable energy. With the waste generation rate of 0.48 (kg/cap/day) as estimated by SCC in the year 2006, around 336 tones of wastes is generated per day of which only 42% (140 tones) of wastes are disposed to the unsanitary dumping site in open areas through crude dumping without any treatment or sanitary land filling where inadequate and uncontrolled management of waste causes serious health hazard, environmental degradation i.e. air pollution and water pollution deteriorating the surface water, ground soil and water, and public nuisance, scabies, vomiting, stomach problem, headache, diarrhea etc. while about 58% (196 tones) of total wastes generated are put and thrown to roadsides, footpaths, open drains, open spaces and low lying areas etc. that clogs and encroaches the drainage system of SCC with huge and gigantic volume of solid waste refuse causing severe environmental decay in the city.

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Towards Zero Waste Strategies: Practices and Challenges of Household Waste Management in Dhaka

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ABSTRACT

Urban waste issue is an influential fact that is mostly related to our daily life. Waste problem increases with the rise of population density and standards of living. Due to the growing rates of waste generation and depletion of landfill space, the need for improving solid waste recycling performance has become a prerequisite to enhance the efficiency of waste disposal system. 'Zero Waste' is a new concept of looking at waste stream that aims to guide people in the redesign of their resource-use system to reduce waste to zero.

This paper represents an over view of waste management practices toward the zero waste strategies and compares the techniques of waste management between developed countries and Dhaka as a city of a developing country. This paper also outlines the action required to create a resource efficient Zero Waste society.

INTRODUCTION

With rapid population and industrial growth, both developed and developing countries are now faced with the double challenge of increasingly serious waste problems. Waste management is a pressing issue facing Dhaka today. The purpose of this paper is to present procedures resulting in significant reduction of the amount of waste deposited to landfills. This, as a consequence, results in saving of energy and raw materials, and in reduction of releases of toxic substances into the environment. This present paper suggests that the concentration should be given on the recovery-centric approach rather than the disposal-centric approach for waste management. This paradigm shift requires some level of public participation by regulating and monitoring waste generation and disposal. And public participation in the waste management system results in reduction of over-consumption, in minimization of wastes, in prevention of their formation and in their recycling.

The main focus of the paper is to introduce new vision in reducing environmental degradation as well as in improving our present thoughts about waste management techniques. So, the objectives of the paper are to guide general people in the redesign of their resource-use system with the aim of reducing waste towards zero and to produce a guideline for an efficient and effective household waste management practice in Dhaka including resource recovery and recycling.

'ZERO WASTE' CONCEPT

Zero Waste is a new vision, a philosophy and a design principle for a new millennium. It is a goal, a process, a way of thinking that profoundly changes our approach to resources and production. Not only is Zero Waste about recycling and diversion from landfills, it also restructures production and distribution systems to prevent waste from being manufactured in the first place. The materials which are still required in these re-designed, resource-efficient systems will be recycled right back into production.

Zero Waste requires preventing rather than managing waste. It includes recycling but goes beyond that by taking the whole system approach to the vast flow of resources and waste through human society. Zero Waste maximizes recycling, minimizes waste, reduces consumption and ensures that products are made to be reused, repaired or recycled back into nature or the marketplace. Bill

Sheehan of Grass Roots Recycling Network (GRRN) says, *"Zero Waste is a design principle. If we plan for eliminating waste, whether we reach 100% elimination is not the point. The point is to start planning for the elimination of waste rather than managing waste."*

BENEFIT AND OPPORTUNITIES OF ZERO WASTE

Zero Waste requires the need for dual responsibility. Firstly, the community has to maximize reuse, repair, recycling and composting. Secondly, industry has to redesign the objects the community cannot reuse, repair, recycle or compost. Zero Waste visualizes our economy as a circular system in which every part supports and affects every other. So we have to replace the current outdated linear economic and production system, which does not recognize the interconnection between the impacts and the trail of wastes left behind.

Progress and Vision

A Zero Waste strategy improves upon "cleaner production" and "pollution prevention" strategies by providing a visionary endpoint that leads us to take larger, more innovative steps. Because of its visionary endpoint, Zero Waste strategies lead to breakthrough improvements as opposed to small step-by-step actions. This not only results in significant cost savings, greater competitiveness and reduced environmental impacts, but also will move us more quickly toward sustainability.

Improved Material Flows

Today's system uses large amounts of new raw materials as shown Figure 1. In addition, large amounts of materials are sent to landfills or incinerated.

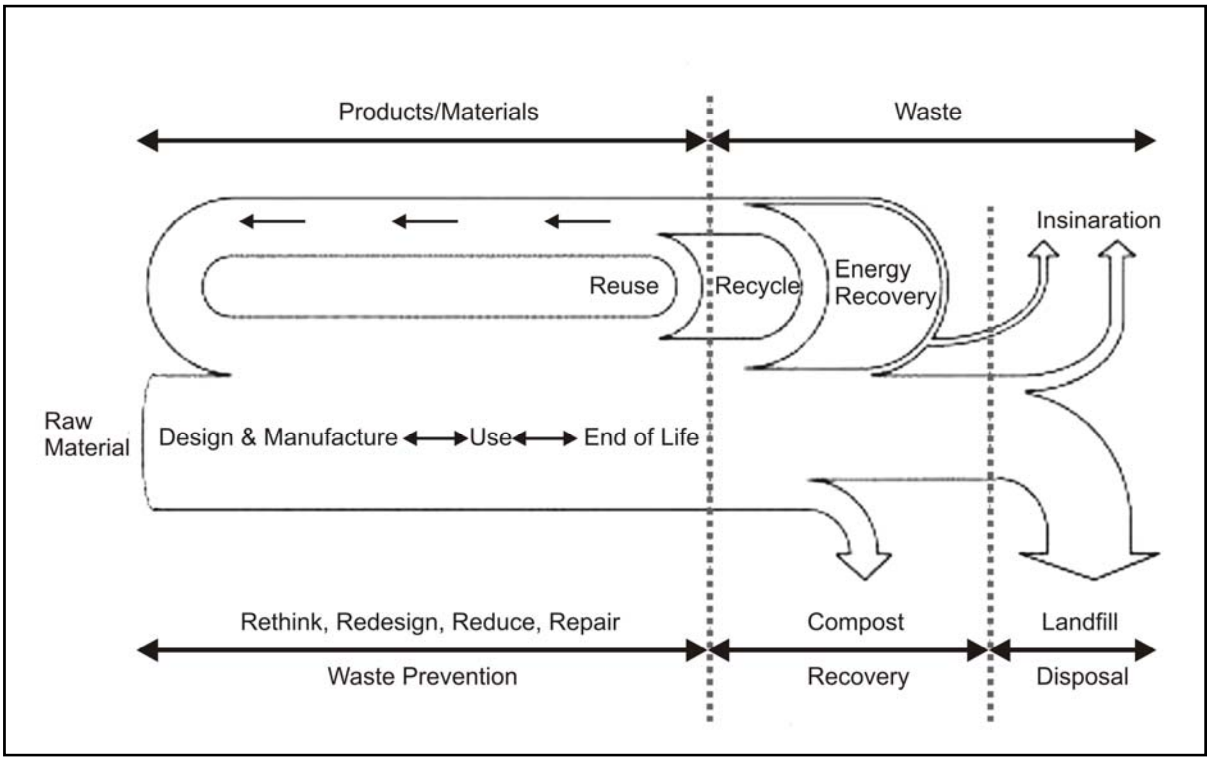

Figure 1 Open loop material flow (www.zerowaste.org)

A Zero Waste society would use far fewer new raw materials and send no waste materials to landfills. As shown in the figure 2, all materials would either return as reusable or recycled materials or would be suitable for use as compost.

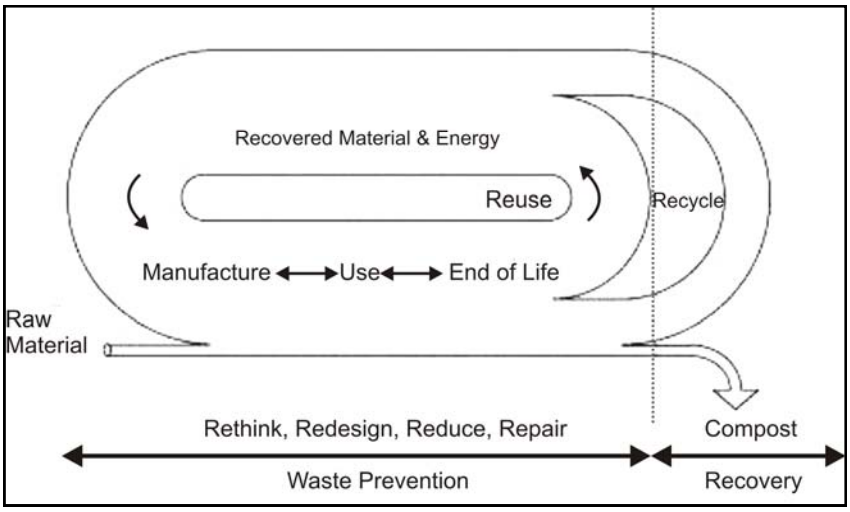

Figure 2 Closed loop material flow (www.zerowaste.org)

WASTE MANAGEMENT CONCEPTS

The Waste Hierarchy

The waste management hierarchy is a nationally and internationally accepted philosophy for prioritizing and guiding efforts to manage waste. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste. The waste management hierarchy establishes approaches to waste management according to their importance and preference in descending order. Zero waste and reduction are regarded as the most optimal approach and, reuse, recycling and recovery of waste is preferred, with treatment and disposal the least preferred approach.

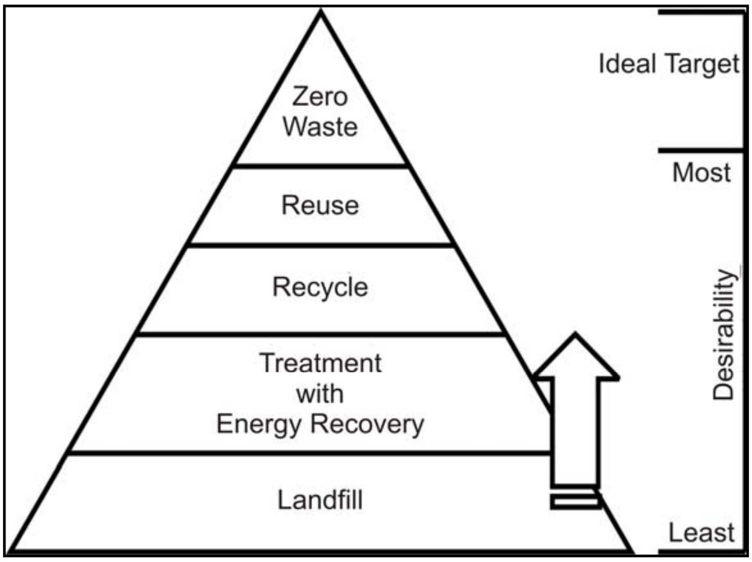

Figure 3 The waste management hierarchy (Cherubini, F., 2008)

Zero waste strategies are often criticized for being an utopist target. This may be true if we consider zero emission strategies as a simple refinement of past actions. Past eco-efficiency strategies, based on improved management of resources, are certainly capable of decreasing the environmental load, but they always face technological, economic and social constraints.

Thus the zero waste may appear an unreachable target. In order to solve the issue of waste disposal, we should not rely only on building new technologically advanced treatment plant, but we should implement waste prevention policies, based on the higher level of pyramid (Recycle and Reuse), on redesigning our production and consumption patterns towards ideal condition of waste prevention, waste reuse or recycling as well as waste valorization as new resource flows.

Extended Producer Responsibility

Extended Producer Responsibility (EPR) is a strategy designed to promote the integration of all costs associated with products throughout their life cycle (including end-of-life disposal costs) into the market price of the product. It is meant to impose accountability over the entire lifecycle of products and packaging introduced to the market. This means that organizations which manufacture, import and/or sell products are required to be responsible for the products after their useful life as well as during manufacture. This concept has arisen in recent years due to the belief that an organizations' responsibility for a product should not end with the sale of that product, but should extend to its disposal and/or reuse.

Essential to EPR is its mandate for producers to 'take back' their end-of-life products and create closed looped systems that prevent pollution and the inefficient use of resources. By promoting a 'cradle to cradle' responsibility, EPR enforces a design strategy that takes into account the upstream environmental impacts inherent in the selection, mining and extraction of materials, the health and environmental impacts to workers and surrounding communities during the production process itself, and downstream impacts during use, recycling and disposal of the products. The ultimate goal of EPR is to encourage cleaner, safer materials and production processes, as well as to eliminate waste at each stage of the product's life cycle.

Source Reduction

Industries are very conscious to optimize production and to reduce resource consumption to make them more competitive in today's global market economy. This includes adopting more efficient manufacturing methods in order to minimize raw material requirements (hence generating less waste), and minimizing the weight and volume of packaging while maintaining product integrity during shipping. Waste prevention measures are also aimed at changing the public's attitude towards consumption, where improved product quality, durability and "environmental friendliness" are being emphasized. Thus, source reduction methods involve changes in manufacturing technology, raw material inputs, and product formulation.

According to the United States Environmental Protection Agency,*"Source reduction refers to any change in the design, manufacture, purchase, or use of materials or products (including packaging) to reduce their amount or toxicity before they become municipal solid waste".*

PRODUCED WASTE IN DHAKA

Waste Generation Situation

According to Dhaka City Corporation (DCC) estimates, everyday between 3000 to 3500 tons of solid waste is generated from residential, commercial and industrial activities in the city. Per capita generation of solid waste in Dhaka City is estimated at 0.5 Kg/day. Of the total waste generated in the city, DCC collect and dump 50.0% and 15.0% are recycled and the rest 35.0% are discarded into streets, drains, ditches, canals and open spaces. Slum and squatter dwellers constitute 35% of city population and only 9% of this population have any form of solid waste collection service, the remaining 91% dispose their wastes into low-lying lands, road side drains or local drain or canals (DCC, 1999). This has a negative impact on the city's environment.

Sources and Quantities of Solid Waste

Generated waste of Dhaka city can be categorized into major categories such as Domestic waste, Industrial waste, Commercial waste, Hospital waste etc. The JICA (Japan International Cooperation Agency) study shows 63% (2120 tons/d) of the total waste (3,340 tons/d) is from residential sources while another project of the DCC estimated that it is 49 % (Table 1).

As the domestic waste is foremost in proportion, this paper mainly concerned about Domestic Waste and it is observed that waste densities (350 to 450 kg/m^3) and moisture contents (50% to 70 % by wt.) are much higher than the wastes in developed countries, generally contains a high organic (60% to 70%) and low combustible matter.

Table 1 The amount of solid waste generated from various sources in Dhaka

Sources of waste	Percentage (%)

Domestic waste	49
Industrial waste	24
Commercial waste	21
Others	6

Composition of Solid Waste

Among the urban solid waste, food and vegetable waste is 67.65%, paper waste is 9.73%, rocks, dirt etc. are 8.79%, plastic, leather, rubber etc. are 5.1%, clinical waste is 4.2% and others including metals, glass, ceramic, textile and rags are the remaining 4.53% (Figure 4).

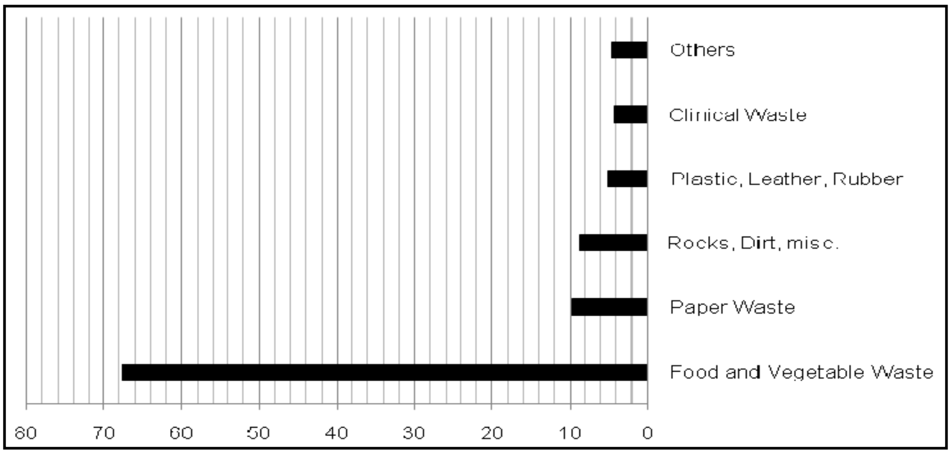

Figure 4 The average physical composition of urban solid waste in Bangladesh (after Sinha 1995)

WASTE MANAGEMENT TECHNIQUES

Collection Methods

Domestic waste collection services are often provided by local government authorities or by private industry. In Dhaka, DCC is the only formal organization responsible for waste management including both waste collection and waste disposal.

Most of the developed countries have well organized collection systems. Different colored collection bins are placed in curbs. These collection bins are also provided for recyclables such as glass, cans, plastic bottles etc. Curbside collection system is efficient in many developed countries. These recyclables are later removed and used for recycling industries. Wastes are later picked by collection vehicles. These vehicles are both single compartmented and multi-compartmented to collect recyclables separately.

In Dhaka, the collection system is divided into primary and secondary collection system. Normally the households bring their refuse to the nearby bins or containers located on the street side, while in some specific areas community has arranged house to house collection of garbage with their own initiatives and efforts. Again, street sweeping is done manually and debris are loaded from the Curbside into the handcarts and delivered into the collection bins. Presently some Community Based Organizations (CBOs) doing the house-to-house collection of Solid Wastes at a reasonable charge, which is, accepted by the city dwellers. These CBOs are playing significant role in the primary collection of the Solid Wastes.

Disposal and Processing Methods

Waste management and disposal is a pressing issue facing Dhaka today, since about 90% of waste is currently disposed by open dumping. Land filling, incineration and composting are some commonly used methods to manage waste.

Land Filling

Disposing of waste in a landfill remains a common practice in most countries. A landfill is an area of land onto or into which waste is deposited. Sanitary land fills are used in developed countries and have facilities for treatment of the leachetes. Beginning in the 1950s, in some more developed areas, the land filling of wastes occurred in “sanitary” landfills. A "sanitary landfill" refers to a managed, controlled site equipped with systems to reduce leachetes and landfill gas migration into the surrounding environment. In USA, Sanitary land filling practice Adopted after 1970.

In Dhaka, The waste is presently being disposed off mainly on a lowland Matuail about 3 kilometer from the corporation area and a number of minor sites which are operated as uncontrolled manner without any proper earth cover and compaction. The uncollected wastes are dumped in open spaces and streets, clogs drainage system creating serious environmental degradation & health risks.

Composting

Waste materials that are organic in nature, such as food scraps and paper products, are increasingly being recycled. These materials are put through a composting or artificial digestion process to decompose the organic matter and kill pathogens. The organic material is then recycled as compost for agricultural or landscaping purposes.

In developed countries, there are a large variety of composting methods and technologies. Composting methods can be broadly categorized into aerobic or anaerobic methods, although hybrids of the two methods also exist. Aerobic (meaning ‘requiring air’) methods of composting seek to aerate the organic material continuously or frequently. Anaerobic (‘not requiring air’) methods of composting seek to maximize the generation of gases such as methane during the process, in order to produce power from the waste materials.

In Dhaka, ‘Waste Concern’ started a community-based composting project in 1995 in urban areas. It is based on the idea that the organic content of Dhaka’s household waste, which accounts for more than 70% of total waste, can be efficiently converted into valuable compost.

Resource Recovery and Recycling Techniques

Zero waste enforces the methods of Resource Recovery through reuse and recycles. ‘Zero waste’ concept depends on the success of the recycling movement. It requires the maximization of existing recycling and reusing efforts, while ensuring that products are designed for the environment and having the potential to be repaired, reused, or recycled.

Recycling is the breaking down of materials from waste streams into raw materials, which are then reprocessed either into the same material (closed loop) or a new product (open loop) including waste separation and material reprocessing.

Table 2 Recycled products from some selected waste materials

Waste materials	Products
Paper	Cartons hardboards, packets in retailing
Glass	Water-glass, jugs, bottles, glass sheets for construction work etc.
Plastic	Sanitary pipes and fittings, wearing pipes, utensils, dolls etc.
Scrap iron and tin	Construction rods, pins, pipes etc.
Tin pots	Cutting up cans into regular sheets, making containers decolouring sheets.

In Dhaka, Waste recycling practices are mainly dominated by the informal sectors. 15% of the generated wastes in Dhaka (mainly inorganic) which amount 475 tons per day are recycled daily (Sinha, 1995). In all stages only inorganic wastes are recycled leaving behind the organic part, but the major component of household waste - organic food waste is totally ignored even though it has a potential value and can be converted into organic compost. Recently a few numbers of entrepreneurs are producing "Compost" kind of organic manure from the organic Solid Wastes. And a number of other recycling schemes also (like waste to electricity, Waste to Biogas, Waste to Tiles/building materials etc) are under the consideration of the Corporation and the Government.

Avoidance and Reduction Methods

It seems that the most effective way is to reduce the amount of waste than to dispose. There are several methods to reduce the production of waste. These include: Redesign of packaging, encouraging the use of minimal disposable material necessary to achieve the desired level of safety and convenience, increasing consumer awareness of waste reduction issues; and the promotion of producer responsibility for post-consumer wastes

Production Process Modification

Waste minimization and resource maximization for manufactured products can most easily be done at the design stage. Reducing the number of components used in a product or making the product easier to take apart can make it easier to be repaired or recycled at the end of its useful life. In some cases, it may be best not to minimize the volume of raw materials used to make a product, but instead reduce the volume or toxicity of the waste created at the end of a product's life, or the environmental impact of the product's use

To reduce materials consumption, product design process should be changed and Eco-Design technology should be incorporated into production processes. Cleaner Production practices should be adopted to ensure avoidance through efficiency measures; and regular audits and monitoring of waste reduction/resource recovery practices should be conducted. To encourage repair, resale, reuse, durability and recyclability, economic incentives should be promoted and provided for product designs. Products and materials that are not to be recycled should be banned unless their manufacturers can present acceptable alternative benefits such as longevity, durability, or long term repair-ability.

Waste Minimization

Waste minimization is aimed at reducing the production of waste through education and improved production process rather than aiming to increase technology to improve treatment of waste. The idea of minimization is not centered on technological advances, it can be viewed a method of managing existing resources and technology in order to maximize the efficiency of available resource use.

Resource optimization is to minimize the amount of waste produced by organizations' or individuals' goes hand-in-hand with optimizing their use of raw materials. For example, a dressmaker may arrange pattern pieces on a length of fabric in a particular way to enable the garment to be cut out from the smallest area of fabric. Where the waste is product of one process becomes the raw material for a second process. Waste exchanges represent another way of reducing waste disposal volumes for waste that cannot be eliminated.

INCENTIVES FOR ZERO WASTE

The Zero Waste concept challenges community people to rethink the incentives for dispose of waste quickly and cheaply, and to redesign the entire system to encourage waste prevention, reuse, recycling and composting. Support for adopting these techniques may be gained from the existing waste collection and disposal industry through continuous dialog with all parties of affected interests. And for this reason, Incentives could include the adoption of policies and the structuring of the marketplace for waste generators, waste and recycling haulers, transfer station and material recovery facility operators, landfill operators and Manufacturers and retailers. Towards zero waste strategies the community people have to adopt and maintain the following incentives:

- Direct involvement and regular action should be needed in some stages of waste management system. For example, curbside collection, compost operations, cleaner production, recycling facilities etc. are to deal directly.
- Institutional strengthening and capacity building should be needed to improve the management system. For example, Landfill design and management, waste reduction and recycling project should be introduced.
- New legal and economic incentives should be introduced instead of old and traditional rules. For example extended producer responsibility, landfill bans, landfill levy etc. will divert activity away from disposal and toward waste reduction.
- New ideas should be provided for the development of waste minimization. Structure and mechanisms are to be created to nurture the development and testing of new social, technical and economic solution.
- Public participation should be needed by communicating and educating them for the very purpose. Actions are that inform the community of the issues and provide opportunity for input and participation. For example, public consultation, education material and programs etc. should be provided.
- Monitoring and feedback from the waste analysis data, participation rate survey should be prepared up to date. Data and information on the characteristics of the waste stream and on the success of the initiatives should be gathered.

CONCLUSIONS

Critics of Zero Waste often point out that we should not aim for something that we can never achieve. It is not actually about whether we can or cannot actually get to Zero; it is about thinking and managing the way resources flow through society in a totally new way. We have a growing population faced with limits of resources from the environment in these days. Each material must be used as efficiently as possible and must be chosen so that it may either return safely to a cycle within the environment.

Zero Waste promotes not only reuse and recycling, but also, and more importantly, promotes prevention that consider the entire product life cycle. These new designs will strive for reduced materials use, use of recycled materials and longer product lives. It strongly supports sustainability by protecting the environment, reducing costs and producing additional jobs in the management and handling of wastes back into the industrial cycle. 'Zero Waste' concept creates a new framework for people to think and behave differently. Zero waste of human resources will protect the environment and lead to a much more productive, efficient, and sustainable future. This simple act of setting a target of Zero and a date within which to achieve it is enormously empowering and enables people to achieve far greater results than first thought possible.

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Solid Waste Management in Dhaka City of Bangladesh

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ABSTRACT

The present study depicted that the solid waste generation in Dhaka city was found as about 5000 tonnes per day in which about 80% was biodegradable. It was also increasing with a rate of 5.6% per annum. It was assessed that a biogas electricity plant of 175.2 GWh (gross) capacities might run properly based on the biodegradable waste in Dhaka city, which will have a great economic and environmental benefit. Investment cost of such a biogas electricity plant will be 1573.66 million of BDT and it will earn 188.20 million of BDT per year. It will also reduce 1,130,538 tonnes of CO_2 equivalent emission. In addition, it was also assessed that without composting the total land area required was 96.97 acres per year whereas with 74% composting it was further reduced to only 34.43 acres per year, which will save 62.54 acres of land per year. The existing Solid Waste Management (SWM) strategy was assessed and the better options to improve the SWM system in Dhaka city were identified through the study.

BACKGROUND AND RATIONALE

Dhaka the capital city of Bangladesh already became the 8th mega city of the World (UNEP 2005). According to World Bank report, the solid waste generation in Dhaka City in 1998 was found as 3,944 tonnes per day. The report of “Solid Waste Management Project” of Dhaka City Corporation (DCC) prepared by JICA and DCC stated that in 2000 Dhaka Metropolitan area produced 4750 tonnes of solid waste per day. In addition, the JICA team of “Clean Dhaka Master Plan” stated that the solid waste generation in Dhaka Metropolitan area will increase to 5100 tonnes per day in 2015 (JICA 2004).

Among the total generated solid waste, DCC collects and dumps 50%, 13% are recycled and the rest 37% of solid waste remain scattered lying around on road sides, open spaces or drains[10]. But proper management of this scattered solid waste is so much important for make hygiene and friendly clean city. The only ongoing initiative to manage the solid waste of Dhaka City is landfill. DCC collects the domestic, commercial and street wastes and finally dump at the Matuail landfill site. But waste is resource. There is high potential to use the biodegradable solid waste as a resource to produce compost or biogas electricity. So, exploration of perfect management strategy of solid waste is necessary. Open dumping of solid wastes affects different environmental resources and components including water, soil and air and also creates diverse health impacts. This also contributes to global warming. So, better options to improve the Solid Waste Management (SWM) in Dhaka City should be found out. To these endeavor, this study depicts the present management strategy of solid waste and hence suggest the proper management strategy for this vast amount of solid waste.

OBJECTIVES

The overall objectives of the study were stated as (i) to assess the existing SWM system and (ii) to identify the better options to improve the existing SWM in Dhaka City.

EXISTING STRATEGY AND PRESENT SITUATION OF SWM

Primary Waste Collection

DCC Ordinance is the basic law regarding street/drain cleaning, waste collection and transportation. According to section 78 of the Ordinance, DCC is responsible for collection and remove the deposited solid waste in dustbins/containers surrounded the whole city area and finally transport it at the ultimate disposal sites[6]. Residents are responsible for bringing their generated solid waste to DCC's primary collection points where dustbins/containers are situated and the overall collection and management system of solid waste in Dhaka city as depicted in Figure 1. Even then, in 2002 DCC introduced an approval system of NGOs/CBOs/private organization for providing door to door waste collection services in all wards of Dhaka city. DCC has given approvals to 47 NGOs/CBOs, however, not all of them have started their activities yet

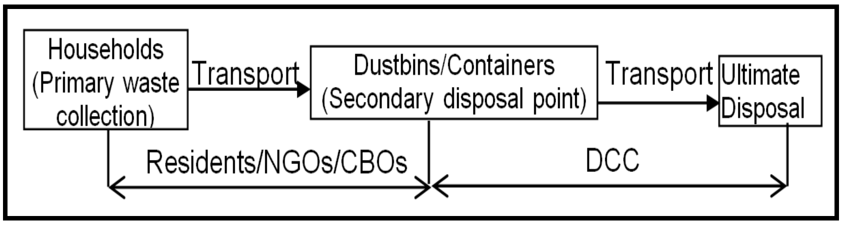

Figure 1 Solid waste collection options by DCC (after JICA 2005)

Secondary Waste Collection and Road/Drain Cleaning

DCC deploys the facilities and manpower for secondary waste collection and it seems to have sufficient capacity of vehicle, but the number of drivers is apparently insufficient. For cleaning of roads/drains and public spaces, DCC deploys about 7,000 cleaners in eight zones while private firms deploy about 600 cleaners in two zones[6]. However, the chain of SWM consists of two actions in opposite directions; namely the chain of command and the chain of report. With the complete pair of chains, the SWM is executed effectively and efficiently. DCC has a well connected chain of command; however, it does not have the opposite direction, the chain of report. To cope with this defect, a pilot project for Management Information Acquisition (MIA) was initiated under the financial assistance of JICA.

Ultimate Disposal of Waste

DCC uses three landfill sites; namely, Matuail, Beri Bandh and Uttara. The Matuail landfill site is the only official site owned by DCC. The rest (Amin Bazar Beri Bandh and Uttara) is the private land. It is stated that owners of the land have requested to DCC to fill the low laying land with solid waste. In response to their request, DCC started for disposing of solid waste there. The remaining capacity of Matuail disposal site was estimated as 1.1 million tonnes at the end of 2004[6].

Recycling of Waste

Recycling industries raises a total of 436 tonnes/day material recovery as stated in Table 1 and also presented in Figure 2. Based on figure, it can be noted that composting facilities contributes very little to the waste reduction although the compostable waste has the largest portion among the total generated solid wastes and overall theme as describe below.

Table 1 Estimated Volume of Recycled Wastes in Dhaka City (JICA-Bd 2005)

Material	Total Generated recyclable waste (t/d)	Estimated recycled waste (t/d)	Recycling rate	Contribute to waste reduction (b/3,200)
Plastic	124	103	83%	3.2%
Paper	260	168	65%	5.3%
Glass	46	24	52%	0.8%
Metal	24	41	-	1.3%
Compostable	2,211	6	0%	0.2%
Others	99	94	95%	2.9%
Total	2,767	436		13.6%

Source: Survey of recycle market by the JICA study team

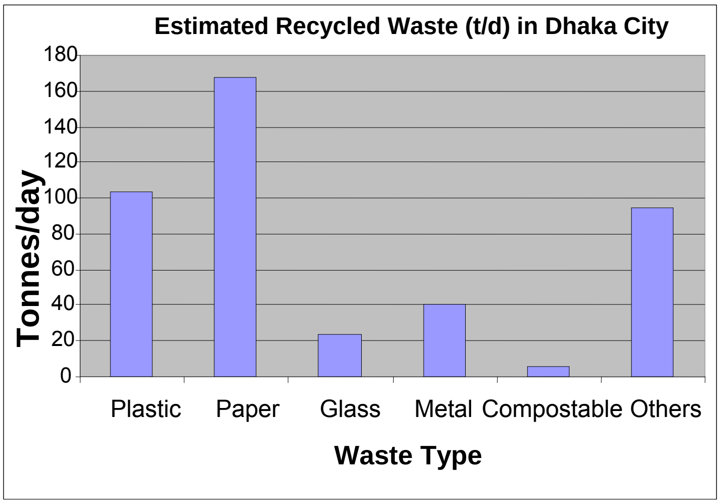

Figure 2 Estimated recycled waste in Dhaka City

Industrial Waste

In case of industrial wastes, reuse and recycling were aggressively done by industries themselves or by industry-related business. As a result, the amount of recovered wastes by waste pickers and scavengers seems to be relatively small compared to those removed at sources. In addition, the survey of industrial waste management has never been conducted except for tannery waste. The amount of tannery waste, which is mostly generated in Hazaribag area, was estimated as 150 tonnes/day. Besides, in the chapter of industrial waste management, cases of the environmental pollution resulted from improper industrial waste management is reported as soil contamination by heavy metals at some industrial zones (Huda, K.M.N. 2008). The main industrial zones in DCC area are Tezgaon and Hazaribag where found the pollutants of Cr, Cu, Zn, Ni, Cd and Pb from such industries as tannery, food, chemical, textile, battery, metal and still.

Hazaribag is a famous tannery industrial area situated inside Dhaka city area, where soil is highly contaminated by toxic chemicals and heavy metals like Cr and Cu. The total pollutant emission from tannery industry shares 57% of national total of toxic chemical and 32% of toxic metals[7].

Medical Waste

There are about 717 public and private hospital, medical college hospital and clinic in the study area containing 12,036 beds. Besides hospitals/clinics there are also about 450 diagnostic centers in Dhaka city that also produce syringes, needles, blood, toxic chemicals etc (JICA-Bd 2005). Their quantities are, however considered difficult to determine. In addition, hospital waste generation rate increases as the size of hospital (i.e as the number of beds) becomes larger (Huda, K.M.N. 2008). In the survey conducted during March and May 1998, it was found that waste generation rate at hospitals in Dhaka city was 1.2 kg/bed/day on average[7], 15% of it was hazardous waste that included infectious waste (10.5%), pathological waste (1.5%), sharp waste (3.5%) and very small amount of pharmaceutical and chemical waste. The total amount of hospital waste and hazardous hospital waste in the study area were projected at 7.2~22.8 tonnes/day and 0.6~2.4 tonnes/day, respectively, by multiplying total bed number with generation rates.

Hospital waste that are segregated at sources, more or less, are normally discharged to a public dustbin in which waste are mixed with general municipal solid waste. The mixed waste is collected by DCC for finally at the ultimate disposal site. Recently, Prism Bangladesh is working for disposal of medical waste separately in some areas as pilot project. But, unfortunately, majority of hospital waste discharged at public dustbin, either hazardous or non-hazardous, are hauled and dumped at Matuail dumpsite together with ordinary municipal waste.

METHODOLOGY OF THIS STUDY

Conceptual Development

Consultation with relevant experts and key personnel of relevant organizations concretized the concept for the study on SWM in Dhaka City.

Collection of Secondary Data and Information

Secondary data on solid waste generation and existing SWM strategy collected from relevant agencies, such as, Waste Management Division of DCC, Waste Concern, JICA Bangladesh etc. and literature review.

Primary Data Collection

To collect primary data such as (i) two Focus Group Discussions (FGD) were conducted- first was with the Community people of 17 no. ward of DCC, second was with the SWM workers of 17 no. ward of DCC anf (ii) In-Depth Interviews were taken with 10 SWM experts to collect their opinions on the activities needed to improve the SWM in Dhaka City.

Process and Analysis of Data

Data and information of FGD reports and in-depth interviews were classified thematically and processed and analyzed. Description and interpretation of thematically classified data was the major techniques of analysis.

Final Report

The report was prepared based on the interpreted data. In this respect information and opinions of the relevant experts were conducted. Comments and suggestions from the relevant experts and stakeholders were incorporated to prepare the final report.

RESULT AND DISCUSSIONS

Electric Energy Generation

At present, about 5,000 tonnes of MSW is producing per day with annual growth rate of 5.6 % and 80% of these solid wastes is the dominant fraction of organic waste. Although the energy content of organic waste of Dhaka City is quite low (1,386-2,600 Btu/lb or 770-1,444 kcal/kg on as received basis), it has a high potential to produce electric energy. By utilizing of these organic wastes a biogas electricity plant of 175.2 GWh (gross) capacities might run properly, which will give a big economic and environmental output[1].

1. Cost and Emission Reduction: A pre-feasibility study for Dhaka City Solid Waste to Electric Energy Project depicted that preparation of 50 landfill gas digesters, each with a volume of 8500 m^3 and a generator of 20 MW capacities may run by the organic solid waste of Dhaka City.

A recent feasibility study on the Dhaka City solid waste by waste concern (Waste concern, Dhaka, Private communication, October 2003) depicted that gas production per kg waste in the open dumping sites vary from 25 liters to 40 liters and the generated gas at a depth of 3-6 meters contains 55-58% CH_4. A reasonable guess by NETs is 45% CH_4 and 55% CO_2. Based on the above values yearly production of CO_2 and CH_4 from 5000 tonnes/day as follows:

Total volume of landfill gas = 59.31×10^6 m^3.
CO_2 (55%) = $59.31 \times 10^6 \times 0.55 = 32.62 \times 10^6 m^3$.
CH_4 (45%) = $59.31 \times 10^6 \times 0.45 = 26.69 \times 10^6 m^3$.

Methane has a GWP (Global Warming Potential) of 23 and as such CO_2 equivalent of 26.69×10^6 m^3 of CH_4 = $26.29 \times 10^6 \times 23 = 613.87 \times 10^6$ m^3. Therefore, yearly production of CO_2 equivalent GHG from the dumping site = $32.62 \times 10^6 + 613.87 \times 10^6$ m^3. Density of CO_2 at room temperature = 1.83 kg/m^3. Mass of 646.49 x 106m^3 = 1,183,076 tonnes from Matuail site. If Power Development Board (PDB) start a 20 MW power plant based on natural gas to continue the progress of power plant installation in Bangladesh, the 20 MW plant based on natural gas will produce 101,092 tonnes of CO_2. So, in the absence of the project the total yearly CO_2 equivalent emission = 101.092 + 1,183,076 = 1,284,168 tonnes[1].

The landfill gas to generate the project will contain CH_4 and CO_2. Since 1 volume of CH_4 give 1 volume of CO_2 on complete combustion.

$$CH_4 + 2O_2 \rightarrow 2H_2O$$

The total volume of CO_2 (CO_2 already present in the landfill gas + CO_2 produced on complete combustion of CH_4) will be equal to the volume of landfill gas produced.

So, the yearly production of CO_2 by the project will be =

$$230 \times 10^3 \times 365 \ m^3/year$$

83.95 x 10^6 m^3/year
153.63 x 10^6 kg/year [1 m^3 = 1.83 kg]
153,630 tonnes/year

So, the yearly abatement of CO_2 by the project will be =
1,284,168 tonnes - 153,630 tonnes
1,130,538 tonnes/year.

50 landfill gas digesters, each with a volume of 8500 m^3 and a generator of 20 MW capacity will need an investment of 1573.66 million BDT. The operation and maintenance cost will be 61.80 million BDT per year and the net generated electricity 131.4 GWh will be sold 250 million BDT. So, the gross profit will be (250-61.8)= 188.20 million BDT per year[1].

2. Additional Environmental and Social Benefit of Electric Energy: "Kyoto Protocol" required that a CDM project activity contributes to the sustainable development to the host country. During the operation, the following necessary arrangement will be made to maximize local benefits:

- Providing jobs to at least 200 people.
- Elimination of bad odour from the area surrounding the Matuail dumping site.
- Providing a permanent solution to the city waste disposal problem because of the modular nature of the biodigesters. Number of biodigesters can be increased on the demand. If the gas is in excess of the requirement of the power plant, the excess gas can be fed to the natural gas line or can be flared up to convert methane into carbon dioxide.
- Addition of electricity to the national grid.
- Soil conditioning by the residues from the biodigesters leading to greater fertility of the soil conditioning.
- Significant reduction of GHG due to capture of methane followed by burning.
- Locally reducing pollution of air, water and soil.

Compost Production

Since there is a high content of compostable waste in the solid waste composition of DCC area, composting is obviously a viable option for reducing the load on the landfill facilities. At the same time, revenue can be earned from sale of compost as organic fertilizer; biogas and trading reduction of GHG emission along with reduced cost of purchasing land fill area. The landfill area required after diverting 50% and 74% of total generated solid waste for composting along with the area required for developing composting plants as presented in Table 2. The comparative picture presented in Table 2 revealed that without composting the total land area required was 96.97 acre whereas with 50% composting it is reduced to 54.61 acres and with 74% composting it is further reduced to only 34.43 acre. In addition, based on the experimental results it can be concluded that the area required for composting plant for the diverted 50% and 74% of compostable waste work out around 55.51 acres and 81.62 acres, respectively(Iftekhar, E. et al. 2005)

Table 2 Area required for landfill and composting plant in Dhaka City (after Iftekhar 2005).

-	Without composting	50% Composting	74% Composting
Landfill area required with 4m. depth, acre per year	96.97	54.61	34.43
Area required for composting plant, acre	-	55.51	81.62

Source: Technical documentation, Waste Concern, 2005.

EXISTING STRATEGY, LIMITATIONS AND SUGGESTIONS OF SWM

The overall existing strategy, limitations and suggestions for SWM were presented in Table 3 and also in Figure 3.

Table 3 Existing Strategy, Limitations and Suggestions of SWM in Dhaka City

Parameter	Existing Strategy	Limitations	Suggestions
Storage and Source Separation	i) Existence of large portion of recyclable materials, such as, newspaper, bottles, cans, glass, plastic, metal, rubber and different containers in the waste. But a very few aware people separate the recyclable items at the source. Due to lack of awareness most of the people do not do that. ii) In the major houses every family stored solid waste in a plastic bin individually. The house holders carry solid waste to the primary collection bins. iii) The waste pickers separate the recyclable items from the primary collection bins.	i) No government initiative yet taken for source separation. iii) Waste pickers (*tokai*) are not properly trained to separate the recyclable items.	i) Source separation is necessary. Every family has to store the recyclable, hazardous and non-hazardous items in separate bins. ii) Every house should have a common waste storage bin for the families of that house. iii) For hazardous waste there should have a separate common bin. iv) Source separation has to be mandatory for every industry, institution and organization and clinic, hospital. v) DCC should take the responsibility to collect waste from houses to the primary collection bins.
Collection	i) Waste collection from houses to the primary collection bins is the people responsibility. ii) Streets are swept and drains are cleaned by the workers and collected to the primary collection bins by collection van. iii) In some places demountable containers are used. iv) The primary collection bins established in some places for brick, concrete or corrugated iron sheet. v) DCC's workers also collect solid waste from meat and fish markets, fruits and vegetable markets. vi) The primary collection bins are placed beside roads or streets, which hampered the movement of people and vehicles.	i) Many people do not encourage bringing the waste to the primary collection bins, if it is little bit far. Then they scatter the waste here and there and create aesthetic insult. ii) The primary collection bins beside a road or street is a major problem. It spread out bad smell hampered free movement of people and vehicles.	i) All the families of a house should store their waste in the common waste storage bin. DCC workers should collect waste from the bin to the primary collection bin by van. ii) The primary collection bins should not be beside any road or street. It should be replaced in suitable places. iii) Waste from meat and fish markets, fruits and vegetable markets, which are biodegradable in nature, should be collected separately and should be carried separately to the processing plants. iv) Bio-medical waste and industrial waste should not be mixed with other waste.
Transportation	DCC authority uses Trucks to carry waste from the primary	Due to over loading waste scatters. During carry bad smell spread	The trucks should not be over loaded. The waste should be

	collection bins to the dumping sites.	out.	properly covered by polyethylene or thick cloth (*tripol*).
Processing of Municipal Waste	No initiative has yet taken by the government or DCC.		The biodegradable waste should be processed by composting and biogas production for stabilization of waste.
Disposal of Solid Waste	The DCC authority carried solid waste to the Matuail landfill site and disposed there.	To unload a truck of solid waste, 2 hours expend for 6 workers.	i) Modern technology should be used to unload the waste. ii) The landfill site should be planned and designed with proper documentation of a phased construction plan as well as a closure plan.

THE OVERALL GUIDELINE

The overall guideline for management tiers of solid waste are stated and hence discussed in following.

Domestic Waste, Commercial and Street Wastes

Storage and source reduction and primary collection

- every family and commercial institution should have separate bins to store separately the recyclable, non-recyclable and hazardous items of waste.
- every house should have a common storage bin/container where all the families of the house should store the solid waste and DCC should collect the waste from the common storage bin of the house by van.
- wastes from households, commercial institutions, streets and drains should be carried to the primary collection bins by van.
- a separate common bin should have for the hazardous items and DCC should carry and dispose this separately.
- second time separation of recyclable items and separation of biodegradable waste should be done at the primary collection bin.

Secondary collection and transportation

- biodegradable items should be carried separately to the processing plant (compost or electric energy), the non-recyclable inorganic items should be carried to the landfill sites and hazardous items should be carried and disposed separately. the recyclable items should go to the recycling processes.
- while carrying the waste should be covered by thick cloth (*tripol*).
- the trucks should not be overloaded.

Processing

- the biodegradable item should be processed to produce electric energy or compost fertilizer.

Disposal

- the landfill site should be planned and designed with proper documentation of a phased construction plan as well as a closure plan.
- modern technology and machinery should be used to disposed the wastes.

Industrial Waste

Storage and primary collection

- hazardous, non-hazardous, recyclable and biodegradable items should be stored in separate bin.
- recyclable items should go to the recycling processes.
- DCC should take the liability of industrial waste management also.

Secondary collection and transportation

- biodegradable items should be separated at the primary collection bin and should be carried to the processing plant.
- the hazardous and non-hazardous items should be carried separately to the landfill site.

Processing and disposal

- hazardous and non-hazardous items should be disposed separately.

Medical Waste

Storage and primary collection

- hazardous, non-hazardous, recyclable items should be stored in separate bin.
- recyclable items should go to the recycling processing by the own initiative of the hospital/clinic/diagnostic lab.
- DCC should take the liability of primary collection of solid waste from hospital/clinic/diagnostic lab also.

Secondary collection and transportation

- the hazardous and non-hazardous items should be carried separately to the landfill site.

Processing and disposal

- hazardous and non-hazardous items should be disposed separately.

The waste management workers should wear safety clothes and equipment (hand gloves, mask etc.) during their work; especially, while they handle hazardous waste. Modernization of equipment, machinery and methods is necessary in every step of management.

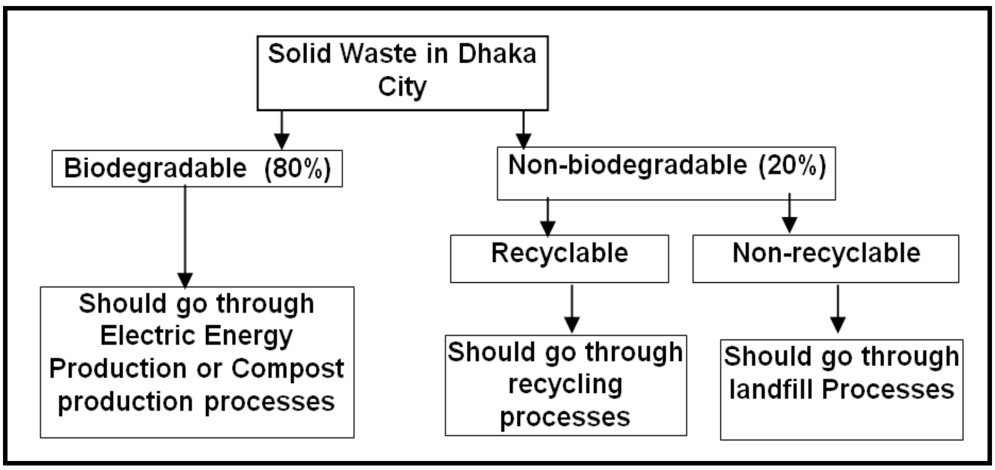

Figure 3 Flow chart of suggested SWM strategy.

CONCLUSIONS AND RECOMMENDATIONS

In this study the total solid waste generated throughout the Dhaka City was found around of 5,000 tonnes per day and it was being managed by DCC. DCC was being collected the solid waste from the primary collection bins and dumps at the ultimate disposal sites. According to DCC Ordinance people are responsible to collect waste from house to the primary collection bins. DCC waste collection workers sweep the roads, clean the drains and carry the waste to the primary collection bins/containers by vans. DCC waste collection workers also collect vegetable waste and commercial waste from every market and other commercial places to the primary collection bins by vans.
The industries have to manage their waste by their own initiative and Department of Environment (DoE) monitors it. Due to lack of collaboration it is a sector of big mismanagement. Nowadays DCC gives liability to Prism-Bangladesh to manage medical waste separately in some areas. But it should be throughout the whole city.

The only initiative by DCC to manage the solid waste is landfill and landfill is not the only solution for SWM. Compilation of some process is necessary to improve the SWM system in Dhaka City. The following measures should be taken:

- Source separation is very important for domestic, commercial, industrial and medical waste.
- Every house, institution, industry should have a common waste storage bin where all the families of the house should store the solid waste. For hazardous waste the house should have a separate bin.
- DCC should take the responsibility of primary collection of solid waste. DCC workers should collect the solid waste from the common bin of houses, industries and institutions.
- The primary collection bins should not be placed beside any road street. It should be re-placed in suitable places.
- Biodegradable waste should be separated at the primary collection bins and should go through the processing to produce electric energy or compost.
- Hazardous waste should not be mixed with other waste and should be carried and disposed separately.
- First time separation of recyclable items should be at the common storage bins. The final separation might be done at the primary collection bins.
- The land filling of biodegradable waste should be stopped and initiative should be taken for electricity generation or compost production processes.
- While carrying the waste the trucks should not be overloaded and should be covered by thick cloth (*tripol*) to prevent scatter and bad smell.
- Modern technology should be used in every step of SWM such as, collection, transportation, recycling, disposal and other processes.

Through the study the limitations of the existing strategy and the better options to improve the SWM system in Dhaka city is found out.

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Planning of Transfer Station for Municipal Solid Waste Management in Khulna City of Bangladesh

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ABSTRACT

The present scenario of Municipal Solid Waste (MSW) management in Khulna City is not satisfactory. Lack of proper management, lack of people's awareness, motivation and participation, inappropriate technology adoption, financial constraints, ineffective legislation and law enforcement, keep MSW situation out of proper management. The most important tier of MSW management is the on-site storage, currently available and poorly managed open space, Community Bins (CBs), Secondary Disposal Sites (SDSs) and Dustbin Points (DBPs). Realizing the present situation of MSW management, it is evident that there is a strong need to change the present secondary disposal system. These problems can be solved by removing these disposal sites in phases with a well designed and properly managed Transfer Station (TS) Networks. This study highlights the adoption of transfer station methodologies and planning. Proper functioning of TS can reduce hauling costs, increase the coverage of primary collection, reduce illegal dumping, littering and scavenging of wastes in the cities along road sites and the increase of overall efficiency and hygienic conditions of the system.

INTRODUCTION

Solid Waste Management has so far been ignored and least studied environmental issues in Bangladesh, like in most of the developing countries. However, recently the concerned stakeholders have begun to consider this area to be an inseparable part to protect urban environment. Despite the inherent constraints, the city authority has been trying to solve this social and environmental issue. Due to the absence of an integrated system, there are many loop holes and constraints in the existing waste management practices, which ultimately failed to improve the overall system. Sustainable management of waste with the overall goal of minimizing its impact on the environment in an economically and socially acceptable way is a challenge for the coming decades.

This study highlights the present situation of MSW in Khulna city and its existing management specially secondary disposal and collection of ultimate disposal, transfer station methodologies in general and possible implementation of transfer station (TS) through proper planning and zoning for efficient waste handling capacity and in compliance with environmental standards and guidelines followed by the acts and other regulations. The proposed study locations of Khulna City Corporation (KCC) area is about 45.65 km^2 with a future plan to extend area of about 70km^2 known as Khulna City Projected Area (KCPA). Basic principles for the planning and design of TS should be in the line of the system that has been practiced in the city for primary collection. Presently, Door to door (DtD) collection is practiced and it is expected that this system will be continued and enhanced further in future. In DtD collection system, Rickshaw van is the preferable means to collect solid waste and hence being carried till the SDSs. This is a manual labor intensive system and a rickshaw van can cover as much as the distance covering an area of 1 km radial distance as revealed in the present situation. TS should be able to handle the waste comes from the catchments and waste should be protected from monsoon rains. So, the TS should be located near the center of waste catchment areas with an access road adequate for transfer vehicle for ultimate disposal such as open or covered trucks. As the rickshaw van in conjunction with demountable container are the major depositing and transporting vehicles of waste, much attention should be given while designing a transfer station. The planning and sitting of transfer station also depends on land use pattern, population density, waste generation rate, proximity to collection area, amount of waste deposition and accessibility of haul routes to disposal facility considering future perspective. Considering all the above parameters, TS should be planned in convenient locations in a proper manner that would meet technical requirements and minimize any adverse impacts to the neighboring communities. From the present situation of waste management system, it is recognized that there is a strong need to change the present secondary disposal system to a transfer station, which can make a change in the present scenarios of MSW in Khulna city which suffers very much due to the unpleasant and unhygienic situations of the SDSs.

EXISTING MANAGEMENT OF MSW IN KHULNA CITY

In Khulna city, KCC is liable to overall management of MSW in urban areas as per the Municipality Act. Solid waste management (SWM) in Khulna, like other cities of Bangladesh, is hampered by the absence of adequate national or local legislation relating to the municipal SWM and the treatment and disposal of hazardous waste. In particular, there are no mandatory regulations or performance standards for city corporations (e.g. KCC) to establish and manage an effective SWM system. The city authority cannot attempt properly due to severe financial constraints, required infrastructures, absence of appropriate and sustainable technology, lack of motivation, awareness and participation, and the absence of effective legislation. As a result SWM in Khulna has developed in a piecemeal and uninterested manner with NGOs, CBOs, informal recyclers and private enterprises being involved along with KCC (WasteSafe, 2005). However, some Non-Governmental Organizations (NGOs), Community Based Organization (CBOs) and Private sectors have been started to work with city authority's initiatives to solve this striking social and environmental issues. Generally, in the City Corporation and/or municipality, Conservancy Department is responsible for solid waste management including other utility services. There is no independent wing with sufficient authority to deal the MSW problems in the urban areas; however, recently city authority has taken the initiates to alter the administrative set-up in developing an independent wing to deal MSW problems. Major reasons for Khulna's poor SWM can be short listed as:

- Low managerial, technical & financial resources available to operate SWM system.
- The lack of public awareness and commitment leads to indiscriminate dumping of waste (workshop, 2009).

Functional Elements of SWM in Khulna

The SWM is a complete chain which connects the various relevant links i.e. components starting from generation point to the ultimate disposal. The functional element of SWM at Khulna is almost similar to that of the other cities of Bangladesh. The functional elements indicating the flow of wastes from the starting point till the collection from on-site storage for ultimate disposal is shown in Figure 1 by a flow chart and hence discussed briefly in the following sections.

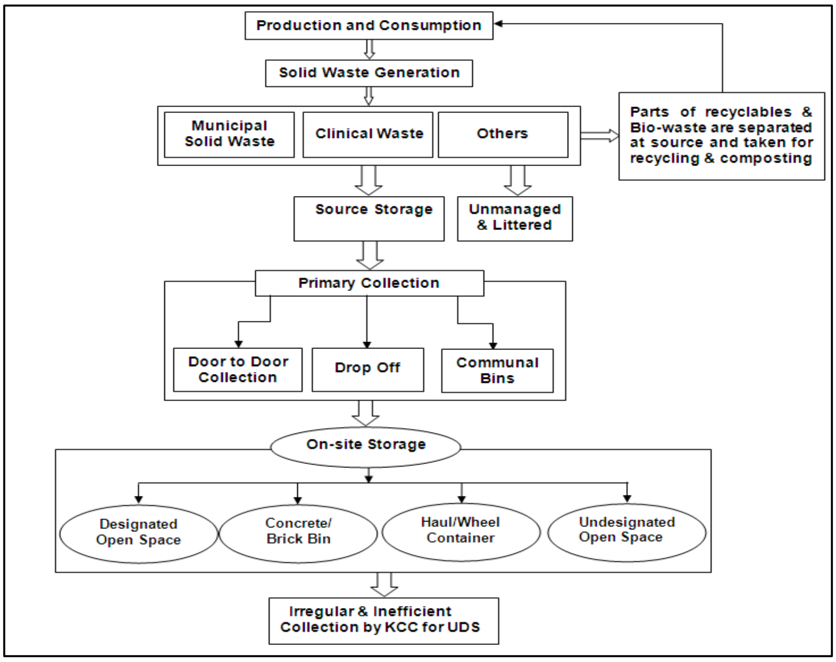


Figure 2 Functional elements of SWM in KCC

Primary Collection and Transport

In Khulna city, primary collection of solid waste management is accomplished in three ways:

a) DtD Collection system,
b) communal collection system &
c) Drop off.

In DtD collection service, the house holders store wastes in a bin, basket or bag within their house premises. Waste collection workers collect the bin, basket or bag, empty it into the collection vehicle and return the containers to the premises. DtD collection is done mainly by NGO, CBOs and city authority who charge a fee for periodic removal of waste where rickshaw van is used for major transporting vehicle for DtD collection of waste as shown in Figure 2. In the areas where DtD systems are not available, house dwellers or servants carry wastes to nearby community bins/secondary sites or similar facilities at their own responsibility. City dwellers also dispose waste to the open land/road sides/drains indiscriminately. It was estimated that fewer than 30% of KCC households had access to waste disposal facilities (CDIA, 2009). While this situation has improved due to the increased involvement of NGOs and the private sector, currently only 50-60% of household waste is collected while most of the remainder (40-50%) being disposed of indiscriminately in drains, at roadsides and into vacant areas. City authority has some limited numbers of non-motorized Rickshaw vans and Hand trolley those are mainly used for the collection of MSW from community bins located at roadside, home side, near market and transfer to the SDS. Non-motorized rickshaw vans are generally used to operate the collection system. One driver and one helper are assigned for each van and the collection generally occurs daily for 8 to 9 hours (7 am to 5 pm) from residential sources as well as some offices. Non-motorized rickshaw vans are almost similar 3-wheeler type, which are used in different cities of Bangladesh. The capacity varies from 250 to 350 kg/van/ trip. DtD collection service is aesthetically and environmentally more satisfactory but comparatively more expensive.

Figure 2 Newly designed manually driven Rickshaw Van for door-to-door collection

On-site Storage

On-site storage is the secondary disposal site (SDS), Transfer Station and Handover Points, which receives wastes from primary source and transferred to the designated location for processing/recycling/treatment and mostly for ultimate disposal. There is no transfer station and handover point in Bangladesh in true sense. SDS is considered as the facilities where large amount of wastes are accumulated at open spaces, dustbin points, and containers (shown Figure 3) and finally transferred to the desired sites by large vehicles such as open or closed Trucks, Demountable haul container truck, etc. Containers of different shapes, sizes and functionality are available. In Bangladesh, city authority is solely responsible for providing SDS, collection of wastes from SDS and transfers them for final disposal as per existing City Corporation Act. SDSs are located in the selected places based on population, space availability, accessibility and other local factors such as desire of influential city dwellers or public representatives. Wastes are deposited in SDS directly by the generators, NGOs, CBOs and city authorities. City corporation's motorized vehicles collect the wastes from SDS and transfer to the UDS. Some NGOS transfer their collected organic wastes to composting plants. In some cases, especially for the residential areas along narrow streets where SDS is not suitable, community bins are provided from where wastes are transferred to SDS. Community bins are mostly made of the concrete but masonry and steel container are also available. The concrete and masonry bins are in variable sizes but normally rectangular in shape of 1x1x1 m. Generally there is a door at one side and no cover on the top of the community bins. Wastes from community bins are transferred to SDS mostly by city authorities through non-motorized Rickshaw van and hand trolley. In KCC, there are more than 60 SDS, around 1200 community bins and 28 haul containers, located on roadsides throughout the city (Chowdhury et al. 2006).

(a) Designated open space (b) Dustbin point (c) Demountable container

Figure 3 On-site storage facilities in Khulna City

Waste Collection from On-site Storage

Wastes irrespective of types are generally disposed at the SDS. In general, city authority collects wastes from the SDS and disposed to the designated UDS. SDS are often in poor condition and/or badly located (e.g. near or on drain, footpath obstructing pedestrian movement), it always remains with wastes even just immediately after the collection shown in Figure 4 and transfer of wastes, its operation often causes traffic jam and waste spreading, flies, dogs and even by scavengers. The situation of SDS in the city is very much unpleasant and it reveals as an effective step causing most nuisances and deteriorating city environment at a large scale. All the SDS of Bangladesh does not have minimum infrastructure requirements and environmental protections. It is evident that all the disposal sites are posed to high threat to health and environment. As a result, city authorities are facing very complicated situations for the management of vast quantities of MSW. Due to non-engineered situation, the existing sites are also going to early closure. Peoples are also protested to close some existing sites because of their hazards nature. So, the existing practices will not get the support from concerned stakeholders in future. So the transfer Station may provide a safety measure in a good waste management system addressing this social and environmental issue despite the realization that only affordable disposal solution in Bangladesh for the foreseeable future –is to establish Transfer station (TS).

Figure 4 Waste collections from SDS

Waste Transport from On-Site Storage and Disposal at UDS

Generally collection vehicles of KCC such as covered waste truck, normal truck, open truck, waste truck with compactor, Tractor with trolley, haul container truck, power tiller with trolley are used for waste collection from SDS and transportation. Figure 5 shows the typical waste collection and transportation in Khulna metropolitan city. The conservancy department of KCC daily transports the MSW deposited in the SDSs. Due to the inherent constraints of resources and mismanagements, the transport efficiency is revealed as 60 to 70% (CDIA 2009). The details of transport used for disposal solid waste in Khulna city with the vehicle fleet is listed in Table 1. Over the years, KCC has increased its staff size and equipment, but these are insufficient in terms of quality and quantity according to the need. However, it is true that even having these constraints the overall situation of management of

Figure 5 Waste carrying vehicles for the UDS

solid waste in Khulna city could be improved introducing a sustainable system (SAP 2008). There is no implemented time related operation plan of the SDS indicating time slots for the city dwellers to drop the wastes until the waste is reloaded to a KCC truck. Average transport velocity in urban areas is 20–25km/h at daytime, 25–30km/h at night time while it is 50–60km/h in rural areas. In average a truck needs 3–4h/tour because of long loading time and low speed on the roads. Given time for the CBOs and NGOs for waste delivery to the SDSs is daily 10am, after 10am the KCC trucks normally load the waste and transport it to the UDS. However, the time schedules are not maintained properly. It also varies at different locations. Normally 40% of the trucks are under repair (WasteSafe 2005). Table 2 shows that KCC can transport between 70–200 t/day. This is well below the estimated daily generation of waste (300 t/day). The situation is exacerbated by the division of SWM responsibilities between the transportation and conservancy departments of KCC.

Table 1 Vehicles used for the secondary disposal of solid waste by the Conservancy section of KCC. (after CDIA 2009)

Vehicle Type	No.	Pay-load [tons]	Location
Covered Trucks	3	5	Mobile
Dump Truck – large	9	7	Mobile
- medium	8	5	
Tipping Truck (container carrier)	L: 5 M: 2	L: 5 M: 2.5	Mobile
Wheel loader	1		landfill
Back wheel loader	1		landfill
Chain dozer	1		landfill
Chain dozer carrier	1		landfill
Garbage loader	1		SDS
Tractor with trolley	1	4	Mobile
Power Tiller with trolley	2	0.25	Mobile
Side Tipper Trucks with double containers	1	2	Mobile
Demountable Container	20	5	Mobile

Table 2 KCC transport capacity for SWM (after CDIA 2009)

Vehicle Type	No. of vehicle	Payload [tons]	Transport capacity [tons/day]		
			1*	2*	3*
Covered Trucks	3	5	15	30	45
Dump Trucks	9	7	63	126	189
	8	5	40	80	120
Tipping Truck (container carrier)	5	5	25	50	75
	2	2.5	5	10	15
Tractor with trolley	1	4	4	8	12
Power Tiller with trolley	2	0.25	0.5	1	1.5
Side Tipp. Trucks double cont.	1	2	2	4	6
	Total**		154.5	309	463.5
	75 % for SWM		115.9	231.8	347.6
	60 % in operation		**69.5**	**139.1**	**208.6**

TRANSFER STATION

Waste transfer stations play an important role in a community's total waste management system, serving as the link between a community's solid waste collection program and a final waste disposal facility (www.epa.gov). Transfer station is a solid waste processing facility where waste is transferred from one vehicle to another vehicle or temporary storage until transferred to a permanent disposal site approved by the solid waste management authority or permitted by any other solid waste management authority having jurisdiction over the location of their permanent disposal site.

There are two principal reasons for constructing a transfer station: (a) Economics: If the destination of the wastes is far away from the area in which they are collected, then it may be more economical to transfer the wastes to large vehicles for haulage than to haul them directly in the original collection vehicles. This situation is becoming increasingly common, as landfills become more difficult to site and, therefore, more remote from populated areas. (b) Service: For a rural area without a garbage collection service, a transfer station is often provided as a service to local residents, so that they do not have far to drive to drop off their wastes. A transfer station is often established at a landfill after it has been closed because people are accustomed to taking their waste to that location. Such a transfer station may or may not be economical.

Types of transfer station

Transfer stations are used to accomplish transfer of solid wastes from collection and other small vehicles to larger transport equipment. Depending on the method used to load the transport vehicles, transfer station may be classified into three general types: (a) Direct –load, (b) Storage –load and (c) Combined direct load and discharge load. Transfer station may also be classified with respect to capacity- (a) Large > 500 tons/day, (b) Medium 100- 500 tons/day, (c) Small < 100 tons/day (Tchobanoglous et al. 1993).

Sitting conditions of Transfer station

A variety of issues must be taken into account during the planning and sitting stages of transfer station development. Ideally, a transfer station should be sited as close as possible to the centroid of the population served, in order to minimize collection costs, or some distance along the haul route to the landfill and should be operated so as to create no environmental or health hazard, and no nuisance. The sitting of a transfer station will be planned and designed based on the evaluation of the following important aspects:

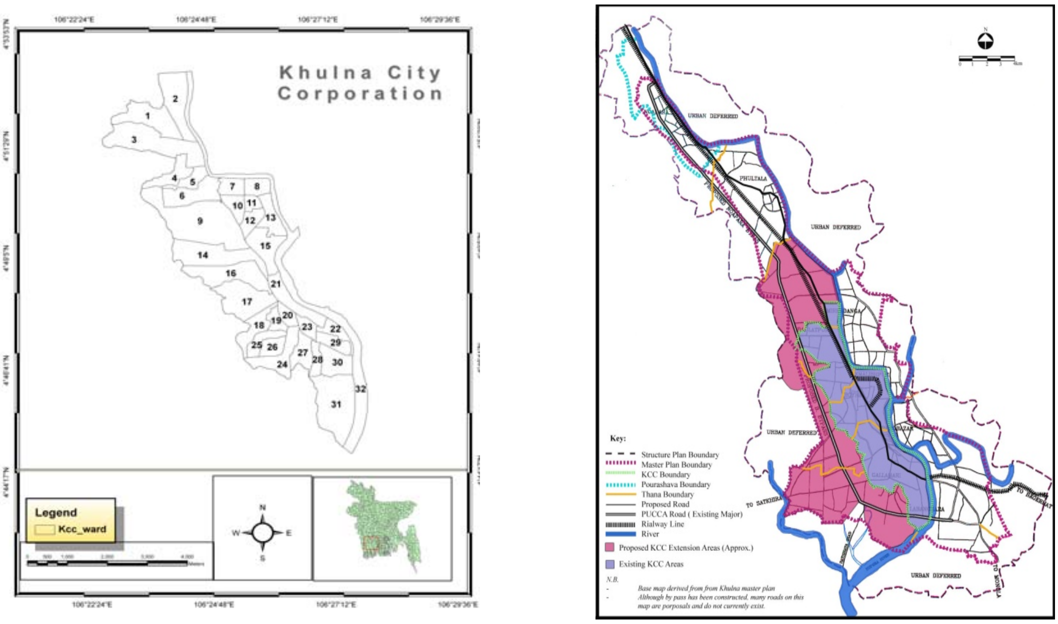
- **Location:** Centroid of waste stream, Heavy Collectors, Existing/future traffic patterns, Railway.
- **Zoning:** Adjacent zoning – different, how close - across the street, Neighbors? Type of businesses, Surrounding properties, type, quality, Area undergoing change.
- **Environmental:** Contaminated site, Wetland, Endangered Species, Migratory route, Flood Plain, Historically or archeologically significant site.
- **Infrastructure:** Water, Fire flow, Sewer, Restrictions, Electricity, Supply, Permitting Requirements.
- **Visual:** Exposed site, Highway, public R.O.W., High rise, Hillside residential, Buffering, Design.
- **Noise**: Sensitive receptors, Retirement, school, hospital, Echo condition, Neighbors.
- **Wind**: Predominant direction, Seasonal gusts, Exposed / protected area, what lies downwind.
- **Area**: Size, Configuration.

PLANNING OF TRANSFER STATION

Proper planning of transfer station is very important before its implementation to cover an area and to serve a community. All the relevant aspects need to consider with great care. However, to make tentative plan about the locations of transfer station in Khulna city, here, limited number of parameters are considered as discussed in the following sections.

Khulna City Plan and Layout

The location and the city plan layout play a vital role in the planning of transfer station for MSW management in any urban areas. Khulna City is a linear shaped city based on the flood free natural levees (height from 2.13 to 4.27m) on both sides of the Bhairab-Ruphsa River. Its elevation decreased sharply to the east and west directions down to flood plains (height from 1.22 to 1.52m). For the purpose of the study a wider future urban area than the Khulna City Cooperation (KCC) is considered as Khulna City Project Area (KCPA) as shown in Figure 6. The area of KCC is 45.67sq.km, while the area of KCPA is 69.71sq.km. At present KCPA has an estimated population of 1,169,000 inhabitants following a medium projection from the 2001 census. Accordingly, the population of KCC in 2009 is projected as 930,000 inhabitants. Overall population density in KCC in 2001 (around 770,000 inhabitants) excluding non-built-up areas was around 200/ha and will increase in future due to limited land availability for city expansion and limited mobility resulting from the continuously low income level. The number of households was stated in the 2001 census for the KCC area as 171,000 and for the KCPA as 199,000. Around 5 % of these households are non-privates with 5.5 % of the total population. KCC is structured in 31 Wards. All proposals are based on a projected population of the KCPA of 1.33 million in 2015 and incorporate likely changes in per capita waste generation and its composition. These projections imply an approximate 60% increase in daily waste generation from 288 tons in 2009 to 466 tons in 2015. However, an informal estimation of KCC'S population by its authority is considered as 1.5 million since 2005 as reported in various reports (WasteSafe 2005). In such estimation, the amount of wastes will be higher than that of as stated earlier.



(a) KCC Map (b) KCPA Map

Figure 6 Map of Khulna City and the surrounding area

Planning Criteria to Set up Transfer Station in KCC

To make a sustainable transfer station system, the existing practice on SWM at Khulna city is considered in the planning. Presently, the DtD collection system by rickshaw van is proved as an effective and popular method to bring the wastes into the SDSs. The Rickshaw van is driven manually and collected wastes with the help of one driver and one helper. In this circumstance, the location of transfer station should not be far from 2 km distance from the source, while rickshaw van will be considered as the major transporting vehicles of waste from generation source to SDSs. As presented in Table 3 for primary collection, rickshaw van can carry waste 0.25 to 0.5ton/tour and transport waste amount is about 0.25 to 1.5tones daily. It can travel maximum 8 working hours and can cover the area maximum 1km radius. Other important aspects need to consider at the design stage to materialize the transfer station concept are: incoming waste amount and type, type of outgoing vehicle, land availability and accessibility, sorting/ no sorting facilities, covered or uncovered, financial sustainability and the management, etc.

Table 3 Rickshaw van transport capacity, acceptable distance and tours per day (After CDIA 2009)

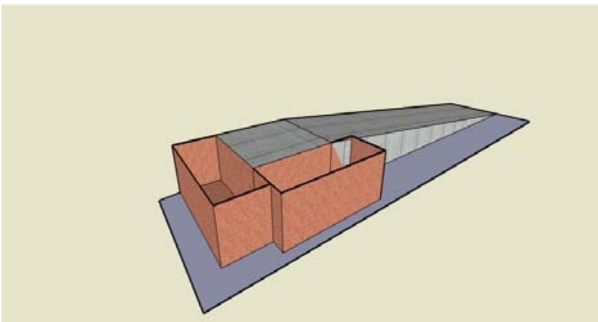
No. of Rickshaw vans	Transport capacity per van [kg]	Acceptable transport radius [km]	Tours per day	Transport capacity per day [kg]
1	500 375 250	1	2-3	1,000 – 1,500 750 – 1,025 500 - 750

Location of Ultimate Disposal Sites

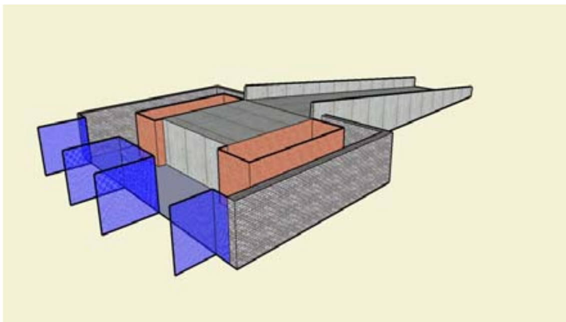
The existing UDS of Khulna city is located at the Mouza Rajbandh under Batiaghata Upazilla, Khulna District, besides Khulna-Satkhira Highway, which is around 8.0 km west away from the city centre (Hotel Royal and Castle Salam Square). The wastes are collected from SDSs and transported by KCC's initiatives and hence finally disposed in UDS. The used transferring vehicles have an average transport velocity of 20–25km/h at daytime and 25–30km/h at night time with a wide variation of pay load ranging from 0.25 to 7tons (CDIA 2009). In an average, a truck needs 3–4h/tour because of long loading time and low speed in the city areas. However, the time schedules are not maintained properly. It also varies at different locations. There are some proposal made by Khulna Development authority (KDA) in its Master Plan (2002) for the possible future UDS. These possible sites are Aronghata, Chachibunia, Phultala and Karnopur (MPKC 2002) as shown in Figure 9. All these sites are located in the west side of newly constructed Khulna by-pass. So there exists very good communication with different parts of KCC and KCPA. These aspects should be taken into consideration for the effective functioning of TS to be developed in the different locations of the city. The distance, road links and traffic congestion in the roads between the TS and UDS might play very vital role in the planning. The use of manually driven rickshaw van can be considered as an alternative of existing KCC's vehicles to transfer the wastes in the UDS.

Configuration of Transfer Station

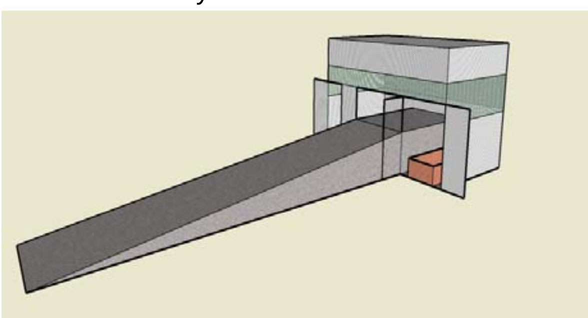
From a series of stakeholders' dialogue and discussion, it is evident that an affordable and sustainable transfer station criterion should be considered in the design. From these perceptions, WasteSafe II and ADB teams (WasteSafe II 2008 and CDIA 2009) proposed several tentative configurations of transfer station were submitted to KCC, separately, as presented in Figures 8(a) to (d). Just to have a rough idea, it can be stated that one of the proposal, Fig.(d) claims (WasteSafe II 2008) that the land required for such transfer station is 21m Length and 15m width. A RCC ramp of 2.5x35m size needs to have a minimum slope of 10% for easy movement of rickshaw van and to unload the wastes over a 3.45m high platform. There is another facility to stand two trucks always under the platform which can directly receive the wastes from the rickshaw van. The movement of trucks can take place easily at the yard of transfer station so that it will not make any trouble in the movement of other traffics and the pedestrians. However, in the final decision and design, these configurations can act as a guideline.



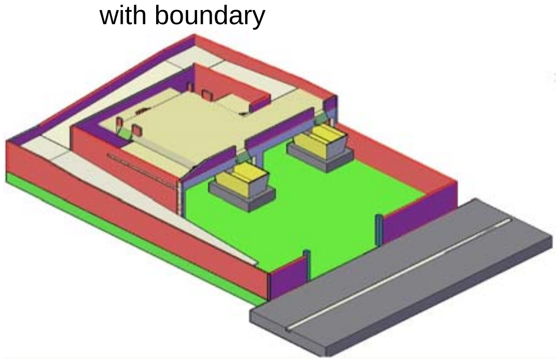
(a) Direct loading to demountable container from incoming Rickshaw van. No boundary



(b) Direct loading to demountable container from incoming Rickshaw van. with boundary



(c) Provision of unloading from Rickshaw Vans, sorting and reloading under covered area.

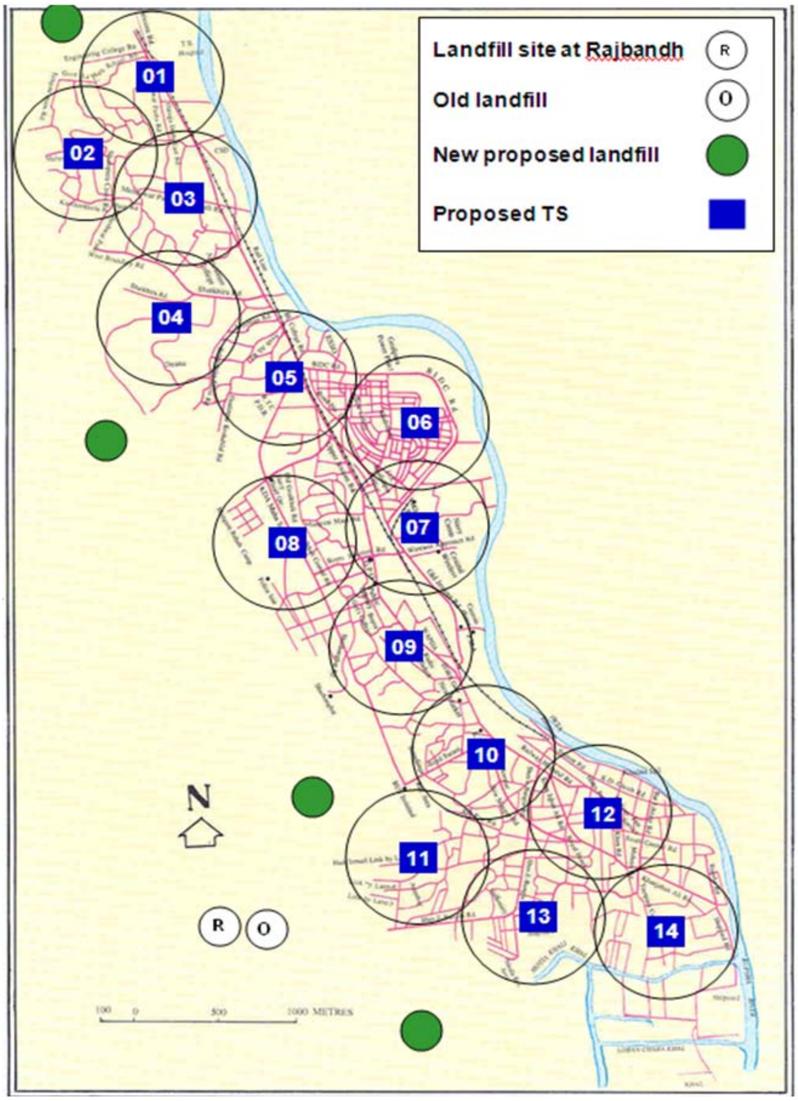


(d) Provision of unloading from Rickshaw Vans, sorting and reloading at open space.

Figure 8 Configuration of the transfer stations having different provisions (CDIA 2009).

Location of transfer station

On the development of appropriate waste transfer station schemes, the socio economic needs of the respective community, technical, financial and environmental aspects need to consider, besides other aspects such as city layout, population and waste amount. As the transport media of incoming wastes to the transfer station is Rickshaw Van, in this study the locations are outlined only considering the zone of influences surrounding the transfer station that can be covered by a manually driven Rickshaw van at a time i.e. per trip travelling capability. On the basis of such a tentative estimation i.e. 2 km covering distance, the KCC has been divided into 14 number of influence regions as shown in Fig 9. In this proposal and planning, 14 Transfer stations have been suggested tentatively to install in these influence regions. These identified locations for sitting of transfer stations are (i) Mirerdanga, (ii) Moheshwar pasha, (iii) Maniktala, (iv) Along old Sathkhira by-pass road, (v) Daulatpur, (vi) Khalishpur, (vii) Charerhat, (viii) Mujgunni, (vix) Choto boyra, (x) Sonadanga, (xi) Nirala, (xii) Sheikhpara, (xiii) Toot Para and (xiv) Labanchara. Although the locations of 14 TS have been identified, however, it is suggested that initially a transfer station may be offered to construct first to justify the performance of transfer station in replacement of secondary disposal sites for future perspectives.



Location of TS:

1. Mirerdanga
2. Moheshwarpasha
3. Maniktala
4. Along old Sathkira bypass Road
5. Daulatpur
6. Khalishpur
7. Charerhat
8. Mujgunni
9. Choto boyra
10. Sonadanga
11. Nirala
12. Sheikhpara
13. Tootpara
14. Labonchara

Figure 9 Locations of Transfer Stations surrounded by the influence areas in KCC

CONCLUSIONS

The present situations of SDS in Khulna City should be changed for further improvement of the existing SWM to achieve environmental sustainability. Transfer station can play a vital role in the replacement of SDSs. Current study highlights on the planning of transfer station at the KCC areas. Planning, design and construction of transfer station will depend upon the space availability, efficiency of primary collection, population density, waste generation rate, financial supports of KCC and the prevailing technological capabilities. However, proper steps should be taken considering layout of the city, proper estimation of area-wise population and waste generation in the present as well as future perspectives. Initially, the tentative locations of 14 transfer stations have been identified based on the covering area only. Further study should be carried out considering all the relevant aspects for final planning and design of transfer station.

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Assess the Problems of Solid Waste Management in Rajshahi Metropolitan Area

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ABSTRACT

This paper represents the problems of Solid Waste Management (SWM) in Rajshahi Metropolitan Area (RMA). The two types of data, the primary and secondary data were used in this investigation. Interviews and personal observations were also used to collect some of the data. Wrong attitudes and perceptions of the people about sanitation issues contributed to solid waste management problems of Rajshahi City Corporation (RCC). The waste management, particularly SWM is one of the important obligatory functions of not only urban local authority but also of the awareness of urban people. But this essential service of RCC is not efficiently and properly performed by the local bodies and the people are not aware about this problem, resulting in many health, environmental and sanitation problems. Virtually, all the people depended on the RCC facilities for the disposal of their household refuse. SWM problems were partly the results of City Corporation inability to manage the situation because of short of equipment and personnel. It is observed that the short of financial resources, institutional weakness, improper selection of technology, transportation systems and disposal options, public's lack of concern towards environmental cleanliness and sanitation have made this service unsatisfactory. It is recommended that more educational awareness of SWM should be provided by the city dwellers of RMA to sensitize the people on the need to keep the surroundings clean.

INTRODUCTION

Solid waste is defined as any useless, unwanted, or discarded material that is not liquid or gas. Something can become waste when it is no longer useful to the landlord or it is used and fails to fulfill its purpose (Gourlay 1992). Waste means unnecessary depletion of natural resources, redundant costs environmental damage that could be avoided (White et al. 1999). People's apathetic and lackadaisical attitudes towards matters relating to personal hygiene and environmental cleanliness, of which waste management in general is its focal point, should not be over looked. In the major cities of Bangladesh, it is observed that the vegetables & food wastes are the predominant component in the waste stream. The composition of municipal solid waste is very much similar to those of other least developed countries and details are presented in WasteSafe (2005), Alamgir & Ahsan (2007a & 2007b). According to a United Nations Conference on Human Settlement report, one third to one-half of solid waste generated within most cities in low and middle-income countries are not collected. They usually end up as illegal dumps on streets, open spaces, and waste lands (UNCHS 1996). Irregular services rendered to producers of refuse by municipal councils compel them to find ways of disposing of refuse. It was observed that the main methods adopted by the producers are burning, composting, or indiscriminate dumping. Although these weaknesses have been attributed to lack of logistics and financial management, people's attitudes towards waste management should not be ignored. It was outlined several factors, which have conspired to promote the massive build up of urban garbage and waste. According to Stirrup (1965), the method of refuse disposal must be related to the nature of the community served, its financial capacity, and the type of materials arising, climatic conditions, the desirability of utilizing materials in certain instances compared with the imperative need to utilize them in order to assist in the provision of vital raw materials. The waste producers generate large volumes of wastes but do not dispose of waste in an acceptable manner. This is important to the study because people's attitudes towards waste management are questionable. With the establishment of the Waste Management Department of Metropolitan and Municipal Assemblies, the public tends to have the view that the departments should be solely responsible for managing wastes. It was further observed that indiscriminate disposal of waste has resulted in the clogging of the few built drainage channels and natural watercourses with garbage and silt, which are not removed regularly. Awareness should be created among the residents to manage household refuse and educate them on the hazards that ill-disposed waste could pose to the environment and to them. People's unconcerned attitudes towards solid waste can be changed for the better through education. There is no single solution to the challenge of waste management. The waste management process is usually framed in terms of generation, storage, treatment, and disposal, with transportation inserted between stages as required. It is therefore becomes important for this study to examine the problems of solid waste management in Rajshahi town. This research is therefore intended to provide insight to citizens, government officials, and business people who might want to help resolve the solid waste management crisis in Rajshahi City Corporation area.

PROBLEM STATEMENT

In spite of the present concerns of individuals and the administration about waste management in Rajshahi City, one of the many suburbs of Rajshahi Metropolitan Area, is still faced with serious solid waste management problems. From observation, domestic and municipal solid wastes are commonly found in Rajshahi Metropolitan Area. Domestic waste comes from activities such as cooking and from human excreta. Municipal wastes are the trash from household's commercial establishments and small industries. These include polythene bags, tins, plastic products, rubbish and vegetable wastes. These form the greater part of the waste observed on the streets, in gutters, and the back of houses in RMA. Containers for storing solid wastes in homes include old buckets, baskets, plastic containers, boxes, sacks, and even polythene bags, which in most cases have no lids. Hence, the wastes are even spread around before they get to the sanitary sites. Solid waste, when treated well, can be turned into a resource, but the greater part of wastes generated in RMA seem not to undergo any treatment before their final disposal. They are left in piles for weeks to create unsanitary scenes that smell bad and, worst of all, create diseases. Solid wastes generated in RMA are most often disposed of in open dumps, gutters, and at the back of houses probably due to the inadequate solid waste management equipment or the long distances to the sanitary sites. People also leave their wastes in piles for days before they finally get to the sanitary sites for disposal. The above problems make it clear that the Municipal Assembly is unable to cope with the problem. On the bases of the above problems, the study has the following objectives:

OBJECTIVES

- to ascertain the attitudes and perceptions of people towards solid waste management.
- to assess solid waste management both at the household levels and by RCC as well as the personnel status of RCC in handling solid waste in the study area.
- to assess the kind of incentives available for the RCC workers dealing with solid waste.
- to make recommendations for improving solid waste management in the RMA area.

PROPOSITIONS

The people's poor attitude and perceptions about solid waste management have contributed to the problem. Inadequacy and inefficiency of solid waste management equipment and personnel are also contributing factors to the problems of solid waste management.

INSTRUMENTS

The primary data were collected using structured questionnaires. The questionnaires contained both closed and open-ended questions, and they were self-administered. In all, 100 questionnaires were administered to households. Secondary data were collected from appropriate data sources, including books, journals, newspapers, and activities both published and unpublished. Seventy-Five (75) females and 25 males were interviewed. This distribution was used because it is observed that the females, mostly mothers, are responsible for domestic waste handling. Again, solid waste production is at the household level. The authorities of the RCC were also interviewed. Personal interviews and observations were conducted to obtain more information. In order to assess whether or not people's attitudes and perceptions have relationships with their level of education, 35 people without formal education were interviewed, and the other 65 people interviewed had some level of education (elementary, junior secondary school level, senior secondary school level, and tertiary level education). The data gathered from various sources were processed and analyzed. Simple descriptive statistical and analytical tools such as frequencies, percentages, and pie charts were employed in the analysis of the data.

HISTORICAL VIEWPOINT

According to historical records, the name “Rajshahi” is commonly believed to mean royal territory, and it is a popular idea that the district was given this name because it was the home of many Rajas (kings). Its legal and administrative status has changed over the years paralleling its growth in population and importance in the national urban hierarchy. Rajshahi City was simply a district town prior to 1947 and became divisional Headquarters in 1947. Rajshahi town upgraded Municipal status in 1876 during the British regime and achieved the status Municipal Corporation in 1987 and becomes Rajshahi City Corporation in 1990. Rajshahi City Corporation is located to the northern part of Bangladesh and about two hundred seventy miles away from Dhaka city. It extends over an area of about 48.06 sq km. of level ground. Its longitudinal boundaries are between 88°28” and 88°38” east. Latitudinally, it is between 24°22” and 24°36” north.

GEOGRAPHY AND PHYSICAL ENVIRONMENT

Rajshahi City Corporation is bounded in the west by Gogagrai Upazila, east by Charghat Upazila, north by Paba Upazila and south by the Padma River. The town occupies the flat alluvial land bordering the northern bank of the river Padma. The core area of the city consists of high land having ground elevation around 18.5 m with higher grounds situated along the bank of the river Padma that gradually slope down towards the north to a minimum level of 15.2 m at the northwest corner of the city corporation area. The plan view of the City Corporation area looks like an inverted ‘T’, its maximum length along east west direction is about 13 km and that north south is 8 km. The map of Rajshahi City Corporation with 30 wards is shown in Figure 1. Among the environmental problems of the RCC area ground water pollution is a critical one. Water contamination is high due to high content of iron 0.4 - 3.5 mg/l, high amount of hardness and high content of manganese 0.1-1.52 mg/l. It should be noted that although the RMA and RCC maps (Figure 1) show an area of around 48.06 km^2, and although this is the area acknowledged by the Rajshahi Development Authority (RDA) as the extent of the RCC area, official figures provided by RCC and the Bangladesh Bureau of Statistics (BBS) give an area of 96.72 km^2. Attempts by the project team to understand this difference have not resulted in success, although it does appear, based on the GIS maps and the RDA 2003 Master Plan (RDA vol-I & vol-2, 2004), that the figure of 48.06 km^2 is correct as presented in Table 1. Land use statistics also vary, depending on the categorization and method of measurement. The other land use categories identified in this survey are provided in Table 1.

Table 1 Land use of Rajshahi City Corporation Area in 2003

Land use	Area (km^2)	Percentage (%)
Residential	16.08	33.45
Agricultural	9.01	18.75
Educational	5.05	10.51
Business	0.95	1.98
Public administrations and institutions	0.96	2.00
Mixed use	0.11	0.23
Industrial and storage	0.39	0.81
Open space, vacant or char land	6.50	13.52
Defense	0.97	2.02
Roads and railways	2.86	5.95
Water bodies	5.18	10.78
TOTAL	48.06	100.0

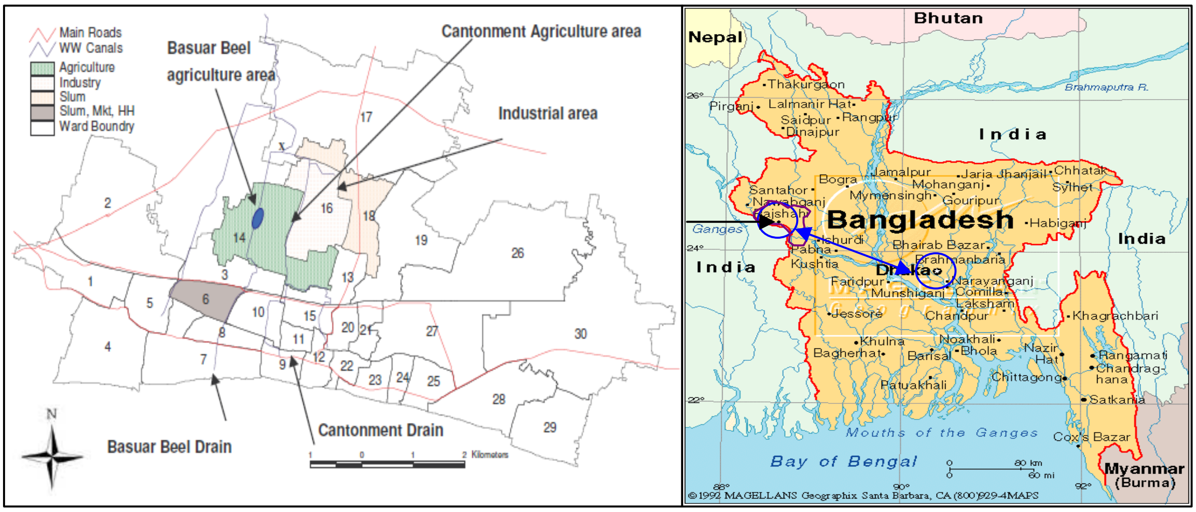

Figure 1 Layout map of Rajshahi district and Rajshahi City Corporation

RESULTS AND DISCUSSIONS

Attitudes and Perceptions of the People towards Solid Waste Management

Issues of attitudes and perceptions appear to affect both inhabitants and authorities regarding solid waste management in RCC. Issues such as people's opinion on responsibilities for ensuring clean surroundings, education of household to clean their surrounding, disposal of household waste, and children's involvement in solid waste management are described in Table 2.

Table 2 People's responsibility for ensuring clean surroundings

Response	Frequency	Percentage (%)
RCC	102	60.00
Individuals	46	27.06
RCC & Individuals	22	12.94
Total	170	100.0

With a large percentage of the population thinking that RCC is solely responsible for ensuring clean surroundings, it is likely that the people may not support clean up campaigns meant for making the surroundings clean. This may partly explain why RCC is engulfed in filth and yet the respondents seem unconcerned. This confirms the studies that with the establishment of the Waste Management Department of Metropolitan and Municipal Assemblies, the public tends to have the view that the RCC should be solely responsible for managing waste. In order to change this trend it is suggested that the people be educated to see the problem as a shared responsibility of both the individual in the respective communities and the RMA. Further analysis of the data showed that about 27% of the total respondents thought it were appropriate for individuals to share in the responsibility of cleaning their own surrounding while about 73% thought it was not appropriate. The 27% respondents who thought individuals must be responsible for cleaning their own surroundings gave their reasons as indicated in Table 3.

Table 3 Incentive for Individuals to help clean their own surroundings

Response	Frequency	Percentage (%)
Residents are affected by the bad odor from dirty wastes	72	42.35
Dirty surroundings cause illness/diseases	77	45.30
It will save the individuals some money	21	12.35
Total	170	100

Besides the above reasons given by the respondents that individuals should take responsibility for the cleanliness of their surroundings, there are others reasons. These reasons include the impressions of visitors to the area, destruction of the area's scenic beauty, and the choking of drainage channels that will lead to flooding and environmental pollutions. The responses suggest the lower level of the respondents' knowledge concerning sanitation issues. More seminars and talk shows on sanitation could be organized by the government or organizations as a remedy. It was realized that there was some kind of relationship between the respondent's level of education and their perceptions about cleaning their own surroundings. A higher percent of those with relatively higher education thought it was appropriate for individuals to clean their own surroundings. A summary of these findings is shown in Table 4.

Table 4 Involvements of educational levels in cleaning their own environments

Levels of Education	Response (%)
University/Similar level	100
Higher Secondary School level	80
Secondary School level	53
Elementary/Primary level	14
Nil	5

From this analysis, the problem of solid waste management and people's attitude and perceptions in the study area can be linked to the levels of formal education. Improved teaching and learning of issues on sanitation in all levels of education could help improve the general sanitation in the communities. This supports the suggestion that perceptions and attitudes are learned response sets and can therefore be modified or changed through education. Hence, continuous public education of the people of RMA may help improve the sanitation in the Area. Education of households on cleaning their surroundings was discussed. The causes of many nations' environmental problems could be found by the way the imbedded behavioral patterns and acquired values are superimposed on the environment. The study showed that as high as about 62% of the respondents do not educate their households on the need to clean the surroundings while about 38% do. The implications of having more people who do not care to educate their household on making their surroundings clean could mean that the society will translate it into acceptable behavior in relation to solid management, and especially the children will not develop the right perceptions and attitudes for sanitation at an early stage in life. This is likely to impact negatively on how the next generation would handle sanitation in general and solid waste in particular. The perpetual creation of the awareness on the need for household heads and well informed members to educate their household on basic issues on sanitation may help curb the problem. Linked to the interest of the households, educating other members is the lesson that should be taught. For the few (25%) that educated their households on sanitation, some of the lesson taught is summarized in Table 5.

Table 5 Instruction to family members on sanitation

Sl.No.	Lessons	Frequency
1	Dirty surroundings cause illness/diseases	25
2	House members must not refuse	10
3	Family must not defecate at unauthorized places	10
4	Both (1) and (2)	17
5	Both (1) and (3)	16
6	Both (2) and (3)	20
	Total	98

Lessons such as the regular organization of communal cleanup exercises, discouraging of people who may be found littering about and respect for sanitary laws did not come up as issues taught. The respondents' inability to point out these lessons could be an indication that general education on sanitation should be further emphasized in the community. The situation as presented above partly explains why the RCC is unable to cope with the problems of solid waste management in the study area. As every household looks up to the RCC for its solid waste disposal, it puts unmanageable pressure on the equipment and insufficient work force, among other things. The study further showed that about 86% of the respondents involved children below the age of ten in the disposal of their household waste. Their parents often ask the children's and other family members to carry household refuse to the sanitary sites for disposal. About 50% of the respondents who involved such children in solid waste disposal claimed it was children's responsibility to carry the household waste to the sanitary site. Thus, according to these respondents carrying of household waste was not the duty of adults. About 14% of the respondents who did not involve such children in solid waste disposal explained that they did not have such children in their household to carry refuse. There is a greater likelihood of indiscriminate disposal of household waste in RCC with children dominating as carriers of household waste to the designated sanitary sites. This may partly explain why refuse is found all over RCC. Table 6 shows the indiscriminate disposal of household waste in some parts of the study area.

Table 6 Household containers to storage solid waste

Containers	Number	Percentage (%)
Plastic Containers	20	28.6
Sacks	24	34.3
Baskets	9	12.8
Polythene Bags	6	8.5
Old Buckets	7	10.0
Dustbins	4	5.7
Total	70	100.0

Role of RCC in Solid Waste Management

Generally, all solid wastes produced in RMA are collected for final disposal at various designated sanitary sites by the RCC. This is because third class residential area with low-income status, poor layout of lanes, poor roads and other infrastructure, and dense population. Unlike the high-income residential areas, the expensive door-to-door system of solid waste collection can be practiced in RCC. The waste management authority is not able to cope with the solid waste management problems in the area as the amount of waste produced far out weighs its capacity to dispose of it. This is because of its inadequate equipment, which is also a result of limited finances and lack of modern equipment and personnel. These problems coupled with the attitudinal and perceptual problems even exacerbate the problem. A summary of the kind and adequacy of Rajshahi City Corporation equipment is shown in Table 7.

Analysis of the data gathered from the Rajshahi Metropolitan Area, indicates that there was 01 sanitary site but this was woefully inadequate. An ideal number of 03 sites were required by the RMA. The major problem arising at this point is that it is even impossible to create new sanitary sites. This is because some recalcitrant residents have encroached upon designed sanitary sites. Consequently, the whole area is well packed with houses and other unauthorized structures and has no available unused space. The bigger problem facing the department has to do with finance. The government has greatly cut down its subversion to the RCC. As a result, the department is unable to afford enough and better equipment as indicated in the previous figure. The number of workers at hand on the field was known from the waste management authority to be practically inadequate. More people need to be employed but the department was unable to do so because of its financial problems. A summary of the finding is shown in Table 8 below the inadequacy of the labor force, number and types of equipment for solid waste management by Rajshahi City Corporation.

Because the RCC is unable to provide enough vehicles, containers, and personnel, more waste continues to pile up for weeks in most sanitary sites before the final disposal is carried out as shown in Figure 2. This problem has encouraged the use of various inappropriate methods for household waste disposal such as wastes being left in the open in pits and open burning of the waste. The help of concerned citizens, governmental organizations, and nongovernmental organizations in terms of the provision of funds and equipment may be a remedy to this problem. In Rajshahi Metropolitan Area, crude open dumping in low-lying areas is the common practice for the ultimate disposal of municipal solid waste. The ultimate disposal site of unsanitary crude dumping practices in Rajshahi City Corporation area is shown in Figure 3.

Table 7 Numbers and types of equipment for solid waste management by RCC

Description	Available	Optimum Required
Garbage Trucks & Trolley	30	60
Compaction Trucks	01	5
Van	140	150
Containers	10	30
Sanitary Sites	01	03

Table 8 Manpower of Rajshahi City Corporation

Manpower Description	Available Number	Optimum Number
Labors	290	300
Sweepers (Man/Women)	409	450
Supervisors	02	10
Team Leaders	20	30
Chief Executive Officers	01	03

Figure 2 Photographic view of unclean communal dustbin in RCC area

The RCC is involved in the preparation of compost but at a smaller scale. The composition of solid waste generated in RMA and many other parts of the city, indicates some problems to compost preparation. Solid waste is not source separated and so comes with combination of other materials such as polythene, which is a problem in composting. This means that more money has to be pumped into composting but this is not easy with regards to the RCC financial strength. Hence the city corporation authority is unable to provide enough equipment, personnel, and better disposal methods, more and more waste continues to heap up in most parts of RCC and the Whole city.

Incentives Available for Workers Dealing With Solid Waste in RCC

Humans are known to work better under certain favorable conditions or incentives. The waste management department complained that working in RMA was not interesting at all since most residents were hostile and sometimes would even beat up solid waste workers as a result of the slightest misunderstanding. This problem is the reflection of the data collected on the field, which showed that about 69% of the respondents did not see the work of the RMA to be important in the area while about 31% saw their work to be important. With such a problem at hand, RCC workers did not work to their full capacity in the area. Further analysis of the data revealed that working in RMA was very exacting where the majority of the residents would leave every aspect of the solid waste management to the RCC of RMA. Meanwhile the by-laws on solid waste management did not say so. This confirms the results obtained on the field, which revealed that about 67% of the respondents would offer no possible assistance for solid waste management in the area while about 33% said otherwise.

Figure 3 Unsanitary crude dumping practices in Rajshahi City Corporation area

The above recognized problems coupled with the inadequacy of solid waste management equipment in RMA suggest that there are virtually no incentives that encourage workers in the area. This may partly explain why RMA is notorious for solid waste management problems. Continuous public education of the people and good funding of the RCC may be better solutions to the lack of incentives in RMA. Figure 4 shows the generation and solid waste management problems in RMA. Figure 5 represents the lack of partnerships among stakeholders.

Figure 4 View of solid waste generation and stakeholders management problems in RCC area

Figure 5 Lack of partnerships among

CONCLUSIONS

This study has been concerned with the problems of solid waste management in Rajshahi City Corporation. The research findings were as follows:

- People of the study area had poor attitudes and perceptions toward solid waste handling. They would store their household refuse in substandard refuse containers such as old buckets, sacks, baskets, polythene bags, and boxes that had no coverings.
- The people lacked household toilet facilities. The majority of them depended heavily on public toilets with associated problems such as joining long queues to use the facilities.
- The people depended virtually on the RMA's facilities for their household refuse disposal.
- The Rajshahi City Corporation equipment and personnel for handling solid waste in the area were woefully inadequate.

- There were virtually no incentives for workers who dealt with solid waste in Rajshahi City Corporation. Sometimes, workers were even beaten up on the field. The greater percentage of the people was not prepared to help the RCC workers in any possible way to enable them carry out their work in the study area.

RECOMMENDATIONS

Based on the findings of the study, the following recommendations are made.

- The Rajshahi City Corporation on solid waste and its related issues should educate the public. Basically, hygiene practices should be taught especially on radios, televisions, in news papers, and in schools to educate people on proper ways of handling solid waste and keeping the surrounding clean.
- The Rajshahi City Corporation should ensure stricter enforcement of byelaws where administrative penalties for minor violations should be taken with urgency. The byelaws on sanitation should be made to require every landlord to provide an environmentally friendly toilet facility in his house. The Rajshahi City Corporation should make it a responsibility of introducing the use of standard bins with lid for domestic and commercial use to the people of RMA. People should develop proper attitudes and perception towards waste handling, which should be achieved through both formal and informal education. Worker dealing with solid waste in RMA should be a resident of the area. The community should adopt a self-help approach to solve the problem. Much can be achieved when the various communities mobilize themselves and organize periodic clean up exercises and by contributing financially to support the exercise, the residents can also act as watch dogs and make sure that they themselves adhere to proper waste disposal practices. The chiefs and other opinion leaders must be given additional roles to play in ensuring environmental cleanliness. This can be done by authorizing the chiefs in each area or community to take up the additional job of ensuring clean environmental practices with the youth playing an important role. The women should be made to play an important role as it has been realized that women do a greater part of solid waste handling and disposal in the community. It is hoped that these recommendations, when considered for action by the government, local authorities, and the people themselves would help address the solid waste management problems and its related issues in Rajshahi Metropolitan Area.

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Solid Radioactive Waste Management in Bangladesh

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ABSTRACT

Human activities related to the application of ionizing radiation generate radioactive waste. This waste arises not only from nuclear power plants and the dismantling of nuclear facilities, but also from research reactor operation, radioisotope applications in medicine, industry, research and educational institutions. In Bangladesh, radioactive wastes are being generated from operation and maintenance of 3 MW Research Reactor, 14 MeV Neutron Generator, production of radioisotopes, application of radioisotopes in medicine, agriculture, research and education, industrial gauges, smoke detectors, calibration sources and radiotherapy sources in oncology centres and so on. In order to protect human health and the environment now and in the future, all radioactive wastes must be safely collected, processed and stored on interim–basis until their final disposal. In 2004, a Central Radioactive Waste Processing and Storage Facility (CWPSF) has been established at the Institute of Nuclear Science and Technology (INST), Atomic Energy Research Establishment (AERE), Savar, Dhaka for safe collection, transportation, segregation, treatment, conditioning, interim-storage and final disposal of radioactive wastes that are arising and expected to be generated in future from the nuclear applications in the country. The facility is equipped with necessary devices, such as Sorting box, In-drum cement mixer, Compactor, Ion-exchange-cum-ultra filtration unit etc., for radioactive waste management. The radioactive wastes are collected, processed and stored in interim storage facility at CWPSF of INST, AERE following the standard rules and regulations until final disposal.

INTRODUCTION

Much interest has been focused on the management and disposal of radioactive waste generated during the use of radioactive material in industrial applications, research and medicine [Roberts C. J. (1998)]. In order to safe management of radioactive waste for the protection of human health and the environment, the International Atomic Energy Agency (IAEA) has developed and published standards and guidelines for radioactive waste management, which have been adopted internationally.

Radioactive waste may occur in any of three physical forms: solid, liquid and gaseous. If the half-lives associated with these waste materials were of the order of hours or even a few days their disposal would present no difficulty. They could simply be stored until the activity decays to a safe level when they could be disposed off just like any other waste. But, some of the waste products are made up of nuclides which have very long half-lives. Therefore, storage and disposal methods will vary according to the form of waste, the radionuclides present, their concentration and radiotoxicity.

SOURCES OF RADIOACTIVE WASTE

Primary sources of radioactive wastes are generated in the operation and maintenance of nuclear reactors, nuclear fuel cycle facilities (uranium enrichment, fuel production, spent fuel reprocessing, etc.) and in the production and the use of radioisotopes in medicine, research and industry. Secondary wastes are also produced during the treatment of primary wastes.

TYPES OF RADIOACTIVE WASTES GENERATED IN BANGLADESH

Bangladesh has modest use and application of ionizing radiation sources in health, agriculture, nuclear medicine, research and education, radioisotope production, medical product sterilization and in industry. The applications are increasing both in numbers and types as the economy is expanding. In Bangladesh, Low and Intermediate Level (LIL) radioactive wastes are being generated from the operation and maintenance of nuclear facility (3 MW TRIGA Mark II Research Reactor) and 14 MeV Neutron Generator, production of radioisotopes, application of radioisotopes in medicine, agriculture, research and education, industrial practices (such as industrial radiography practices, irradiator facility and well-logging practices), teletherapy and brachytherapy in hospitals/clinics, gas mantle, soil moisture and density & other industrial gauges, smoke detectors, calibration sources etc.

The types of solid radioactive wastes arising are generally spent ion-exchange resins, graphite, dry central thimble (DCT) from research reactor, lead and polythene plugs, contaminated vials, hand gloves, plastic syringes, tissue papers, shoe-covers, protective cloths, plastic and metallic wares, spent and disused sealed radiation sources (SRS), activated carbon, etc. The radionuclides involved in these wastes are e.g., Co-60, Cs-134,137, Sr-90, Ir-192, Tc-99m, Tc-99, I-131, I-125, C-14, Ra-226, Am-Be neutron sources, Cm-244, Am-241, Cr-51, Mn-54, Zn-65, P-32, Sc-46, etc.

Solid radioactive wastes may also be generated from naturally occurring radioactive materials (NORMs). The gas industry is an important source of NORMs in Bangladesh. Moreover, processing and use of phosphates in fertilizer factories; extraction, processing and use of coal & gas and scrap metal recycling work are major sources of NORMs in Bangladesh. NORM deposition in the gas production facilities occurs with the drop in pressure and temperature in the production stream. Generally NORM can accumulate in any surface facilities in the gas processing plants such as separator (internal and external surfaces), filters, sludge pits, pumps, elbows, condensate tank, water tank, water outlet, down hole tubing safety valves, well head and production line.

LOW AND INTERMEDIATE LEVEL (LIL) CENTRAL RADIOACTIVE WASTE PROCESSING AND STORAGE FACILITY IN BANGLADESH

In order to protect human health and the environment now and in the future without imposing undue burdens on present and future generations, all radioactive wastes have to be safely collected, processed and stored on interim–basis until final disposal. Recently a Central Radioactive Waste Processing and Storage Facility (CWPSF) has been established at INST, AERE, Savar under the Annual Development Programme (ADP) of the Government of Bangladesh and the IAEA Technical co-operation (TC) project for safe collection, transportation, segregation, interim-storage, treatment (e.g. volume reduction), conditioning (e.g. immobilization), storage and final disposal of radioactive wastes including solid and sealed radiation sources (SRS), that are arising and expected to be generated in the future from the nuclear applications in the country. The facility consists of several necessary machines/equipment such as Sorting box, In-drum cement mixer, Compactor, Ion-exchange-cum-ultra filtration unit etc.

Objective of CWPSF Facility

The prime objectives of the CWPSF facility are as follows:

(1) Safe collection and handling of low and intermediate level radioactive wastes;
(2) Sorting/segregation of solid radioactive waste;
(3) Processing (pre-treatment, treatment, conditioning) and interim-storage of the conditioned wastes;
(4) Safe interim-storage of the wastes (non-conditioned and conditioned).

METHOD OF SOLID RADIOACTIVE WASTE MANAGEMENT

A National Strategy for Radioactive Waste Management has been formulated which is a combined system that includes both on-site (places of generation of wastes) primary management on the spot and a centralized management at CWPSF, AERE, Savar. The primary objective of radioactive wastes management is the change of the wastes' characteristics to improve safety, environmental compatibility or economy. The ultimate objective of the waste management is to facilitate waste conversion into a stable solid form that meets the acceptance criteria for disposal.

Some of the solid radioactive wastes may require conditioning and treatment prior to disposal. Safe collection, interim-storage, etc. of solid radioactive wastes and spent SRS are done in the following manner:

- Solid radioactive wastes are collected, segregated at the place of generation and stored in interim-storage rooms of CWPSF. Solid wastes containing only short lived radionuclides are managed by delay-and-decay storage and released into the environment [R. H. Clarke (2000)].

- Some spent SRS (of hospitals, industries) are collected and stored on-site and some are safely transported & stored in shielded enclosures within CWPSF.

Figure 1 Spent sealed source room

- Compressible (soft) wastes and non-compressible (hard) wastes are separated by using sorting box. The compressible wastes are compacted using compactor; and hard wastes are conditioned using in-drum cement mixer.

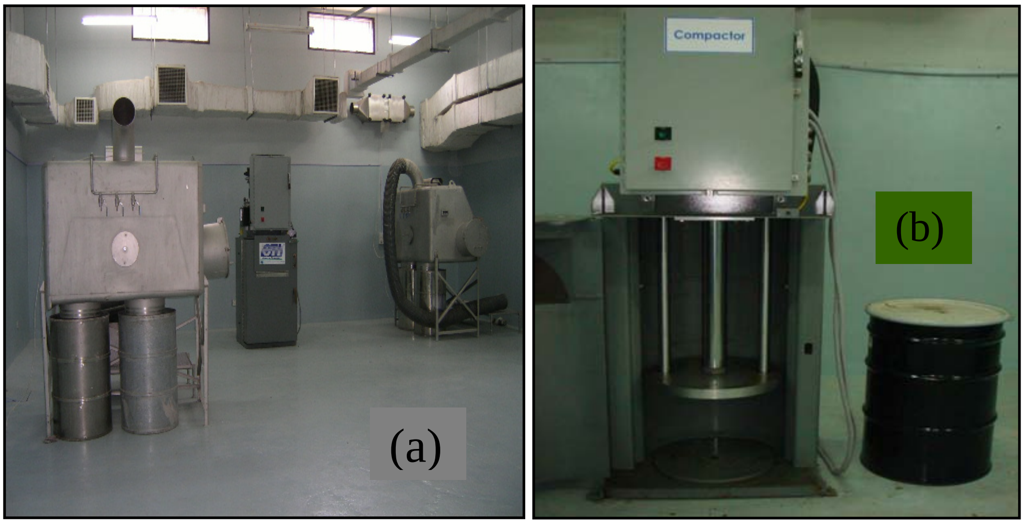

Figure 2 (a) Solid waste sorting box and (b) Solid waste compactor

- The compacted wastes are stored without further conditioning, while the other wastes (e.g., hard wastes) are immobilized with cement grout (in 200L drums) and stored on interim–basis until final disposal.

Figure 3 (a) In-drum cement mixer for solid waste conditioning and (b) Interim-storage (solid RWs)

INVENTORY OF RADIOACTIVE WASTES OF CWPSF

Spent Radium-226 sources (half life: 1622 years) of about 1 Ci (~35.6 GBq) activity have been collected from different hospitals, industries, laboratories of the country. The sources (mainly needles, applicators, calibration sources) are conditioned by encapsulating the sources in stainless steel capsules. The capsules are kept in heavy Pb-shielding device which is placed and protected in 200L capacity concrete lined MS drum and finally stored within CWPSF.

The solid radioactive wastes have also been collected and stored in the CWPSF from Titas Gas Transmission and Distribution Company Limited, Eastern Refinery, Chittagong; Institute of Food and Radiation Biology (IFRB), AERE, Savar; Six Medical College and Hospitals; Karnaphuli Fertilizer Company Limited (KAFCO), Chittagong; Dhaka University, National Institute of Cancer Research and Hospital, Dhaka; TRIGA Mark II Research Reactor, ICDDRB, Dhaka; Radioisotope Production Division and Health Physics Laboratory, AERE, Savar Dhaka. Table-1 & 2 present the inventory of the solid radioactive wastes collected and stored at CWPSF till the end of June 2009.

Table1 Inventory of solid spent radiation sources stored at CWPSF

Waste ID	Radionuclide	Waste receiving date at CWPSF	Activity in GBq on receiving date	Origin
HS_SS_UN_1	^{137}Cs	09-08-1999	*	National Institute of Cancer Research and Hospital, Mohakhali,Dhaka
HS_SS_P_2 HS_SS_P_3	^{226}Ra	October 2000	35.60	Medical College & Hospitals, Nuclear Medicine Centre, Atomic Energy Centre
HS_SS_UN_4	^{137}Cs	26-06-2004	*	Dhaka Medical College & Hospital, Dhaka
HS_SS_UN_5	^{60}Co	08-06-2005	49813	Chittagong Medical College & Hospital, Chittagong
HS_SS_UN_6	^{60}Co	08-06-2005	43871	Dhaka Medical College & Hospital, Dhaka
HS_SS_UN_7	^{60}Co	06-06-2008	30213	Rajshahi Medical College and Hospital, Rajshahi
HS_SS_UN_8	^{60}Co	07-06-2008	30213	Rangpur Medical College & Hospital, Rangpur
HS_SS_UN_9	^{60}Co	10-06-2008	30736	Sylhet M.A.G. Osmani

				Medical College & Hospital, Sylhet
HS_SS_UN_10	^{60}Co	13-06-2008	30625	Sher-E-Bangla Medical College & Hospital, Barishal
IS_SS_UN_1 IS_SS_UN_2	^{60}Co (2 units)	-	*	Eastern Refinery Limited, Chittagong.
IS_SS_UN_3	^{60}Co	31-05-2004	0.088	Karnaphuli Fertilizer Company Limited (KAFCO), Chittagong
IS_SS_UN_4	^{192}Ir	11-07-2006	1.193×10^{-5}	Titas Gas transmission and Distribution Company Ltd.
IS_SS_UN_5	^{55}Fe	06-02-2008	0.618	Basundhara Tissue Industries Ltd., Dhaka
IS_SS_UN_6	^{137}Cs	23-04-2009	13.11	Karnaphuli Fertilizer Company Limited (KAFCO), Chittagong
ES_SS_UN_1	^{252}Cf	26-04-2006	*	Physics Department, University of Dhaka
ES_SS_UN_2	241Am/Be	26-04-2006	*	Physics Department, University of Dhaka
RS_SS_UN_1	^{60}Co	14-06-2006	165679	Institute of Food and Radiation Biology (IFRB), AERE, Savar
RS_SS_UN_2	^{137}Cs	30-06-2009	0.241	Road Research Laboratory,
RS_SS_UN_3 RS_SS_UN_4	$^{241}Am/Be$ (3 units)		1.796 (each unit)	Road and Highway, Mirpur, Dhaka

* Not defined by the user
HS: Hospital Source, **SS**: Sealed Source, **IS**: Industrial Source, **ES**: Educational Institution Source, **RS:** Research Institutional Source, **P**: Processed, **UN**: Unprocessed.

Table 2 Inventory of solid radioactive wastes stored at CWPSF

Type of Waste	Origin	Volume in m^3
Contaminated hand gloves, shoe covers, polythene, poly bags etc.	TRIGA Mark II Research Reactor, AERE, Savar	0.68
	Health Physics and Radioactive Waste Management Unit, AERE, Savar	0.24
Contaminated syringes, vials, crucible, saline tubes, hand gloves, polythene etc.	Radioisotope Production Division (RIPD), AERE, Savar	0.96
Contaminated cloths, tissue papers, hand gloves, vials, syringes etc.	ICDDRB, Dhaka	2.16
Spent Resin	TRIGA Mark II Research Reactor, AERE, Savar	0.30
	Aqua Express, CWPSF, AERE, Savar	0.05

FUTURE PLAN

The safe collection, storage and disposal of radioactive wastes are basically a national responsibility. If disused radioactive sources are stored for a long period of time, there may be a probability of being lost somehow [D. J. Benjamin (2000)]. Therefore, it is reasonable to establish a permanent disposal facility for these sources. Again, disposal of very low level radioactive wastes may not significantly influence the overall safety situation but the disposal of radioactive waste of higher activity may cause a considerable public health hazards for which engineered repositories are to be built up after studies pertaining to geo-hydrology and other important aspects of the site. In order to develop a near surface disposal facility for final disposal of these wastes, site investigations and processes for site selection are under progress at AERE, Savar, Dhaka.

CONCLUSIONS

This paper specifies how the low and intermediate level solid radioactive wastes are collected, processed, packaged, transported and stored on an interim basis at CWPSF to ensure the protection of public and the environment by the Health Physics and Radioactive Waste Management Unit at the Institute of Nuclear Science and Technology (INST), AERE, Savar, Dhaka. The organization has also a plan to establish a permanent radioactive waste disposal facility for final disposal of the radioactive wastes in future.

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An Integrated Approach to Managing Wastes

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ABSTRACT

This paper presents a case study of sound management practices undertaken by Manipal University in order to manage rainwater, wastewater, solid wastes, and solar energy effectively and efficiently. Implementation costs as well as monetary and environmental gains thus accrued are mentioned. This is contrasted with some of the poor practices undertaken by 600 rural and urban households in managing their domestic wastes, particularly plastic waste. The extent of their reducing, reusing, and recycling of plastic waste is also stated. An integrated approach, involving local municipal administrators, educators, children, members of households, voluntary groups, and private organizations in managing wastes is suggested.

INTRODUCTION

Rapid growth of Indian cities due to industrialization and urbanization are straining the limits of municipal services of solid waste management today causing serious environmental degradation. Post liberalization in 1991, multi-national companies, particularly IT, opened offices in several cities. Population in these cities increased primarily due to migration of people from smaller towns in search of employment. Higher salaries have led to higher purchasing power and consumerism among households. Further, free market has permitted foreign products to be sold in Indian markets. With more products, there are more varieties of materials and packaging that need to be disposed. With more consumption, there are more quantities and varieties of waste that needs to be handled. Unfortunately, municipal services and industrial waste disposal facilities have not been able to keep pace with the growing population and rapid industrialization and urbanization. Not all the municipal waste that is generated is being collected and treated. It is a common sight in India, to see dustbins overflowing with mixed wastes: discarded food, plastic, paper, unused and outdated medicines, glass bottles, tube lights and bulbs, batteries, etc. Rag pickers rummage dustbins and pick up items to be sold to scrap merchants for a living. Open topped municipal trucks manned by bare-armed workers clear public dustbins and dump the waste in an open area, either within the city or outside. This mixed, untreated waste is then allowed to smoulder over days. There is no conscious effort made by local municipalities to collect segregated wastes from homes. In certain localities, private agencies offer door-to-door collection of domestic wastes on a daily basis against a monthly payment.

INITIATIVES UNDERTAKEN BY MANIPAL UNIVERSITY

Manipal University, located in South India has undertaken several innovative environmental initiatives to manage natural resources effectively and efficiently. The initiatives include domestic waste management, sewage treatment and reutilization, rainwater harvesting, recharging ground water, recharging dried bore-wells, vermi-composting, arboriculture, energy saving methods, and solar water heating.

DOMESTIC WASTE MANAGEMENT

Manipal University has set up a door-to-door daily collection of domestic waste in the University campus. Each family living is given 2 containers for disposing their organic and inorganic waste. Households recycle newspaper, glass bottles, and metal.

SEWAGE TREATMENT & REUTILIZATION

39.6 lakh litres of sewage from the residences, a hospital and a hotel are being treated in two separate plants and this provides irrigation for the gardens in Manipal that would normally have required 15-20 lakh litres of water daily. Sullage treatment involves treating bathing and washing water and pumping it back to the students' residences for flushing toilets. This has saved two lakh litres of fresh water everyday.

VERMI-COMPOSTING

This involves introducing worms into vegetable waste, converting it into organic manure. Vegetable waste collected daily from the households in the campus and the food courts is layered into specially prepared pits containing live worms. Sludge from the sewage water is added to the organic waste to keep it moist. With simple precautions excellent organic manure is ready for the several gardens of Manipal in forty-five days, thus saving chemical fertilizers.

ARBORICULTURE

Manipal University has planted over 3000 trees in the campus and has over 35 acres of lawn, shrubs, hedges and ground cover. Sewage water is treated and used to water the gardens. The total capital cost of arboriculture is over Rs. 467 lakhs and the university is spending approximately Rs. 59 lakhs per year in the upkeep and maintenance of its gardens.

RAINWATER HARVESTING

Manipal University has installed water filters in 20 hostels. Rainwater collected from the rooftops of the hostels passes through water filters and into sumps. This water is regularly tested for purity. It is used for bathing and drinking in all the hostels. The cost of installing the entire system over 3 years has been 10 lakh rupees while the approximate cost of electricity saved due to non-operation of bore-wells and saving of water has been 14.39 lakh rupees. Results showed: a) bore-wells were rested during the three months of monsoon; b) levels of ground water rose; c) nearly Rs.3.60 lakhs of power was saved d) potability tests on the filtered rainwater showed this was of a better quality compared to the Municipal supply or traditional bore-well water. The initial cost of Rs. 2.90 lakhs for installing filter units was recovered in the very first year through power saving.

RECHARGING GROUND WATER

Pipes have been laid at catchment areas of the hilly town of Manipal. During the three months of monsoon, rainwater is allowed to percolate into bore-wells so that rainwater is not wasted but utilized to recharge ground water.

RECHARGING DRIED BORE-WELLS

Rejuvenation of dry bore-wells was undertaken in 13 locations at a cost of Rs. 12,000 each and involved filling a two-meter square pit around the bore-well with filter media. Storm water drains and rainwater from building terraces are connected to the bore-well. A V-wire strainer in the casing at its base allows percolating rainwater to refill the bore-well in two monsoons.

ENERGY SAVING METHODS

Manipal University has taken the initiative to install state-of-the-art integrated building management systems in all Central Air Conditioning Plants. Energy-efficient centrifugal and screw chillers using environment-friendly refrigerants such as R-134 A and R-407 have been installed. Power saving T-5 fluorescent tube-lights and compact fluorescent lamps are used in all buildings. Street lights in the campus are controlled by photo voltaic cells which switch them on and off automatically depending upon the natural light conditions. All these initiatives have reduced electricity consumption by 21%.

SOLAR WATER HEATING

Solar Water Heating systems have been installed to provide 195,000 liters of hot water at 60 degree C per day to all the student hostels. The cost incurred is over Rs. 200 lakhs. Rs. 100 lakhs have been saved towards power charges since the installation of solar systems.

A QUANTITATIVE STUDY

A quantitative study of 600 households of Udupi district of the southern state of Karnataka was undertaken to understand the behaviour of rural and urban people with reference to reducing, reusing, and recycling plastic waste.

METHODOLOGY

Udupi District, with a population of 1,112,243 (2001 Census conducted by the Government of India) in three taluks, namely, Udupi, Kundapur, and Karkala has 211,454 households of which 170,900 are rural and 40,554 urban. A 95% confidence level and a 4% confidence interval gave a sample size of 600. This was further proportionately stratified on the basis of taluk and urbanity into 211 rural and 86 urban households in Udupi taluk, 174 rural and 15 urban households in Kundapur taluk, and 100 rural and 14 urban households in Karkala taluk. Data was collected from households with the help of 21 Child and Development Project Officers who selected households on the basis of income and number of people in the house. Each officer was instructed to ensure that they gather data from the income categories: a) Below Rs. 5000; b) Between Rs. 5001 and Rs. 10,000; c) Rs. 10,000 and above and number of people a) 3 and below; b) Between 4 and 6; c) 7 and above; more or less equally so that all categories are equally represented.

FINDINGS

"Reduce" Behaviour in Udupi District

The study showed that a high percentage of respondents (81.3%) have tried to reduce plastic. The remaining 18.7% have not done so. It can be concluded that a majority of the sample has tried to reduce plastic. Looking closer into the extent of plastic reduction in Udupi District (Figure 1), it is evident that there are three major groups that are almost equal-sized: one group that does no reduction at all (18.7%); another group that reduces between 6 – 10% (18.7%) and another group that reduces more than 35% (21.3%). This shows that there is, on one end of the spectrum, a group that does no reduction of plastic at all and on the other end, there is a group that does more that 35% reduction and then there is one another group that does a small amount of plastic reduction. All other groups are negligible.

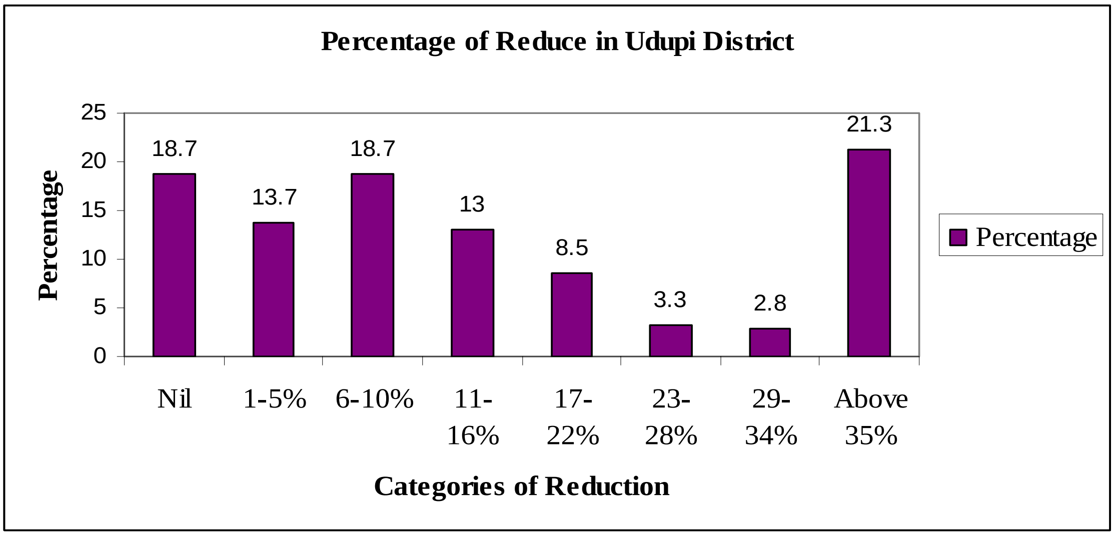

Figure 1 Percentage of reduction of plastic in Udupi district

The most common plastic item that is reduced in the district is the carry bag which is reduced by 65.5% of the sample (Figure 2). The item that is least reduced is the biscuit wrapper which is reduced by only 5.3% of the sample. Considering the fact that 130 households out of 600 (21.7%) consume biscuits daily and another 143 households (23.8%) consume them once a week, and that 74.2% of the sample disposes biscuit wrappers, it must be borne in mind that biscuit wrappers are items that are harming the environment because of the manner in which they are being disposed. Apart from those who do not dispose biscuit wrappers and those who dispose them through scrap merchants (a total of 28.5%), the remaining 71.5% of the respondents are causing considerable pollution (either air, soil, or water) by burning plastic biscuit wrappers or putting them in public dustbins (which are later on burnt in open dump yards) or in vacant land or in empty wells/pits. The reduction of other plastic items is also minimal.

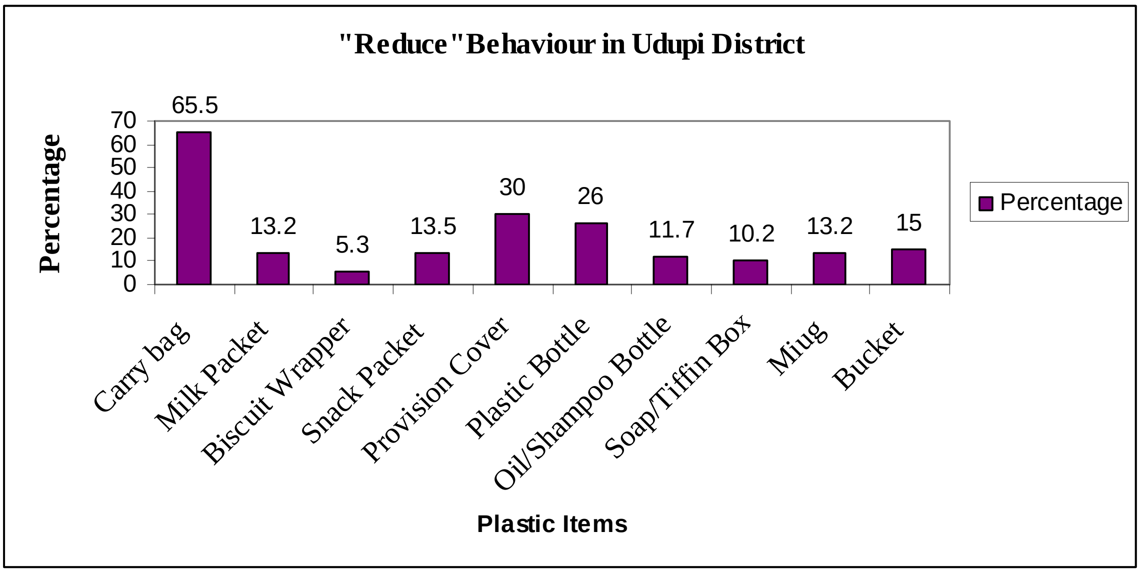

Figure 2 Plastic items that are reduced in the district

"Reduce" Behaviour of Rural and Urban Households

There is not much difference between the rural and the urban sample with reference to reducing plastic. 82.1% of the rural population and 78.3% of the urban have tried reducing plastic. The remaining population has not tried reducing it. Looking at urban and rural differences in the extent of plastic reduction (Figure 3), we find vast differences at the higher side and middle range of reduction.

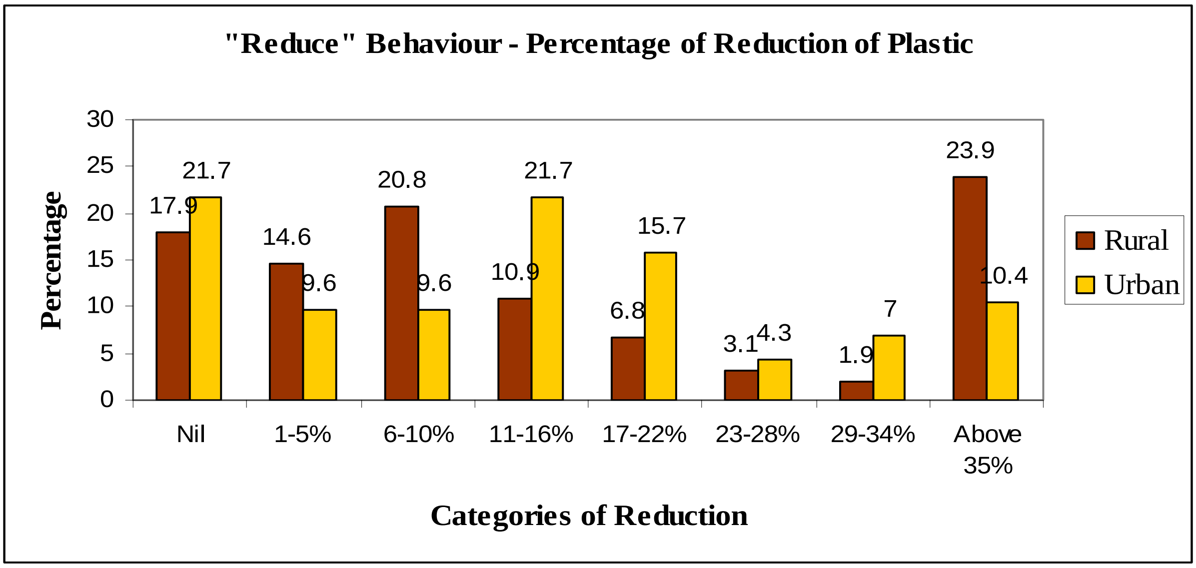

Figure 3: Comparison between rural and urban population

Certain plastic items like carry bag, milk packet, snack packet, soap/tiffin box, mug, and bucket are reduced more by urban people than the rural (Figure 4). One plastic item, whose reduction is markedly different in rural and urban households, is the plastic bottle. Rural households tend to reduce it more than urban households.

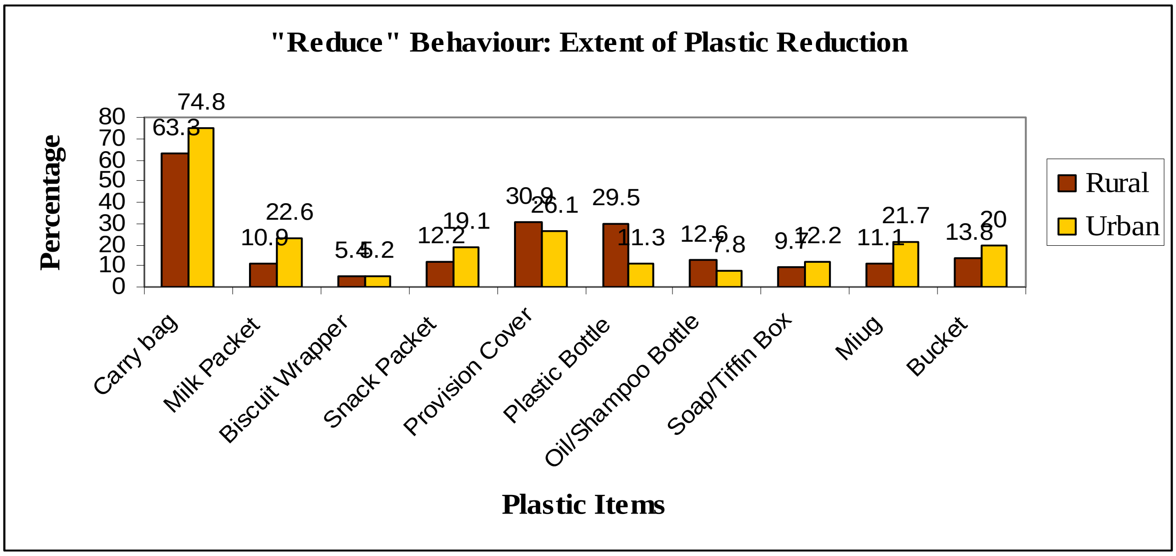

Figure 4 Rural and Urban differences in reduction of plastic items

“Reuse” Behaviour in Udupi District

The study shows that a moderate percentage of respondents (65%) have tried to reuse plastic. The remaining 35% have not done so. But the extent of reuse is not at all encouraging (Figure 5).

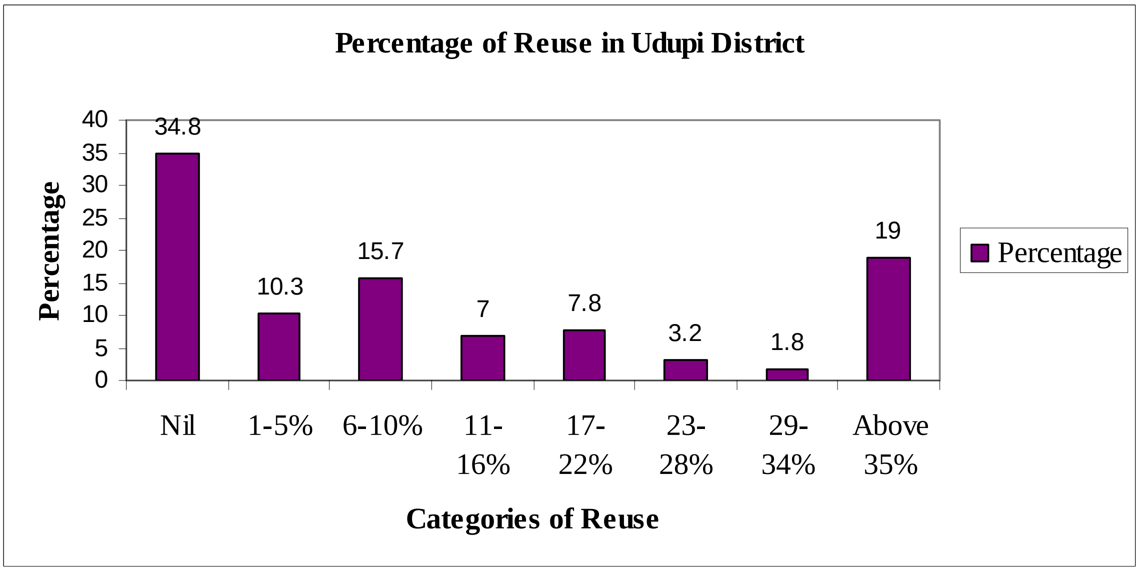

Figure 5 Percentage of reuse in Udupi district

Almost 35% of the sample in Udupi District does not reuse plastic at all which means that more than one third of the sample makes use of plastic but disposes without reusing. Further, a large portion of the remaining 65% reuse minimally. Only about 19.1% reuse above 35%.

The product reused the most in the district is the carry bag, reused by 53.8% of the sample (Figure 6). The product that is least reused is biscuit wrapper, reused by only 0.2% of the sample. That is, out of 600 households in Udupi district only one household reuses biscuit wrappers.

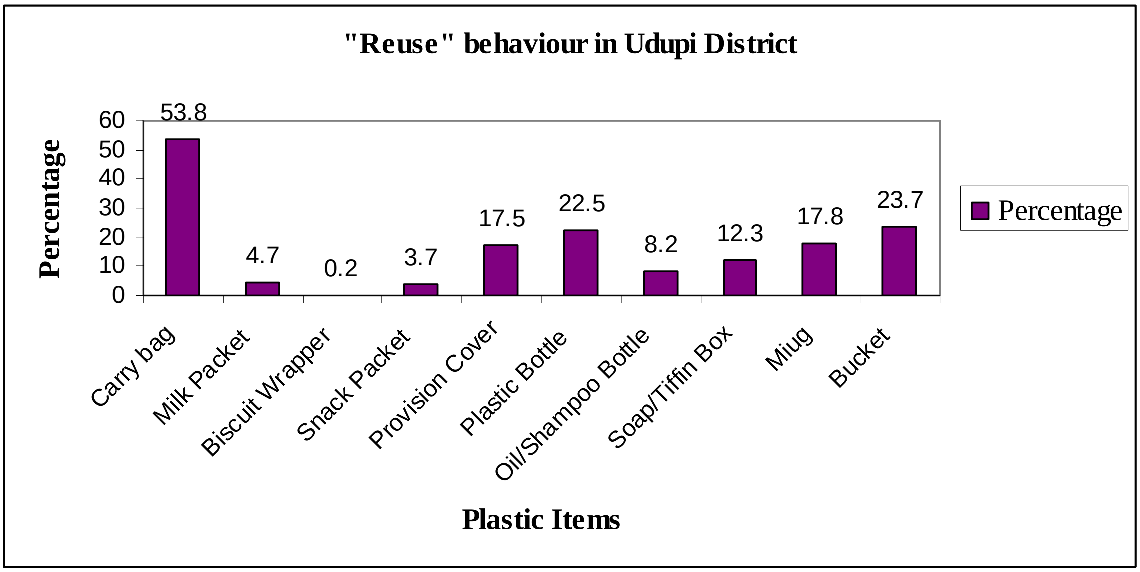

Figure 6 Plastic items that are reused in the district

"Reuse" Behaviour of Rural and Urban Households

There is a vast difference between the percentage of rural and urban people involved in reusing behaviour. More rural households (70.3%) reuse their plastic than urban households (57.4%). When we look at the extent of "reuse" behaviour among rural and urban households, we can huge differences on either side of the continuum (Figure 7).

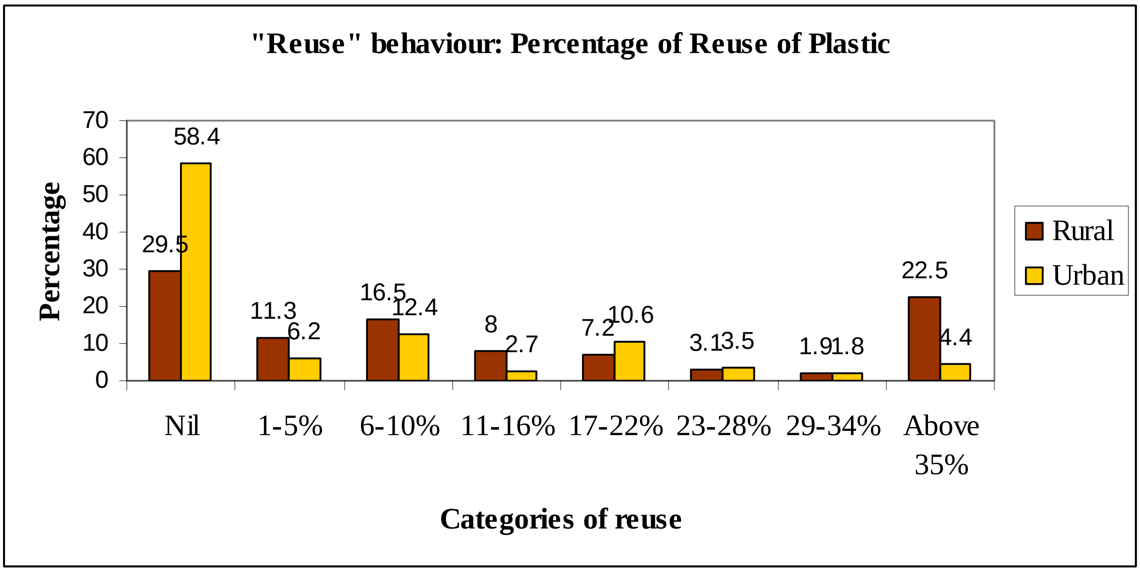

Figure 7 Percentage of reuse of plastic in rural & urban households

More urban households (58.4%) do not reuse than rural households (29.5%). On the other end of the continuum where we have those whose percentage of reuse is above 35%, there are more rural households (22.5%) than urban households (4.4%). This clearly indicates that urban people do not reuse their plastic products much. In all categories except one (17–22%), there is a higher percentage of rural households engaging in reuse behaviour than urban households. This shows that rural people do not dispose their plastic items after initial use but reuse them. This behaviour is environmentally friendly as it prolongs the life span of the product, and delays the product from entering into the waste stream too early, thereby prolonging the life of waste management facilities.

Coming to rural and urban differences in the extent of reuse of plastic products (Figure 8), it is evident that certain products like the carry bag, plastic bottles, soap/tiffin boxes, and buckets are reused more by rural people than urban. Milk packets, snack packets, provision covers and mugs are reused more by urban people than rural. It must be remembered that fewer rural people (32.6%) use milk packets daily than urban people (81.7%). Hence, the low reuse behaviour of milk sachets by rural households is justified.

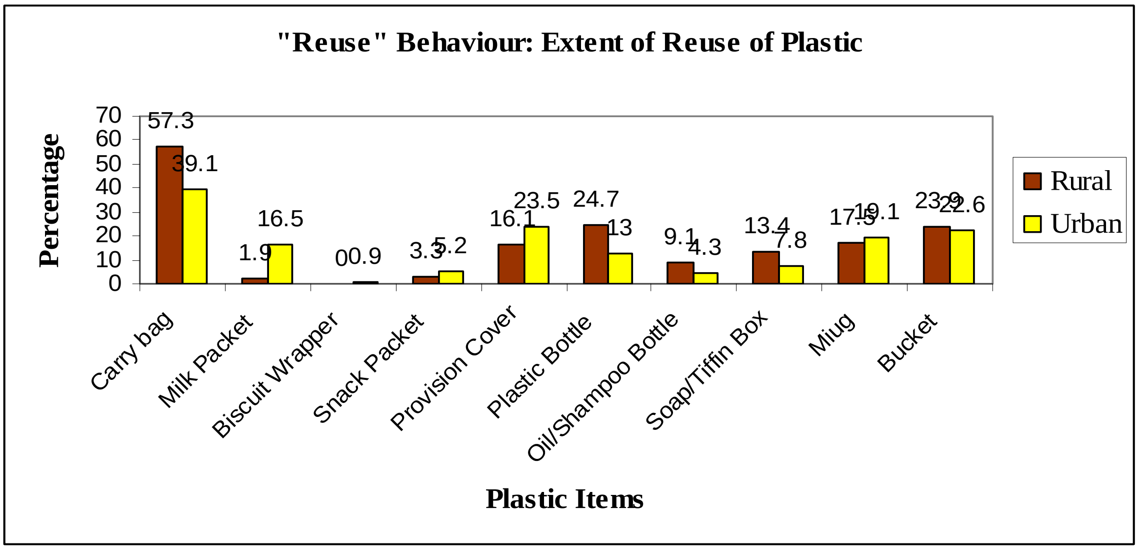

Figure 8 Percentage of rural & urban population that reuses various plastic items

More urban than rural households tend to use plastic bottles daily but the reuse behaviour of this product is higher among rural than urban households. That is, 31.3% of urban households use oil/shampoo bottles once a month as compared to 21.2% of the rural households but only 4.3% of the urban households reuse oil/shampoo bottles as compared to 9.1% rural households. Of all the plastic items, the carry bag is the most reused both in rural and urban households. All other items are reused only by a few.

"Recycle" Behaviour in Udupi District

The study showed that Udupi District indulges in a fairly high percentage of "recycle" behaviour (72.5%) whish is higher than the "reuse" behaviour (65%) but less than the "reduce" behaviour (81.3%).

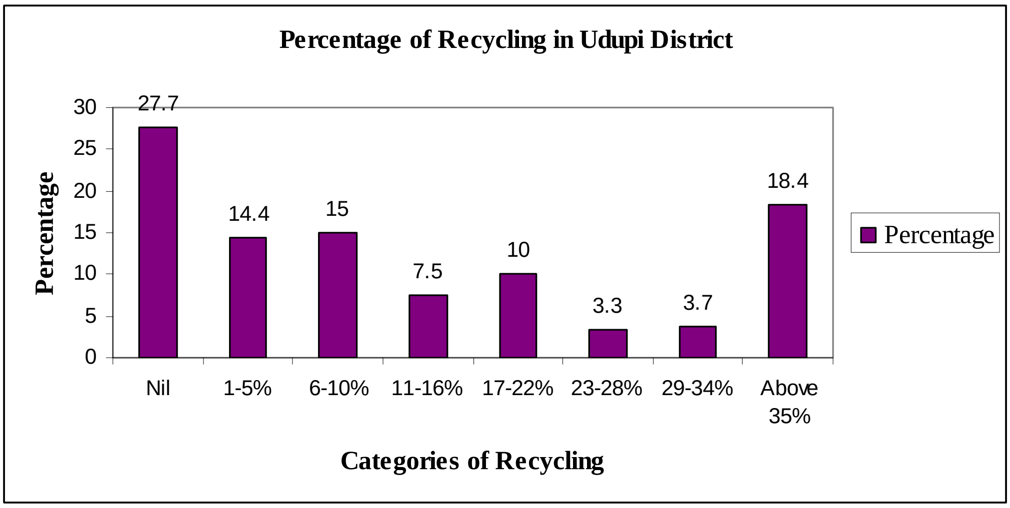

Figure 9 Percentage of recycling in Udupi district

Figure 9 that there are two major groups of people: households that do not recycle at all (27.7%) and those that recycle more than 35% (18.4%). It is alarming to note that, almost one third of the district does not recycle at all while less than one-fifth of the sample in the district does some amount of recycling. Moreover, as the percentage of recycling increases in the categories, there appears to be a reduction in the percentage of households recycling.At the district level, the plastic bucket is one item that is recycled by most people (46.1%) followed by the mug (35.2%) and the carry bag (30.7%) as shown below (Figure 10).

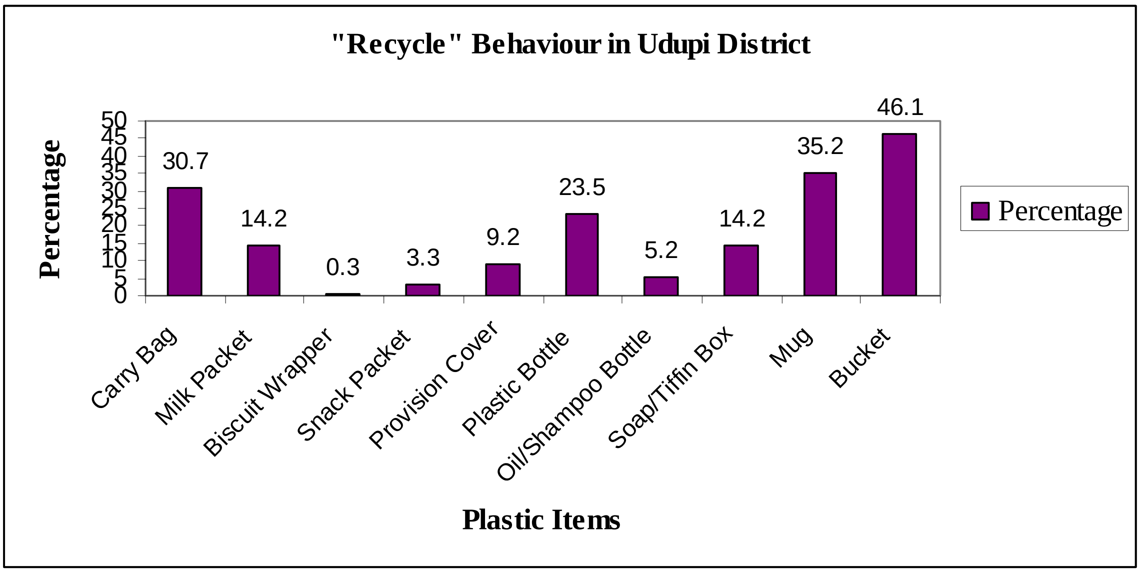

Figure 10 Items that are recycled in the district

"Recycle" Behaviour of Rural and Urban Households

More rural households (75.3%) than urban (60.9%) recycle plastic despite having less access to recycling centres.

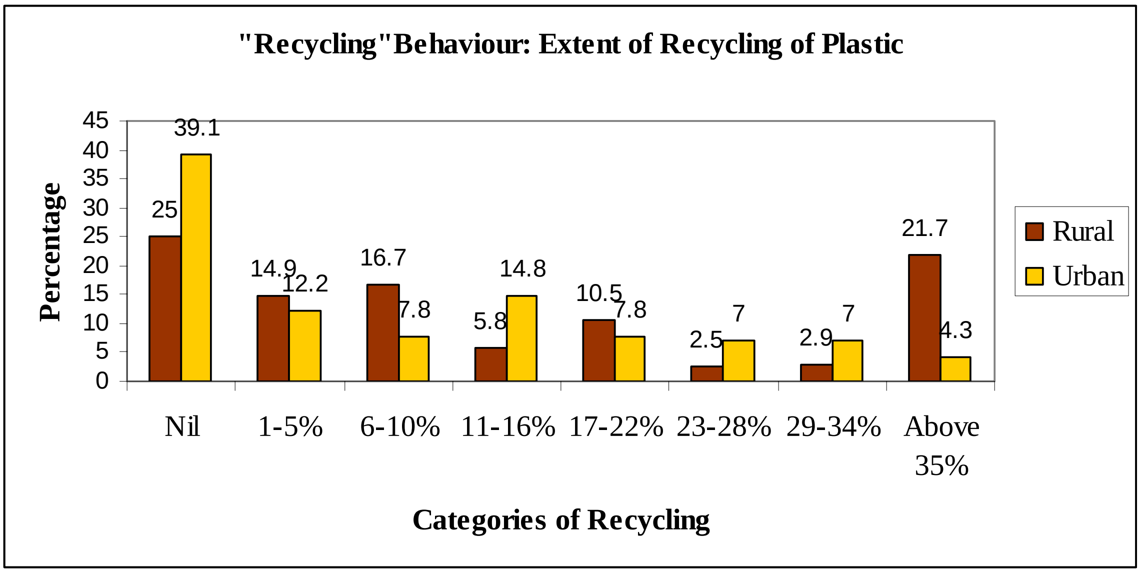

Figure 11 Percentage of recycling in rural & urban population

When we look at the differences between the percentages of recycling in rural and urban recycling (Figure 11), we can observe that 39.1% of the urban sample does not recycle at all. There appears to be a wave (in some categories, rural people recycle more than the urban whereas in some other categories, urban people recycle more than the rural). Hence, it is not possible to state categorically that rural people recycle more than the urban or the vice versa.

Rural households differ from those of urban with regard to the recycling of certain plastic items like carry bag, milk packet, and plastic bottle, soap/tiffin box, mug, and bucket. More urban households tend to recycle the carry bag, milk packet, and plastic bottle than rural households. More rural households tend to recycle the soap/tiffin box, mug, and bucket than urban households. There is not much difference between rural and urban households in the recycling of biscuit wrapper, snack packet, provision cover, and oil/shampoo bottle.

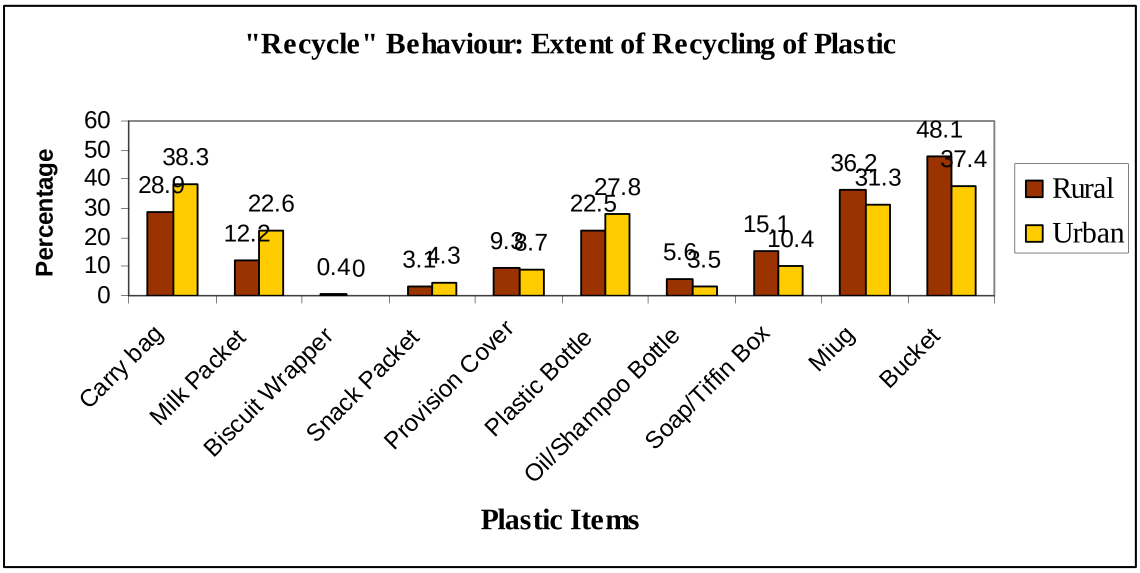

Figure 12 Percentage of rural & urban population that recycles various plastic items

CONCLUSIONS

An integrated approach that calls for a co-coordinated, committed, and continuous effort by educationists, municipal officials, law makers, government officials, manufacturers, householders including maids, and scrap merchants is required to handle the ever-increasing quantities and types of wastes generated by households. Children have to be taught from a young age about the importance of protecting the environment, conserving natural resources, about separation of wastes and composting. Municipal officials must provide guidelines to householders about segregation, disposal of organic, inorganic and hazardous wastes. They must also provide separate bins for the same and ensure regular and convenient methods of collection of domestic wastes. The government must realize the importance of scientific disposal of waste and allot adequate land, technology, labour, and funds to effectively manage domestic waste. Lawmakers must ensure strict rules about waste disposal and penalize lawbreakers. The government must also encourage scrap merchants by giving them subsidies to undertake recycling extensively. Manufacturers must create eco-friendly products with minimum packaging. Collection centres must be located centrally and at convenient locations in the town so as to enable residents to dispose recyclables and hazardous items. Thus, a systemic approach to domestic waste management is required to ensure effective and efficient waste disposal.

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Urban Solid Waste Management Using GIS Technique: A Case Study on Mohammadpur Thana at Dhaka of Bangladesh

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ABSTRACT

Urban Solid Waste Management (SWM) is an integrated concept and a complex issue in an urban area of least developing Asian countries like Bangladesh. The study area of Mohammadpur Thana (11.65 km^2) is a residential area; about 64% of its generated solid wastes were managed by Dhaka City Corporation (DCC). Geographical information system (GIS) was used to propose an efficient scenario with relocating the existing waste bins and containers and another scenario was proposed with number of bins (25), containers (30) and existing illegal dumping sites (14) to attain an 80% waste collection efficiency including optimization and selection of waste collecting routes for Mohammadpur Thana. A participatory Community Management Information System (COMMIS) and further suggestions for an integrated SWM were also recommended.

INTRODUCTION

Bangladesh is a developing country with rapid urban population growth in a limited land area. Solid waste (SW) generation is also increasing proportionately with the growth of urban population. The SWM is an obligatory function of urban local bodies in Bangladesh. At present there are 522 urban centers including 254 municipalities and 6 cities in Bangladesh (SAARC, 2004). Solid waste is non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services (Palnitkar, 2002). Urban solid wastes include commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes and the types of solid waste depend on the commodity usage and lifestyle of the people.

The estimates for solid waste production for Dhaka city has varied in the range of 3500 to 4500 metric tons per day on very rough per capita basis, which has been taken to be in between of 0.45 and 0.50 kg. Taking the mid-figure of 4000 tons per day at present, and with a 5 percent growth rate of population, the city is apprehended to have a proportionate increase in solid waste generation. By 2015, more than 6000 tons of Solid Waste will be generated in DCC area (DCC, 2004). So, urban SWM has its significance for Dhaka city.

The issue of solid waste is not only because of the increasing quantities but also largely because of an inadequate management system (Tinmaz & Demir, 2005). Geographic Information System (GIS) is a good decision support tool for SWM planning. The more the layers in terms of information, the more will be better decision analysis (Ogra, 2003). Urban SWM practices require collection of decisive information which is for taking corrective measures as well as for proper planning to ensure sustainability of SWM (Ramachandra & Saira, 2003).

Urban solid waste was defined to include all urban non-liquid materials no longer required by an individual, institutions or industries such as all domestic refuse and non-hazardous commercial, institutional, industrial waste, construction debris and street sweepings. Such a SWM system must also be integrated, that is, be using a range of inter-related collection and treatment options, at different habitat scales, involving all stakeholders, the governmental or non-governmental, formal or informal, profit-or non-profit oriented groups and taking into account interactions between the SWM system and other urban systems (Martin *et al.*, 2004).

The study area of Mohammadpur Thana was located at 23°44′32″N-90°20′E to 23°45′40″N - 90°23′E in Dhaka district of Bangladesh. It was consisting of 198306 house hold units in its 11.65 km² area. The study area was covered with six wards in Dhaka City of 41, 42, 44, 45, 46 and 47 (part) out of 90 wards.

The main desired aims and overall objectives of this study were to explore the current SWM practice including waste generation, location of waste bins, type, size and frequency of solid waste removal from the bins and to propose requirements and relocating of bins by using GIS considering the current practice for better SWM.

METHODOLOGY

Primary data about the SW of the study area were collected through questionnaire and Global Positioning System (GPS) survey. The exact location of the solid waste bins, containers and illegal waste disposal sites were collected by using GPS device (Explorist 200). Preparation of thematic maps includes the digitization of collected secondary data. Questionnaire survey concurrently conducted while taking the GPS data. Spatial data were generated using collected GPS data with using Google Earth Images. An amount of secondary data about SWM associating other relevant information, like demographic, economic data, were collected from various Non-Government and Government organizations (NGOs & GOs).The information of different types and forms has converted into the GIS database. GIS software (ArcGIS 9.2) with its network analyst extension was used to recommend waste bins, containers location and for the preparation of final maps.

RESULTS AND DISCUSSIONS

Current SWM of the Study Area

The study area was covered with six wards of 41, 42, 44, 45, 46 and 47 (part). As DCC managed solid wastes on ward basis, so ward boundary was highlighted in the map of study area as presented in Figure 1. Municipal Solid Waste Management (MSWM) bodies were unable to prove a 100% efficient system and even were not able to reach the efficiency of 70% (Ogra, 2003). So, we couldn’t expect 100% efficient SWM practice in urban area. But appropriate SWM could raise the SWM efficiency to a substantial limit. The SWM practice of the study area was moderate. Door-to-Door (DTD) waste collection, initiated by local community and supported by DCC, was observed. But in some areas, the SWM practice was not so maintained recurrently resulting jumbled waste disposal. At the north-western part of the study area (ward-46), there were no such bins or containers for dumping of solid wastes. Waste collecting bodies had no such bin or container at that site. Population density of that site (Dhaka Uddan) was lower than the other parts. Community based SW collection vans had collected wastes rarely (once or twice a week) from that site. Emerging housing (Chandrima, Nobodoy Housing) facilities at that part of the study area need proper SWM with considering future population projection and rapid urbanization. The southern part (ward 45 & 47) of the study area was fully residential area and DTD waste collection was practiced. In Jafrabad (ward-47), no major illegal site was found at the housing sections (Kaderabad, Jafrabad Housing). Lalmatia, Zakir Hossain Road and Iqbal road were clean and regular DTD collection was practiced in that part of Mohammadpur Thana. With some exceptions of illegal dumping, quite good waste management practices in ward 44, 45 and 47 were observed. The only waste Mini Transfer Station (MTS) of the study area was located at the Lalmatia (ward-45), where the waste container was bounded by concrete partition. In some part of the ward-42, mainly in slum areas, population density was quite high. These unprivileged peoples had a lack of proper sanitation, drinking water and solid waste dumping facilities, and only wastes are collected at night from the adjacent containers.

In slum areas (Geneva Camp) of ward 42, local waste collecting bodies were inactive and need proper SWM practices. In slum areas and in quarters, which comprise a huge number of people, SWM practice was not so good. Lethargic waste collection management was responsible for the worst situation of the slum areas of Mohammadpur Thana (Figure 2a). The other section of the ward-42 was clean rather than slum areas. Ward-41 was mainly mixed (residential & commercial area) type area and was quite clean. Except one location, no major illegal dumping was seen at that part of the study area. Two DCC containers and a 10 ton carrier where placed where local waste management bodies dumped wastes. From the questionnaire survey, it was found that more wastes were generated from April-July month of the year. In rainy season, the scenario was quite bad with the flooding the wastes to the roads with rain water. Temporary drainage congestion with flooding of wastes was a regular problem in some part of ward-42.

Comparatively DTD waste collection helps to minimize the SW problem of the study area, but the crevice and timing of waste collection from household by the local SW collecting bodies were responsible for the illegal waste disposal. As the residential area was highly over-populated, people threw their wastes beside the play ground, along the roadside and to the open-spaces as well.

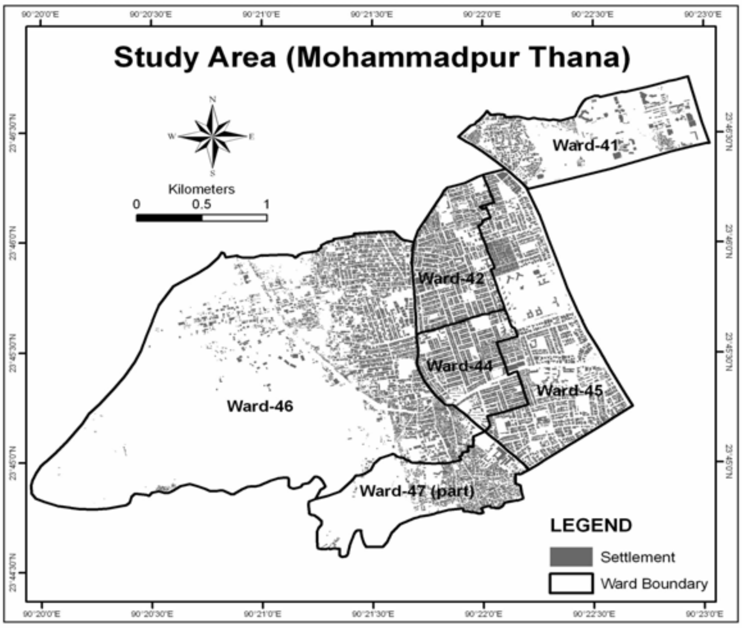

Figure 1 Map of the Study area (Mohammadpur)

Figure 2 a. Illegal wastes dumping at the slum area; b. Placement of waste container induce traffic problem; c. Current waste bins lacking proper maintenance; d. Waste disposal around waste containers initiate traffic and health problem

The managing body and the workers collected wastes at day-time but the DCC trucks collected the wastes at night or at early in the morning. So, the collected wastes plunked for a huge time on the containers which induce odor and health problems. Waste compilation around the waste containers reflected traffic problem. The pedestrians can also get affected by odor problem induced by SW around the containers beside the roads (Figure 2b, 2d). The ragpickers of the study area were mostly women and children and they might be severely affected by diarrhea or other vector borne diseases collecting SW.

The household, commercial, institutional and medical wastes were deposited in the same waste collection bins located on the streets (Figure 2c). As the DTD collection has a remarkable success in SWM in Dhaka city but the local Community Based Organizations (CBOs) of the study area were facing staff problems, service charge collection, evasion, timing of DCC trucks, lack of suitable sites for keeping waste collecting vans and budget problems. So, an initiative for integrated urban SWM was essential to minimize waste generation with supporting reuse and recycling options at Mohammadpur Thana.

SWM Practice by DCC

The study area was in zone 3, 6 and 7 of the DCC area. Japan International Cooperation Agency (JICA) started technical cooperation on SWM with DCC in 2000. During the period from November 2003 to March 2006, a development study was implemented. Clean Dhaka Master Plan, the main output of that study was the first master plan on SWM in Bangladesh that covers all aspects of SWM. DCC collect and dump 50.0% and 15.0% are recycled and the rest 35.0% are discarded into streets, drains, ditches, canals and open spaces. Slum and squatter dwellers constitute 35% of city population and only 9% of these populations have any form of solid waste collection service, the remaining 91% dispose their wastes into low-lying lands, road side drains or local drain or canals.

DCC is responsible for secondary waste collection to remove waste from its dustbins/containers, and transport the waste to final disposal sites. Residents are responsible for bringing their waste to DCC's waste collection points where dustbins/containers are located. Three waste management systems are readily seen in Dhaka city and other urban areas of Bangladesh as shown in Figure 3.

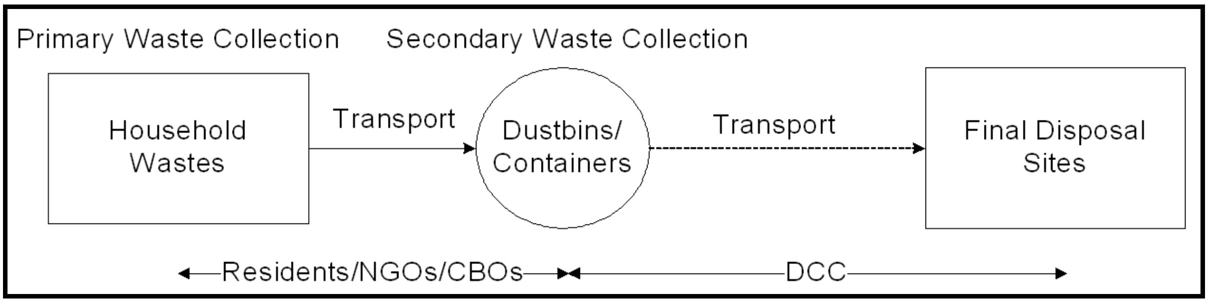

Figure 3 Current waste management flow diagram of Dhaka City (Source: DCC, 2007)

Uncollected waste has been recognized as the root of inferior environment such as scattered garbage, offensive odor; drain clogging, water pollution and mosquitoes. Dhaka City Corporation is mandated the task of solid waste disposal and carries out the task by mobilizing more than 7,000 workers and 300 plus trucks as presented in Table 1

Table 1 Total infrastructure facility of DCC

Manpower		Other Logistics	
Cleaners/Sweepers	7156	Supervision transports -	1 No.
(Male: 4048 + Female: 3108)		Motor Bike-For Inspector	122 Nos.
Supervising staff/officer:	190	Wireless Set -	55 Nos.
Average Cleaners/Ward:	80	Truck/Container Carrier/Hand trolley:	
Total Vehicle Operators:	370	Trucks:	250 Nos.
Dustbins/Containers.		Container Carrier:	300 Nos.
Brick/Concrete Made:	2500 Nos.	Hand trolley:	3500 Nos.
GI Sheet built:	2000 Nos.	Total:	4050 Nos.
De-mountable:	420 Nos.	Dumping Grounds:	4
Total:	4920 Nos.	Matuali	Currently in use
Handcarts:	3000 Nos.	Gubtoly	Not in use
Hand Broom: 1/Sweeper/Month		Amin Bazar	Currently in use
Baskets: 1/Cleaner/Year		Badda	Not in use

(Source: DCC, 2004)

The achievement of cleaning was not yet being appreciated by either of citizens or the government. The waste volume is still increasing as the city grows although DCC not had a confident view to solve the problems of uncollected waste. To solve the collection and transportation problem, an idea of compactor vehicles in the long term to respond to growing demands for Clean Dhaka was proposed by DCC, JICA study team (DCC, 2007).

SW Dumping Sites

The solid wastes collected from the wards of the study area were mainly disposed down to the Beri bund and Amin Bazaar landfill sites. A portion of the waste disposed approximately 65% to the Amin Bazaar site and about 35% (app.) at the Beri bund waste dumping site. As the Amin Bazaar landfill was managed by DCC, the overall management system at that landfill site was quite good. One bulldozer and one wheel dozer were working in the Beri bund dumping site but no other facilities were installed. This site was also filled without soil covering. It was informed that the site was private land and owners requested to DCC to fill by solid waste. In the dry season there was no leachate discharge. As the site was located outside the flood protection band, the site may be flooded in rainy season. Also, it was noted that there are several place filled and/or dumped by solid waste along the flood protection band. A necessity to stop illegal dumping along this important facility was observed during field survey.

Total Generated Wastes of the Study Area

From the DCC statement, it was found that the wastes of the study area were composed of 69% food wastes, 10% paper, 6% wood and dust, 2% plastic contents, 5% sand and dust and 8% other wastes. In recent study, the estimated domestic waste generation was found about 1950 t/d with considering street waste was about 200 t/d in Dhaka city. The generation rate was about 0.34/kg/d/person but considering domestic, business and street section the waste was up to 0.50 kg/d/person.

Table 2 Household and total population of the study area (ward-based)

Mohammadpur (Wards)	Households	Population
41	20750	87240
42	12735	56459
44	8583	44507
45	8566	48581
46	132304	60922
47	15368	64070
	Total: 198306	Total: 361779

(Source: BBS, 2001)

According to Census 2001 as presented in Table 2, total number of population in Mohammadpur thana was about 361779 and the average per capita waste production per day is considered as 0.50 kg. So, the total production of wastes in Mohammadpur Thana was 180890 kg/day per capita.

Capacity of Existing Waste Bins and Containers

The collection capacity is about 85% literally but in real condition many of the waste containers were shared by other adjacent wards as illustrated in Table 3. With considering this sharing of waste bins and containers, trimmed down of 25% waste collection capacity due to other wards contribution to the adjacent bins and containers. About 116250 kg (64%) wastes were collected by the DCC from the study area.

Table 3 Total waste collection from the waste bins and containers of study area

Type	Capacity (Kg)	Total Number	Total Waste Collection (Kg)
DCC Containers	5000	25	125000
Waste Bin (Brick & SI Sheet)	1500	20	30000
			Total: 155000

Required No. of waste bin and containers for the Study Area

By calculation, a waste container was for 14470 people and a bin or a container for 8040 people. With considering space, timing and disposal waste containers were better to manage rather than waste bins.

Table 4 Total waste collection by proposed waste bins and containers

Type	Number	Capacity (kg)	Total Waste Collection (kg)
Waste Bins	25	1500	37500
Waste Container	30	5000	150000
			Total: 187500

As the waste bins were needed for primary and emergency collection, 80% waste collection can be achieved with increasing number of waste containers with considering numbers of waste bins as presented in Table 4.

Selection of Optimum Location with Current Waste Bins and Containers

At present, about 20 waste bins and 25 containers of the study area were observed. Current route selection was feasible with existing bins and containers but had an over-populated and un-served area as shown in Figure 4. According to the vehicle capacity distribution by Zone 6, the study area wards 42- 46 showed a carrying capacity more than 70% of collection ratio. [Zone 6: Ward 39, 42-46] but 41, 47 wards shows less than of that ratio (DCC, 2007).

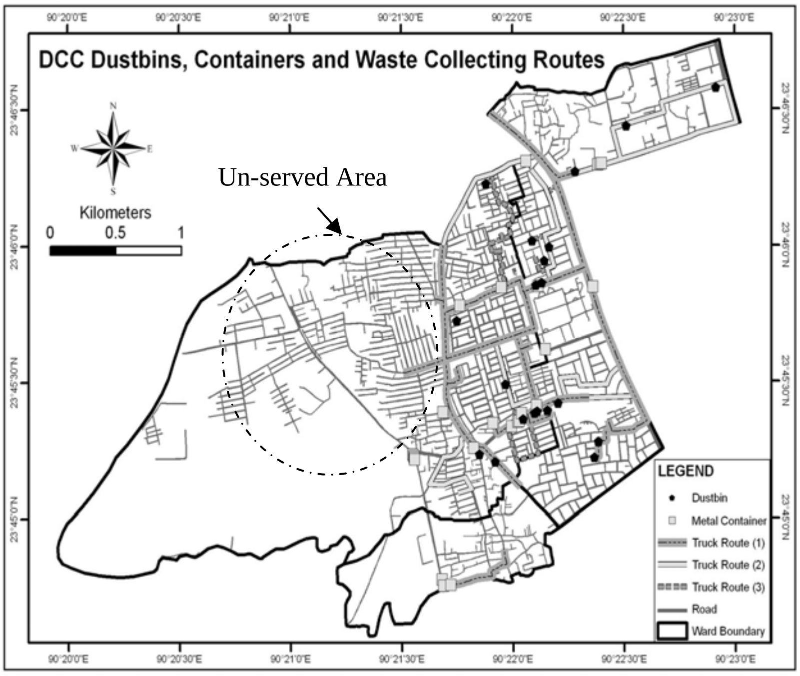

Figure 4 Current locations of DCC dustbins, containers and waste collecting routes of DCC indicating un-served area

The optimum location of waste bins and containers had been suggested with delineating present containers and bins. The relocations of waste bins had been chosen by try and error method. Self judgment was applied to choose the essential locations. The proposed locations were analyzed with network analysis and the overall coverage of the study area with the existing bins and containers have been proposed. The waste bins locations were modified with analyzing route optimization and concerning final disposal site of wastes as shown in Figure 5.

The collection time would be reduced and the route selection would be more optimistic for the final disposal. The two ways out to the disposal site (Beri bund Road and Mirpur Road) were taken into account concerning the route selection and relocation of the waste containers and bins. A distance of 200 m was considered for dustbins and 500m for waste containers.

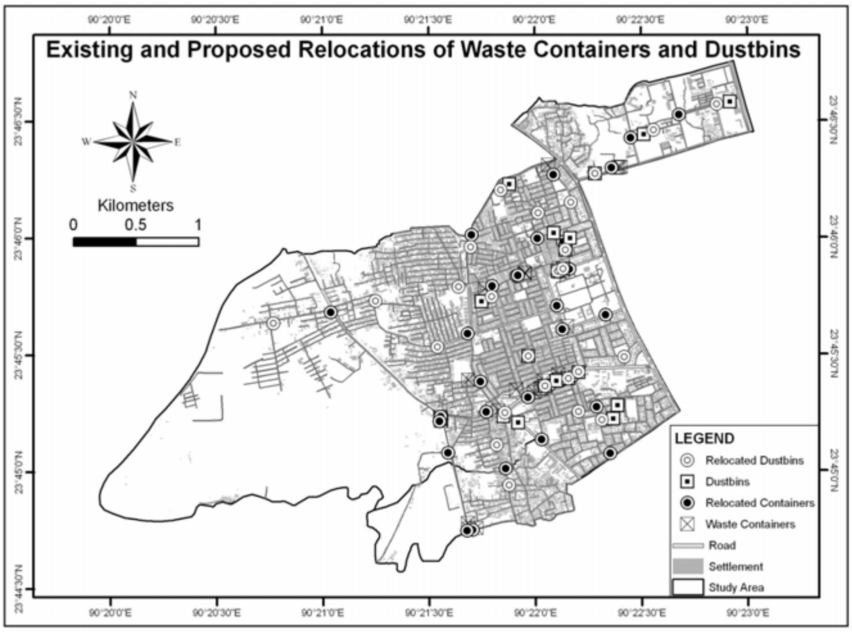

Figure 5 Existing and proposed relocation of waste containers and dustbins of study area

Illegal Dumping, Rag Picking and Recovery and Recycling of Generated Wastes

A common scenario in the open dump site was obnoxious odor at the surrounding environs. About 14 illegal dumping sites were found at the time of questionnaire and field survey (Figure 6a & 6b). The dumping sites were not very big in size but these were seen around the open places and beside the side of the roads as shown in Figure 7. Burning of wastes close to the container site of ward-41 was observed and the burning was a common solution for street wastes which was deteriorating the air quality and initiating many respiratory diseases.

Figure 6 (a, b) Illegal dumping sites of the study area

Rag pickers were seen scavenging around the dumping sites and from DTD collecting vehicles. About five hundred waste pickers (mainly children and women) at the study area were directly involved in collection of recyclable wastes. Rag pickers had contributed to the SWM by selling waste materials to the buyers and wholesalers and thereby providing raw material for the recycling. Rag pickers were a part of the whole recycling sector of SWM in the study area. About 55% of the recyclable wastes (6% total wastes) were collected by the rag pickers of the study area.

Collection and segregation of recyclable wastes were mostly conducted along with the waste collection and dumping. Among the places of recyclable waste collection, those conducted around dust bins or containers produce negative impacts to keep the street clean and to remove waste efficiently because recyclable waste collectors spread waste around there for their convenience. Ragpickers don't return the remaining wastes to dust bin or containers after finishing picking recyclable materials.

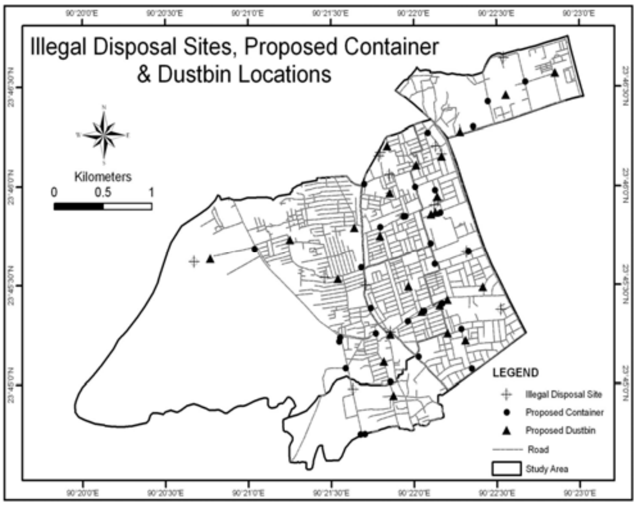

Figure 7 Illegal disposal sites, proposed container and dustbin locations of the study area

Waste Collecting Route Optimization with Proposed Waste Bin and Container locations

The waste collecting routes were proposed using GIS techniques. Present waste collecting routes and self-judgment were put into consideration at the route selection. A route was proposed using the Beri bund highway considering the wastes collected from N-W part of the study area (ward-46) and for disposal at Beri bund site.

The other routes were considered using network analysis and the routes suggested an overall two trips for each ward of the study area as shown in Figure 8.

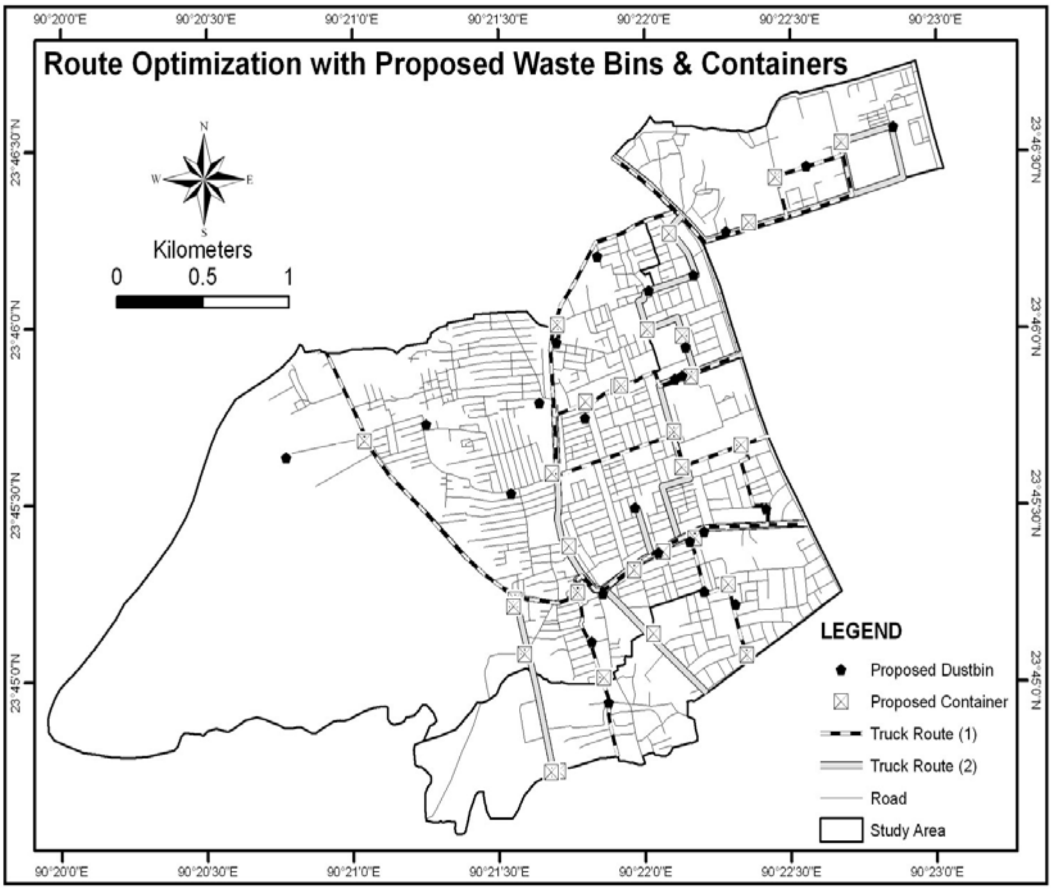

Figure 8 Route optimization with proposed waste bins and containers

The routes were mainly were selected based on bin and container locations. So, all the routes which validated all the locations could not ensure 100% time efficiency (Ward-45). The routes were based on the proposed waste bin (25) and container (30) locations and about 90% of the study area would be covered with the proposed bin and container locations.

CONCLUSIONS AND RECOMMENDATIONS

About 64% of generated SW had been collected by DCC with the existing bins and containers. The proposed bin and container relocations were suggested considering the existing number of bins and containers and another suggestion were made with 80% collection efficiency. Based on the present study, it was conducted that about 55% of recyclable wastes were collected by local ragpickers. In addition, this study also depicted that about five hundred people were directly involved with the rag picking and about 14 small illegal dumping site were found around the Mohammadpur Thana. A number of proposed bin and container with their locations and their optimized routes considering present illegal disposal sites were tried to delineate using GIS technique with its associated tools to achieve 80% waste collection efficiency. About 25 waste bins and 30 waste containers would be sufficient to achieve the 80% collection efficiency with reducing existing illegal disposal sites.

For an integrated approach, strategic SWM planning should be taken by the waste management authorities of DCC. Communal bins should be designed according to the waste generation and characteristics. The modified communal bins can help to minimize waste dumping as well saves collection and disposal cost. Lack of management information system (MIS) contributes to a complicated process of setting for proper waste storage, suitable routes assignment for trucks, etc (Mwakalinga, 2005). Mini transfer Station should be constructed at each waste container location. As only the single MTS was seen in Lalmatia (Ward-45), such type of construction will reduce the odor and traffic problem. Segregation of wastes at primary and secondary level at waste collection should be conducted at the study area. So, a Community Management Information System (COMMIS) should be built considering waste generation, collection and transportation (schedule, numbers of truck, etc). People's participation and technology should be incorporated for efficient SWM. GIS technique could be an efficient tools for constructing MIS, such technologies will be helpful for not only minimizing wastes but also to utilize the wastes in different ways. 3R (Reduce-Reuse-Recycle) campaign should be supported at all levels of the waste management and Clean development mechanism (CDM) should be incorporated in SWM model for waste minimization and proper utilization in Dhaka City.

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Solid Waste Management Status of Khulna City a Comparative Analysis between Public and Private Sector

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ABSTRACT

Solid waste management in Bangladesh is primitive and needs modernization and innovative approach for its proper management Khulna city is reported to generate some 200-455 tones of solid wastes daily, per capita per day generation variously quoted lying between 0.22 kg and 0.75 kg. The city has a population of about 1.5 million. In khulna the City Corporation is responsible for solid waste management services beside this some NOGs and CBOs also provide solid waste management services at community level. The report begins by bringing into focus the seriousness of the issue of solid waste management in Khulna city. It also highlights the comparison of solid waste management services between public and private sectors. It also describes the prevailing system, as employed by the Khulna City Corporation (KCC), to deal with this growing waste management problem. Next, it presents the activities of a community-based experiment to manage solid waste in Khulna city and examines the effectiveness of the experiment through the level of satisfaction of the consumers. The paper concludes by drawing some planning implications from the study.

INTRODUCTION

As humans developed new technologies, the magnitude and severity of pollution increased. Almost all, if not all, human activities lead to the generation of waste. Human living and the creation of waste, both solid and liquid, go hand in hand. In fact, waste is an essential by-product, or the necessary evil, of everyday human living. Thus, the idea of eliminating waste all together is an impractical proposition--what is realistic is the management of it in an effective manner. Human well being depends on such effective management involving the collection, transfer, recycling, resource recovery and ultimate disposal of waste.

Solid waste management has become a matter of major concern in Bangladesh. Rapid population growth and uncontrolled urbanization are severely degrading the urban environment and placing serious strains on natural resources and consequently, undermining equitable and sustainable development. Solid waste generation of the urban areas of Bangladesh is increasing proportionately with the growth of its population which is 5.4 percent per annum, while solid waste management capacity of the cities and towns is lagging behind and the gap is widening every day. All these are making the environmental scenarios of our urban life quite gloomy and dismal for the 21st century. Solid waste management in Bangladesh is primitive and needs modernization and innovative approach for its proper management. In addition to modernization of the solid waste management in urban areas, there is an urgent need for framing of necessary laws and by-laws.

KCC is responsible for the operation and maintenance of municipal services including solid waste management. The solid waste management organizes waste collection from approximately 1200 city corporation bins, located on roadsides throughout city. KCC trucks only pick up waste from the roadside bins while waste is frequently disposed in open drains, free land and around the waste bin sites. It is estimate that of the 200 tons of waste generated daily, between a third and a half remains uncollected. Beside this some NGOs are also involved in solid waste management service in Khulna City by realizing the need of the Citizens and keep the City clean. NGOs are mainly operating door to door collection system. In this system generally, a garbage collector comes with a rickshaw van to collect waste from individual households. The collector then disposes off the waste to a transfer point from where the municipal truck picks it up and carries to the waste disposal site. But NGOs operations are limited within few Wards of KCC. For developing better municipal solid waste management system not only the City Corporation but also NGOs have to take necessary initiative immediately. This study will highlights such a picture of solid waste management scenario between public (KCC) and private (NGOs) sector in two different WARD of KCC.

PRIVATE SECTOR INVOLVEMENT IN SOLID WASTE MANAGEMENT

Private sector mainly NGO in Khulna is playing an important role in recycling of solid waste. Prodipan, a local NGO was established in Khulna city in March 1997 with the passing out date of August 2003. The project was financed by the Swiss Agency for Development and Cooperation (SDC) with the technical and management support from the water and sanitation programme. This NGO Prodipan was selected to implement project activities in collaboration with KCC. Prism Bangladesh is a non government voluntary organization. Since 1998 Prism Bangladesh is working for environmental development of Khulna metropolitan area under the supervision of Ministry of Environment and Forestry. Sustainable Environment Programme (SEMP) (financed by UNDP) works as a project of Community Based Urban Solid Waste Treatment in Khulna City also.

Waste collection of 6 project wards was divided into 26 primary waste collection blocks. Where total number of households is 12,250 and population is 69,944. Blocks consist of an average of 500 households and can be served by one waste collection van. The blocks are bounded by roads or other obvious physical limits. The primary waste collection system consists of daily house to house collection by rickshaw vans. Households gather their days waste in the plastic bags or containers, hand them over the van driver who takes the waste to a local transfer point. Prodipan and Prism Bangladesh collects solid waste from door to door in the ward no 24.The number of primary collection blocks is 8.

Functions of Prodipan and Prism Bangladesh

1. Door to door collection
2. Increasing the awareness of the urbanities on solid waste management by publicity, campaign, arranging rally, etc.
3. Ensuring peoples participation in solid waste management.
4. Developing the appropriate model on community based solid waste management.
5. Developing the paying tendency of households for proper solid waste management.
6. Provide support to the conservancy department of KCC.

OBJECTIVE

- To know the present solid waste management system in Khulna city.
- To compare the existing solid waste management system between public and private services.
- To measure the level of satisfaction of the consumers about solid waste management.

STUDY AREA

Khulna is the third largest city in the country and is located in the southwest part of Bangladesh (At 22° 49' north latitude and 89° 34' east latitude). The city has a population of about 2 million. Khulna the port city of south Bangal is surrounded by river named Rupsha and Bhairab. It became glorious for the presence of the seaport named Mongla and Mangrove forest named Sundarbans. The city core, which is about one-quarter of the total city area, is densely populated with mostly multi-storied residential and commercial buildings. The rest of the city is a mixture of urban and peri-urban areas. There are several low-income housing areas and slums located throughout the city.

The inhabitants of the city usually dispose off their solid waste in nearest convenient places, open spaces, drains, and in and around street-side waste bins. The municipal trucks pick up solid waste only from bins and the waste thrown elsewhere remains scattered all around in other places.The main part of this study is to compare the solid waste management system between public and private services. So, two different wards are selected in this study for the comparison of solid waste management system between public and private services. These selected wards are Ward No. 1 and ward No. 24. For proper comparative analysis, ward no.1 is selected where private services for solid waste management are not available. On the other hand, ward no.24 is selected where private services are available.

METHODS OF THE STUDY

In every research a good and sequential methodology is a must with the help of some procedure the study is undertaken. For conducting this study at first two different wards were selected where one have public service and another have private services for solid waste management in Khulna City Corporation area and the selected wards are 1 and 24. A Reconnaissance survey was conducted to get an overall picture both the study areas which helped later to get the ideas about the problems concerned with the solid waste management of the study area. It also worked as the guidelines for the surveys and necessary information. After that primary data were collected through a questionnaire in these selected wards (ward no. 1 and ward no. 24). Some necessary information was also collected from different secondary sources such as: BBS Report, Khulna City Master Plan, Local Government Engineering Development (LEGD) maps of the study area. After Primary Data collection raw data were processed according to meet up the study objectives and for this task Statistical Package Software Spreadsheets (SPSS) software was used.

Sampling Techniques for Data Collection

There are 4291 households in ward no.1 and 5713 households in ward no.24. For this study it is not possible to survey the entire household. So, total 125 household are surveyed for this study from the two different wards through stratified sampling technique. In stratified sampling technique the population is divided into groups according to one or more characteristics. The purpose of dividing the population into groups is to achieve greater degree of homogeneity within the groups or sub population. The characteristics, which are considered to form groups, are economical, social, cultural etc.

FINDINGS AND ANALYSIS

Present Solid Waste Management Status of the Study Area

It is found that most of the people of ward no 24 dispose their waste by door to door collection system which is provided by the private sector "PRODIPON" and this is 75.8%.On the other hand, the involvement of private sector for waste collection system is totally absence in ward no.1. In ward no.1 waste are disposed by block collection system and it is 76.56%. The following table portrays the waste collection system of the study area.

Table 1 Waste collection system of ward no. 1 and ward no. 24

Ward	Name of the Area	Collection System			Total
		door to door	block collection	curb side collection	
Ward No :24	NIRALA	33		2	35
	Baghmara	14	2	4	20
Ward No :1	Shiromoni		22		22
	Badamtola		27		27
Total		47	51	6	104

Source Field Survey, 2005

The data of total waste generation were collected from 100 respondents out of 125.The rest of the respondents are not using both public and private services. About 1-2 kg wastes are generated by the 57 household and about 2-3 kg are generated by the 35 household. A very few no. of family are generated more than 3-4 kg of waste. The table 2 shows the per head waste generation status of the study area

The table below represents that in ward no.24 the amount of per head waste generation is within the range of .3-.5 kg is higher than other range. The figure is nearly same for the ward no.1.

During the study it was found that in ward no.24 most of the respondents are using private services and this is 75.8%. In this case, NGOs collects waste regularly through their vehicle in door to door collection system. Usually waste is collected in one time a day by the private sector by door to door collection system. A very few no. of them are using canal & dustbin for waste disposal. This picture is clearly different in ward no.1, here about 78.12% household are using dustbin for waste disposal system and some people are using drain and canal for dumping their daily waste without any environmental consideration. In ward no.1 collection system is fully different. In ward no.1 about 76.56% waste are collected by the KCC in twice a week

Table 2 per head waste generation status of the study area

Name of the area	Per Head Waste Generation							Total
	.2-.3 kg	.3-.4 kg	.4-.5 kg	.5-.6 kg	.6-.7 kg	.7-.8 kg	.8-.9 kg	
Nirala	2	16	11	4	3	2	2	40
Baghmara	3	5	8	2	2	2		22
Shiromoni	8	12	7	2	2	1		32
Badamtola	7	12	8	2			1	30
	20	45	34	10	7	5	3	124

Source Field Survey, 2005

Availability of Waste Dumping Facility

The quality of services of KCC for waste collection system in ward no.24 is very poor. There are only 4 person receiving dustbin facilities in ward no.24. On the other hand about 51 people are using dustbin facilities in ward no.1. Most of the people of ward no.24 are not satisfied with the services of KCC and most of them are agreed with the absence of dustbin in this ward as the problem while disposing the solid waste. So at present they are receiving private facilities due to lack of public services. Though there is proper no. of dustbin in ward no.1 but people arte not satisfied with these services. Most of them mentioned that the present dustbins are not in appropriate location, always overloaded and not regularly cleaning as the problem while disposing of solid waste.

Table 3 Problems while disposing of solid waste

Name of the area	Problems encounter while disposing solid waste				Total
	Absence of dustbin in this area	Dustbin is not appropriate location	Dustbin is always overloaded and no regular cleaning	Others	
Nirala	29	8	2	1	40
Baghmara	12	8	1	1	22
Shiromoni	11	8	15		34
Badamtola	3	15	12		30
Total	55	39	30	2	126

Source Field Survey, 2005

Service Delivery Status of Private Sector

Private sectors start their solid waste management services in KCC area not long ago. As private services for solid waste management found in ward no. 24 and here it is found that 48 respondents are receiving private services for waste collection system in last from last 2 years. About 25 respondents are receiving these facilities from more than two years. So it is clear that these waste collection facilities are recently provided by the private sector and it must not be more than 3 or 4 years.

Though private services for waste collection system is present in ward no 24 but some people are not fully satisfied with these services. Here 47 house holds are covered with private services and responded about its quality and reliability. Among them 35 respondent mentioned the reliability of private collection system is high whereas 11 respondent mentioned it as medium.

The respondents of ward no.24 were also asked about the efficiency of private collection system. Most of the people were agreed positively with the efficiency of private services. The present services are efficient according to 63.8% respondent and 36.18% respondents mentioned it as medium.

Cost involvement is very much important factor for private sector involvement in solid waste management system. In ward no. 24 people made payment to the private sector (NGOs) for their waste management service. Most of the people in ward no 24 are paying 15 BDT monthly for using private services. On the other hand the people of ward no1 are neglected from private services and they are using public services for waste collection system as free of cost.

During the study the respondents were also asked about the sustainability of the private services. It was found that most of the respondents are mentioned the present services as sustainable practices than public services. The Table 4 shows the response pattern regarding the sustainability of the private services.

Table 4 Sustainability of private service

Hygienic practice in private service	Name of the area		Total
	Nirala	Baghmara	
High	7	3	10
Medium	23	11	34
Low	3		3
Total	33	14	47

Source Field Survey, 2005

Hygienic practices are very much important for solid waste management system .The present waste collection system of private sector is not fully hygienic. Most of the people declared it as medium for hygienic collection (34 out 47 respondents) and 10 respondents declared it as high respectively. The people of the area expect that the collection system should be more hygienic than that of present condition.

Service Delivery Status of Public Sector

The quality of services provided by public sector (KCC) is very poor in both ward no 1 & ward no24. This condition is very much low in ward no1 than ward no24. Because private sector is already involved for waste management in ward no.24 but this service is absence in ward no.1. The table 5 shows the quality of services of public sector below:

Table 5 Quality of service of public sector

Quality of services in public organization	Name of the area				Total
	Ward no.24		Ward no.1		
	Nirala	Baghmara	Shiromoni	Badamtola	
high			1	1	2
medium			4	5	9
low	2	2	29	24	57
Total	2	2	34	30	68

Source: Field Survey, 2005

The respondents of the study area were also asked about the reliability of public services. But it is found the public services are not reliable in the study area. In ward no 24 people are using private services due to lack of proper reliable services of public sector. The scale of reliability is very much negative in ward no.1. Out of 67 respondents only 6 respondents of ward no. 1 mentioned solid waste management service performed by public sector as medium.

The respondents were also mentioned the in efficiency of solid waste management service of public sector. Out of 67 respondents 65 respondents mentioned public sector service as inefficient service where only 3 respondents mentioned it as medium level of efficiency. In the study area two different views are observed from in the question of sustainability of public services for solid waste management. Most of the respondents of ward no.1 marked the present public services as highly sustainable. On the other hand it may not be sustainable according to the respondents of ward no 24.

The respondents were asked about the hygienic practices of the public sector for solid waste management system. The services provided by the public sector are not totally hygienic at present condition. About 65 respondents marked the present collection system as unhygienic out of 68 respondents. The following table portrays the response given in question to the hygienic practices of pubic sector by the respondents

Table 6 Quality of service of public sector

Hygienic practice in public service	Name of the area				Total
	Ward no. 1		Ward no. 24		
	Nirala	Baghmara	Shiromoni	Badamtola	
Medium			2	1	3
Low	2	2	32	29	65
Total	2	2	34	30	68

Source Field Survey, 2005

CONCLUSIONS

Unhygienic waste disposal by household in Khulna City are posed serious health hazard to the city dwellers and caused environmental pollution. The solid waste management service by Khulna City Corporation organizes waste collection from approximately 1,200 City Corporation masonry bins, located on roadsides throughout the city. But it is not sufficient in consideration of the city population and rapid urbanization of this city. Private sectors perform their service for solid waste management in some selected areas in very minimal scale. It is expected that KCC must provide solid waste management services in a sustainable way and should develop efficient solid waste management services through proper reliability, hygienic practices for pollution free city. At the same time they must encourage the privet sector for being involved in the waste management service for the future betterment of solid waste management system for Khulna City. Eventually, they should also incorporate the Non-Governmental Organizations to upgrade their present waste management system with sustainability consideration.

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Municipal Solid Waste Management in Dhaka City: Case Study

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Dhaka, Bangladesh

ABSTRACT

The paper illustrates that Municipal Solid Waste (MSW) remains unmanageable in the Dhaka City. To understand the solid waste management, 36 and 41 no wards of Dhaka City were selected as study area. The present MSW collection system of the study area is inadequate and inefficient. By extensive data collection it has been observed that only 70% to 80% of the total generated waste is collected and disposed of per day by Dhaka City Corporation (DCC). The rest of the wastes remain on the roadside bins and curbside creating unhealthy environment. In addition, based on the experimental results it was found that the waste generation varies from 0.110 to 0.142 kg/capita/day. The generation rate also increases with the income level due to more consumption. Majority of the respondent preferred house to house collection. Finally, it can be concluded that the collection time and frequency should be such that maximum amount of waste is collected from the source. Different area may be covered by different collection time and frequency.

INTRODUCTION

The increasing quantity of solid wastes is a growing environmental problem in developing countries. Compared to cities and towns of industrialized countries, those of developing countries generate less solid wastes per capita because, in developing countries, people have less purchasing power and therefore consume less, there is less industrial activity and there is a very high rate of refuse of solid wastes by the poorer sections of the community. Despite this, large volumes of solid wastes are produced and constitute an enormous public health and environmental problem in most developing countries. Unplanned and inadequate collections of solid wastes contribute greatly to an unhealthy environment. Solid waste management today is considered to be one of the most immediate and serious problems of environment, confronting urban local government in developing countries. Long experience states the failure and efficiencies of local government by hundred's of year in solid waste management. Dhaka is the largest metropolitan city in Bangladesh. The significance of the study is increasing day by day for its socioeconomic role, which help to the overall development of Bangladesh. The solid waste management in Dhaka City is an acute problem. The roads and street remain dirty and create serious environmental pollution (Ahmed, 2000). The total daily wastes generated in DCC areas is about 5400 tons, in which residential, commercial and institutional wastes are about 4048,1178 and 62 tons, respectively. Residential waste is the main portion of solid wastes streams which is about 76% of total wastes. It is time to take necessary action to overcome the solid waste management problems and make a sustainable solid waste management system for Dhaka Metropolitan City. As local government failed to manage the solid waste, community participation is necessary for better addressing of this problem.

As long as the city would continue to grow, the amount of waste would grow proportionately. Solid Wastes Management (SWM) in the country is still in its primitive stage. The conservancy by the DCC with a century old mechanism has proved to be inadequate to meet the present demand. If proper solid waste management plan is not taken for growing metropolis of Dhaka, it will cause severe gradation of urban environment and pollution problem. As such waste management is one of the key areas of concern for urban sanitation and cleanliness for healthier metropolitan development. It is therefore, highly desirable to study solid waste management system of Dhaka City for better planning and management of solid wastes from environmental view point and sustainable development.

CHARACTERIZATION OF THE STUDY AREA

Because of limitation of time and resource, it was fully impossible to survey the whole of the city. For this reason, to understand the solid waste management and thaw traditional means of response of the people towards solid waste management, 36 and 41 no ward is selected.

GENERAL INFORMATION OF WARD NO 36

Ward No. 36 under Zone- 4 of the DCC area, and covering the area of North Shajahanpur, South Shajahanpur and Shajahanpur railway colony. As per DCC (2005),- there are 16,550 households, 70,781 total population with 38,930 male and 31,851 female in this ward. This ward is almost flood free area. In this ward 3 primary schools, 1 Govt. degree college, 1 private hospital, 5 mosques, 1 kacha bazaar and 1 NGO. Mainly middle and lower middle class people mostly live in this area. However higher middle class people also live in North Shajahanpur. The municipal solid wastes (MSW) are disposed in the designated concrete dustbin and container provided by the City Corporation. Local in initiatives are very active in this ward for door-to-door collection of wastes by dividing the whole zone into 5 segments. Total 18 rickshaw vans, 28 staffs are engaged in this system. The residence are paying monthly fees varies on economic condition, usually 20 TK to 30 TK. DCC collects wastes from secondary sites. Since some ditches are filled with MSW as like small dumping sites. Major concern is the medical wastes generated at Islamic Bank Hospital, which are disposed in the special type of pick-up van carefully (dhakacity.org).

GENERAL INFORMATION OF WARD NO 41

Ward no 41, under Zone-6 of the DCC area, and covering the area of Agargaon, Taltola Govt. Colony, Shamoli Road 1& 2 and Amlertak. As per DCC (2005), there are 20,750 households, 87,240 total populations with 46,249 male and 40,991 female, in this ward. This ward is almost a flood free area. In this ward, there are 3 Government High Schools, 1 Technical College and 1 Government Hospital. Some important offices like Local Government Engineering Division (LGED), Passport office, Bureau of Statistics, SPERSO, Abhawa (Weather) Bhaban, Science Museum, etc. One of the biggest colony of the city. Taltola Govt. staff quarter with an area 10 acres land is located in this ward. Mainly middle and lower middle class people mostly live in this area. However, higher middle class people also live in Shamoli Road Nos.1 & 2. The municipal solid wastes (MSW) are disposed in the designated concrete dustbin and container provided by the city corporation. Local initiatives are very active in this ward for door-to-door collection of wastes by dividing the whole zone into 4 segments. Total Rickshaw vans and 21 staffs are engaged in this system. The residence are paying a monthly fee varies on economic condition. DCC collect wastes from the secondary sites. Since some ditches are filled with MSW as like small dumping sites. Major concern is the medical wastes generated at National Orthopedic Hospital and other health care facilities, which are disposed the wastes in the same dustbin of MSW in mix condition (dhakacity.org).

DATA COLLECTION

This study is based on collected field data, questionnaire survey and literature review to identify the present stature of solid waste management in a typical city area of Bangladesh mainly ward no 36 and 41 of Dhaka City Corporation.

DATA COLLECTION FROM THE SELECTED HOUSES

To determine the total generation of solid waste of the 36 & 41 no wards from the households, three houses were selected from each ward from which solid waste was measured regularly. Four buckets was supplied to household to store their waste in the bucket.

- *Biodegradable waste:* Biodegradable wastes are the wastes which are biologically degradable and mainly produced in the kitchen. e.g. vegetables, food waste, fish scales, meat etc.
- *Reusable waste:* These are the wastes, which can be used again after its original use is ended for the same purpose or other use. e.g. reusable bottles, ash from kitchen and reusable bags .

Table 1 Capacity of waste bins and waste category

No of bins	Capacity (liter)	Type of waste
1	20	Biodegradable waste
1	12	Reusable waste
1	5	Non-reusable waste
1	5	Other waste

- *Non-reusable waste:* These are the waste, which can not be used again for the same purpose or other use. e.g. paper, cosmetic bottle etc.
- *Other waste:* These are mainly metals, glass, plastic, can etc (Techobanoglous, 2002).

SAMPLE SURVEY OF STUDY AREA FOR PRIMARY DATA COLLECTION

A sample survey was conducted in the 36 no & 41 no wards to account for the total generation of solid waste in the whole ward. Data was collected on the residential, households no and beneficiaries are shown in Tables 2 and 3.

Table 2 Residential areas of 36 no ward

Ward No	Area	Households	Beneficiaries
36	North Shajahanpur	2,979	11,728
	South Shajahanpur	3,641	17,307
	Shajahanpur railway colony	9,930	41,746
Total		16,550	70,781

Table 3 Residential areas of 41 no ward

Ward No	Area	Households	Beneficiaries
41	Agargaon	4,150	17,448
	Taltola Govt. Colony	7,263	30,534
	Shamoli Road 1	3,735	15,703
	Shamoli Road 2	3,320	13,959
	Amlertak	2,282	9,596
Total		20,750	87,240

With the increase of total quantity of solid waste, it is estimated that 60% to 80% of total cost of solid waste management is spent on the collection page alone. Hence, a small percentage improvement in the collection operation can lead to a significant saving in the overall coat. There are several method used for collection of solid waste such as Community collection, Block collection, Curb- side collection House-to-house collection. A sample survey was conducted in the 36 no & 41 no wards to account for the opinion of the public in waste collection system. 100 people of each ward were interviewed for collecting data.

Table 4 Households performance to solid waste collection system

Households performance to solid waste collection system		Collection (%)
Choice of respondent	House to house collection	88
	Curb side collection	1.73
	Block collection	1.03
	Communal collection	9.24

Table 5 Desired collection frequency of solid waste collection system

Desired collection frequency of solid waste collection system		Collection (%)
Frequency	Twice a day	14.5
	Daily	85
	After day	0.5
	Every two days	Nil

Table 6 Time of collection preferred

Time of collection preferred		Collection (%)
Collection time	Morning	14.33
	Noon	28.4
	Afternoon	49.38
	Evening	7.89

RESULTS

Solid Waste Generation Rate and Physical Composition in the Study Area

Average total per capita waste generation rate of households in ward no 36 is 0.142kg/capita/day. Average total per capita waste generation rate of households in ward no 41 is 0.110kg/capita/day. It may be seen that a major portion (80% - 90%) of solid waste in residential, commercial and market areas of Dhaka City is organic. This indicates the potentials of recycling of organic waste for resource recovery. Domestic waste generation rate which is proportional to the income rate are shown in figure 7&8. The average values of different types of wastes are shown in table 9&10. And percentages of different types of wastes are shown in figure 3 & 4.

Table 7 Summary of waste generated from three houses income level in ward 36

House no	Income level	Waste generation rate (kg/cap/day)
1	About 5,000	0.098
2	About 12,000	0.118
3	About 17,000	0.123
4	About 20,000	0.183
5	About 22,000	0.185

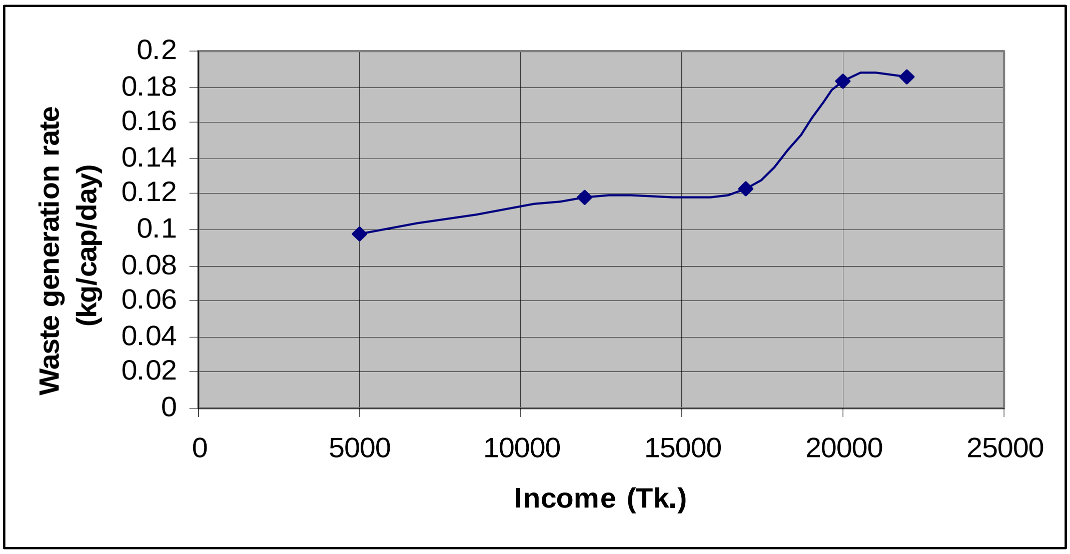

Figure 1 Domestic waste generation rate of 36 no Ward

Table 8 Summary of waste generated from three houses income level in ward 41

House no	Income level	Waste generation rate (kg/cap/day)
1	About 5,000	0.068
2	About 12,000	0.082
3	About 17,000	0.095
4	About 20,000	0.151
5	About 22,000	0.152

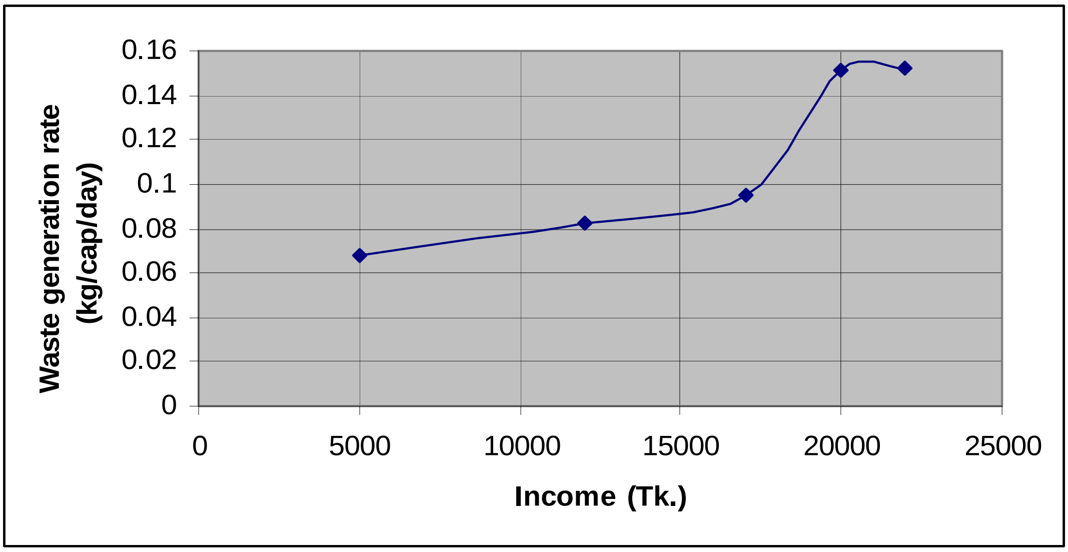

Figure 2 Domestic waste generation rate of 41 no Ward

Table 9 Average value of different types of wastes in 36 no ward

Type of wastes	Average value, kg/cap/day	(%) by weight
Biodegradable waste	0.149	96.20
Reusable waste	0.0013	0.84
Non-reusable waste	0.0023	1.48
Other waste	0.0023	1.48
Total	0.1549	100%

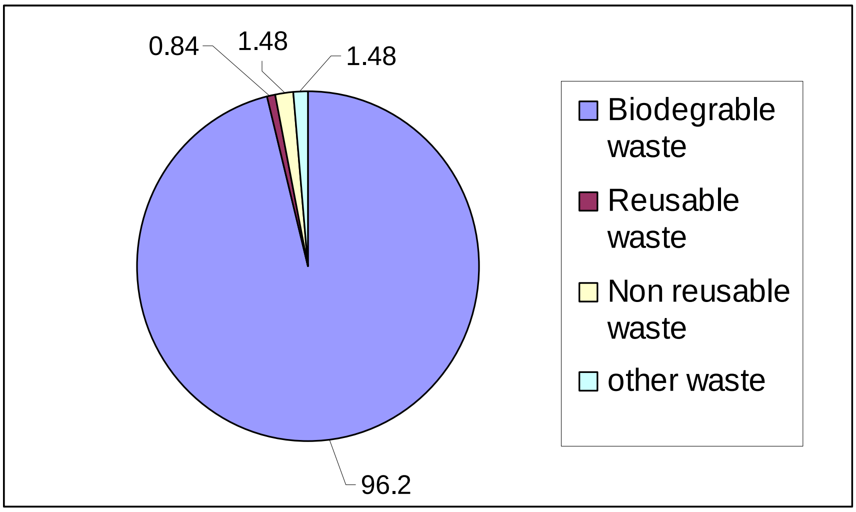

Figure 3 Percentage of different types of waste of 36 no Ward

Table 10 Average value of different types of wastes in 41 no ward

Type of wastes	Average value, kg/cap/day	(%) by weight
Biodegradable waste	0.124	92.95
Reusable waste	0.0057	4.27
Non-reusable waste	0.0023	1.72
Other waste	0.0014	1.06
Total	0.1334	100

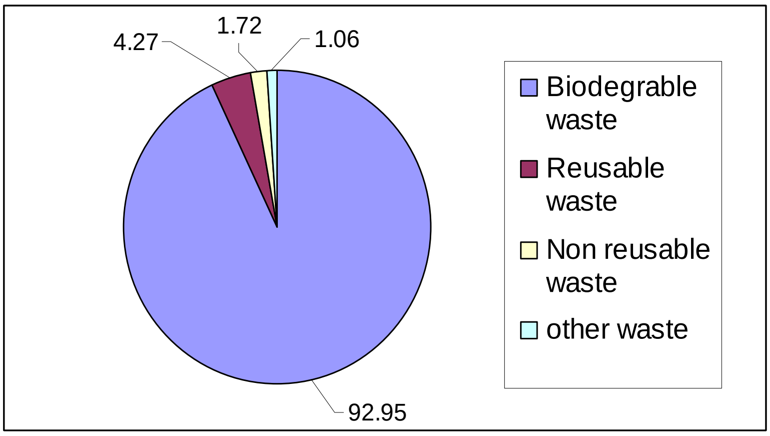

Figure 4 Percentage of different types of waste of 41 no Ward

TOTAL GENERATION OF SOLID WASTE IN THE STUDY AREA

Generation of solid waste in different households was achieved previously by measuring waste of six houses. Generation of solid wastes in other sources such as shops, institution, business center, and hospital was found by field survey.

Table 11 Total generation of solid waste in 36 no ward

Source	Collected solid waste (ton/day)
Household	1.785
Shops	1.253
Institution	0.036
Business center	0.048
Hospital/Clinic	0.021
Total	3.143

Table 12 Total generation of solid waste in 41 no ward

Source	Collected solid waste (ton/day)
Household	1.862
Shops	1.548
Institution	0.048
Business center	0.065
Hospital/Clinic	0.925
Total	4.448

COLLECTION OF SOLID WASTE IN THE STUDY AREA

It has been seen that actual generated solid waste from various source of study area is not properly collected. Hence, therefore amount of collected solid waste is less than that amount of generated solid waste. Table 13 & table 14 indicate the total collection in the study area.

Table 13 Collected solid waste from various source in 36 no ward (DCC)

Source	Collected solid waste (ton/day)
Household	1.458
Shops	0.936
Institution	0.018
Business center	0.039
Hospital/Clinic	0.010
Total	2.461

Table 14 Collected solid waste from various source in 41 no ward (DCC**)**

Source	Collected solid waste (ton/day)
Household	1.583
Shops	1.362
Institution	0.118
Business center	0.039
Hospital/Clinic	0.101
Total	3.203

PROPER MEDICAL WASTE MANAGEMENT IN THE STUDY AREA

Medical waste has become a major health hazard in many countries including Bangladesh at various divisions. So Dhaka is not out of this effect. Medical waste generated by hospitals, clinics and pathological laboratories. In 36 no ward solid waste presently being disposed in the special type of pick-up van carefully but in 41 no ward solid being disposed of carelessly by generators. These may cause deadly diseases like HIV and Hepatitis among the people who may get infected unknowingly by coming contact with such waste. At present there is no regulation by the authorities to control collection, storage, treatment and disposal of medical waste. As a result medical wastes are indiscriminately disposed near hospital, clinic and pathological laboratories.

CONTRIBUTION OF NGO's

Several NGO's are working in different area of Dhaka City for the management of solid waste with DCC. In 36 no ward Samannito Shishu Shastha Songstha (Integrated Child Health Organization) and in 41 no ward Environmental Cleaning Illiteracy and Anti Drag Organization have been working for several years. They mainly collect waste from house to house in different para/mahalla by small van (manually driven) and store the waste in road side bins. From the storage bins DCC truck collect the waste and dump it in ultimate disposal site. By giving this service the NGO's take about 10 to 20 Tk per house.

ULTIMATE DISPOSAL OF SOLID WASTE

Ultimately the collected solid wastes should be disposed properly. There mainly alternative waste disposal methods may be employed. But in existing solid waste management system of the study area, disposal on land is most common and widely used.

The safe and reliable long term disposal of solid wastes is an important component of integrated waste management. Although source reduction, reuse, recycling and composting can divert significant portion of MSW, large amount of wastes still needs to be placed in landfills. The sites are situated in and around the city areas of low-lying open spaces, unclaimed land, riverbanks and roadsides.

DCC operate three sites, namely, Matuail, Gabtali and Uttara. The sites are located in and around city areas. All types of MSW are deposed including some portions clinical/hospital wastes Crude open dumping sites are always incompatible with the surroundings. The exposed wastes spreads all over the site are unsightly as no proper system maintain for filling the area. Wind blows litter and indiscriminate the dumping waste outside the site and on the surrounding pond and adjacent surface water. Every site poses high threat to health and environment. Upgrading of existing UDS based on the available local materials and technologies and controlled disposal of MSW can be considered as key sustainable issues to reduce the level of contamination and other hazards.

Environment pollution at open dumping site includes air pollution, water and soil contamination due to propagation of generated leachate, emission of landfill gases, odors, dust and potential fire hazard etc. The uncontrolled burning of solid waste creates smoke and other air pollution. Garbage nuisance conditions are also pose higher risk for human beings. As the wastes deposition continues and the major parts of disposed wastes are biodegradable organic wastes, landfill gases generate continuously. But there is no provision for the control of gases in the existing sites, causing risk of explosion and fire hazard. In UDS, leachate percolates and contaminates surface and ground water. In some sites, the sources of groundwater are very close to UDS. Peoples are uses this water in various purposes such as bathing, washing, drinking and farming. Surface water is also contaminated because solid wastes are being dumped near/at the marshy land, ponds, rivers and canals. Contaminated water is harmful for fish and aquatic lives by reducing the amount of oxygen in the water. Chemical and oil spills, which are mixed with MSW, also cause water contamination.

As one of the most densely populated countries and heavy pressure of new inhabitants in the cities, city authorities are facing severe problems to get new sites for ultimate disposal. Due to non-engineered situation, the existing sites are also going to early closure. Peoples are also protested to close some existing sites are also going to early closure. Peoples are also protested to close some existing sites because of their hazards nature. Even the city authority tries to buy some land for this purpose hiding real information to the adjacent inhabitants. So, the existing practices i.e. open dumping for ultimate disposal will not get the support from concerned stakeholders in future. The city authority might think about the upgradation of existing sites to control the present situation and proposed full environment friendly future disposal sites in accordance with local conditions and technological capabilities (Alamgir 2005).

DISCUSSIONS

The study revels that generation of solid wastes depends on the income level of the people. Detailed data collection from three houses of each ward also shows that when income level is higher, solid waste generation rate is also higher. From table 11, 12 total generated solid wastes in the study area, 36 and 41 no ward, are found to be 3.143 and 4.448 ton per day respectively and from table 13, 14 total collected solid waste in the study area, 36 and 41 no ward, are 2.461 and 3.203 ton per day, that means, 72% to 79% of total generated solid waste is collected from various source.

Various type of solid waste like paper, glass, plastic, metal, cloth, food and vegetable product, polythene, garden waste, tin/can are generated in study area. A major portion (80% - 90%) of solid waste is organic. This indicates the potentials of recycling of organic waste for resource recovery. About (70% - 80%) of generated solid waste is collected from various sources.

Solid waste management system today is considered to be one of the most immediate and serious problems of environment, confronting urban local government in developing countries. Long experience states the failure and inefficiencies of Dhaka City Corporation (DCC) by hundred of years in solid waste management. DCC is not fully successful in solid waste management. During field survey some of disorder has been observed through various stages of existing management system such as lack of effective sanitation, poor supervision of DCC stuff and not collecting waste from bins. As few numbers of NGO's are working in the study area, condition of existing solid waste management system is improving day by day.

CONCLUSIONS

The present waste collection system of the study area is inadequate and inefficient. By extensive data collection it has been observed that only 70% to 80% of the total generated waste is collected and disposed per day by DCC. The rest of the wastes remain on the roadside bins or curbside creating unhealthy environment all around such as bad odor, soiled street and aesthetically problem. To solve the problem DCC need to find a proper solid waste management system in the Dhaka City. More over NGO's may play a certain role by involving the community in the waste management system.

The waste generation rate in the study area varies from 0.110 to 0.142 kg/capita/day. The generation rate also increases with the income level, as it should be due to more consumption. Majority of the respondent in the study area preferred house to house collection. The collection time and frequency should be such that maximum amount of waste is collected from the source. Different area may be covered by different collection time and frequency. If possible a waste recycling plant may be established for better resource recovery from solid waste.

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Domestic Solid Waste Management towards the Sustainable Resource-Recovery Option in Khulna City Corporation of Bangladesh

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ABSTRACT

Domestic Solid Wastes (DSW) covers the major portion on an average 90% of Municipal Solid Wastes (MSW) of Khulna City Corporation (KCC) of Bangladesh that consist of a heterogeneous composition of wastes. Among these compositions, the major portion is organic (around 92.5%) that characterized by a rapidly biodegradable-associated with a significant factors of environmental health risks. The existing management system of these wastes is creating unwanted environmental problems in the relevant communities and its surroundings. About 549 tons/day of domestic solid wastes is generated in the KCC area that has a potential value as burnable biogas and environment friendly organic bio-fertilizer. The research revealed that the burnable biogas could easily be converted into valuable potential electricity. To visualize the mentioned usages of DSW three residential areas were selected randomly depending on different income levels in order to get average generation rate of DSW in KCC area and three representative samples from each sampling site were collected randomly and sorted out the organic and inorganic portion from these samples. Percentage of average moisture content of organic DSW was measured by using electric oven and then the Total Solid (TS) was also measured. An anaerobic digestion technology has been set up besides the Environmental Engineering Laboratory of Environmental Science Discipline of Khulna University, Bangladesh. Depending on the different percentages of TS value, the already measured same amounts of wastes were kept into four airtight plastic drums for anaerobic digestion in the laboratory for initiation of gas production. The average gas flow rate in the set experiment was measured and calculated as 0.23m^3/KgTS. A comparative analysis has also been taken and found that 6% TS is better for optimum gas production. Based on the analysis, the study suggested that about 22,932.78 kWh/day electricity can be generated by using the daily produced gas.

INTRODUCTION

Wastes that are generated in houses and apartments includes paper, cardboard, food cans, plastics, food wastes, glass containers and garden wastes resulting from human activities that are normally solid and are discarded as useless or unwanted. Khulna is the densely populated city of Bangladesh and is, therefore, subject to solid waste pollution. It is situated below the tropic of cancer, around intersection of latitude 22.49 ^{o} North and longitude 89.34 ^{o} East. About 1.5 million people are living in Khulna city and its area is 47 sq. km and the population growth rate is 2.96 percent per year. The average per capita waste generation rate in KCC area is 0.346 Kg/day and major portion of generated wastes is organic in nature. Total organic wastes are 88.40 percent, 90 percent out them residential. Per day about 420-520 tons of solid wastes are generated and total amount of organic wastes is 459.68 tons; among them about 413.72 tons are residential solid wastes (Alamgir *et al*., 2005). The increasing quantity of solid wastes and its indiscriminate disposal in public places causes serious environmental hazards and health risks, block drains, create water logging and spill over the road and enhance the traffic congestion and it is a growing environmental problem in developing countries. These wastes hampered the daily life of the inhabitants and entirely lose the city and the country their resources. Usually it causes damage or loss of the trend of economy and development of the city (Ahmed and Rahman, 2000). Thus, it is essential to take proper steps and to find out an inventive technology for possible resource recovery from DSW for sustainable waste management in Khulna city.

Besides, there is a critical demand of electricity for consuming in households, factories, industries and public institutions. However, the supply is totally insufficient due to scarcity of high cost of fuel (Azad *et al.,* 2003). Therefore, organic wastes of the city areas can be utilized to produce biogas which can be used further to generate electricity or for other necessary purposes. In this way, technology can be resolve the accessible energy problem of Khulna city

OBJECTIVES OF THE STUDY

The purpose of this study is to learn, 'how to convert the organic portion of domestic solid wastes into usable biogas resource at a small-scale low cost basis by the process of anaerobic digestion', with the following major objectives

1. To identify the utilizable organic portion of Domestic Solid Wastes (DSW)
2. To analyze how to utilize these unused organic wastes into possible resources as biogas and bio-fertilizer and
3. To analyze how the recoverable biogas from DSW can produce the usable energy.

MATERIALS AND METHODS

To select the sampling points and data collection, a Reconnaissance Survey has been conducted in different spots of the KCC area. Random sampling procedure was chosen for the collection of samples. During the collection of samples three residential area were selected (Sonadanga residential area: ward no-17, Dolkhola slum area: ward no-27 and Gagon Babu residential area: ward no-29,) because these three sites are categorized on the basis of income level. Samples were collected randomly from each sampling point and brought it by using plastic bags into the laboratory. In the laboratory, the samples were sprayed upon the polythene paper and prepared it as a composite sample. From this composite sample three samples were taken and sorted out the various portions of DSW. After sorting the DSW, the weight of the organic and inorganic SW was taken. For the determination of the moisture content, slicing of organic SW was done before to keep it on the tray for dryness**.**

Figure 1 The oven drying process of DSW

Figure 2 Drums for anaerobic digestion

Three samples were kept on the separated tray by taking the initial weight (Triple beam balance) of each sample and placed into the chamber of the oven (Binder, made in Germany) for 24-36 hours at a temperature of 60-90 ^{0}C to dry it. After drying the samples were weighted. The percentage of moisture content, TS (factors for biogas production) as well as the amount of influent calculated by using the following formulas:

Percentage of moisture content = (Initial weight – final weight, after drying)/Initial weight x 100

Total solid content = (100 – moisture content) %

Influent calculation = 100/ Percentage of TS x TS of used materials. (Biogas operation and training manual, 1999)

Fifteen and a half kilogram (15.5 Kg) of solid wastes was used in each drum for anaerobic digestion that had four different percentage of TS content. The amount of TS and influent for 15.5 Kg solid wastes were calculated in the following way.

Table 1 Influent calculation for each drum of the different percentage of TS

% TS	Solid waste (Kg)	TS content (Kg)	Influent (Kg)	Water to be added (Kg)
5	15.5	1.98865	39.77	24.27
6	15.5	1.98865	33.14	17.64
7	15.5	1.98865	28.40	12.90
8	15.5	1.98865	24.85	9.35

Source: Laboratory experiment, 2008

According to the calculation, the four plastic drums (5%, 6%, 7%, and 8% TS) were set up in the laboratory for anaerobic digestion of organic DSW. Each drum contains (15.5 Kg) SW, and the amount of wastes and water that has to be added into each drum was calculated depending on the TS value and after that the drums were sealed.

Figure 3 Checking up of leakage

Figure 4 The gas measurement process

Each cap of the drums was set up by two nozzles with PVC pipe and gate valves. One pipe is for passing out gas and another is to identify the pressure height of gas. To make the drum airtight, extra-sealant was used (locally known as “katcha rubber”-Generally used in motor glass windows) instead of oil-based putty.

For enhancing microbial growth, the seeding (residue of old biogas plant) was added in to the each drum .The sealed time was noted and kept the drums into the laboratory for digestion. The production of gas measured from the next day for 60 days. The amount of biogas production, energy and electricity generation was calculated by using the following formulas.

CALCULATION OF TOTAL BIOGAS PRODUCTION

Amount of biogas (A) generated from DSW,

A (m^3) = Amount of raw materials (Kg) x Total solid content (%) x Gas generation rate per unit of solid waste (m^3/ Kg TS)

ENERGY FROM BIOGAS

E_1 (kJ) = A (m^3) x (%) of methane x LHV (kJ/ $m^{3)}$

ELECTRICITY GENERATION FROM BIOGAS

Total electricity generation is

E_2 (kWh/ day) = E_1 (kJ) x Generator efficiency / 3.599884 MJ. (1 kWh = 3.599884 MJ)
(Biswas and Lucas, 1996).

RESULTS AND DISCUSSIONS

Waste Generation Scenario In KCC Area

The study conducted various areas (Sonadanga Residential Area; ward no-17, Dolkhola slum Area; ward no-27, and Gagon Babu Residential Area; ward no-29) through questionnaire survey to find out the exact generation rate of solid waste per capita per day of KCC area. It is found the generation rate is 0.366 Kg/day/capita. Alamgir (2006) mentioned in his edited book, entitled 'Waste Safe' that the generation rate is 0.345 Kg/day/capita. The generation rate is almost same compare with one another study. If it is assuming an annual GAP (Gross Area Product) of 4% and 70% of the additional income coming into consumption, waste generation growth factor may be taken as 4*0.7=2.8%.With this trend, the year wise growth rate per day of domestic solid waste generation up to 2025 is shown into the following graphical representation.

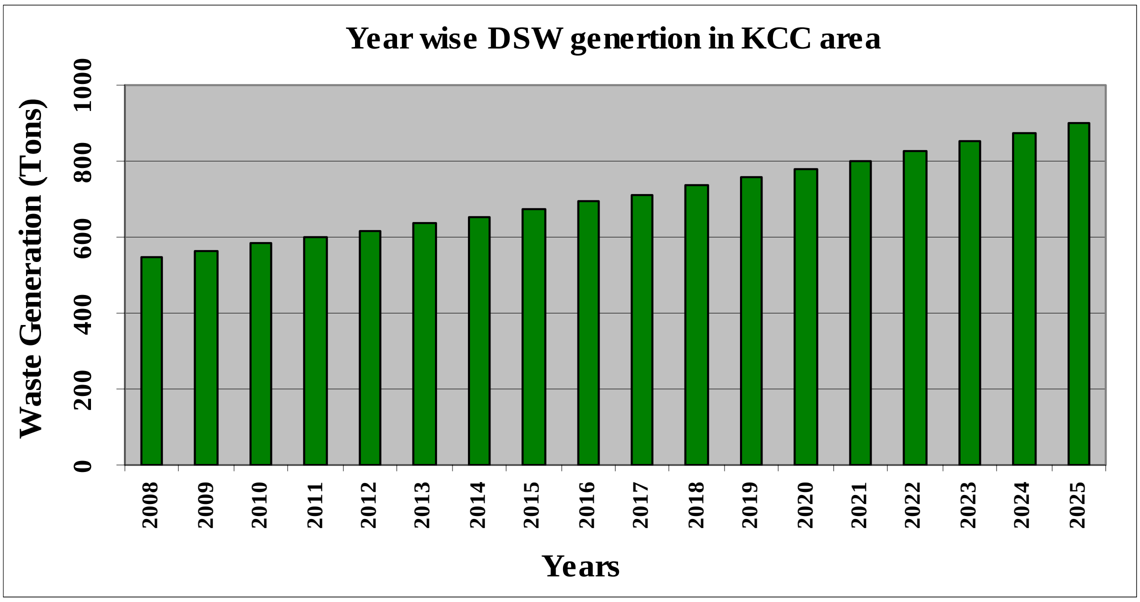

Figure 5 Year wise DSW generation in KCC area

From this graph, it is seen that the generation of wastes is increasing sharply in the urban areas and it will reach at around 901.44 tons in the year 2025. This huge amount of wastes will require a large area of land. This huge amount of wastes also produce a significant amount of GHG_S that will increase into the atmosphere, in which is composed of huge amount of CH_4 gas, an important precursor of electricity generation.

Moisture Content, TS and the Amount of Influent

Average Percentage of moisture content of the sample(S) = $(S_1+S_2+S_3)/3\%$ (86.21+87.32+88) /3% = 87.17%
The Total Solid (TS) = (100-87.17) % =12.83%
The amounts of TS for 15.5 Kg solid wastes = 1.98865Kg
For 5% TS the influent = 39.773 Kg solid waste influents

Carbon-Nitrogen Ratio

Table 2 Carbon-Nitrogen ratio determination

Samples	Organic Carbon (C)% in an average	Nitrogen (N)% in an average	C/N Ratio
S_1, S_2, S_3	31.65	2.61	12.12

(Source: Laboratory experiment, 2008)

Comparison between Different Percentages of TS –as a Factor of Biogas Production

To detect which percentage of TS is appropriate for biogas production from DSW by anaerobic digestion, the comparison graph of several experimented percentages of TS is shown below:

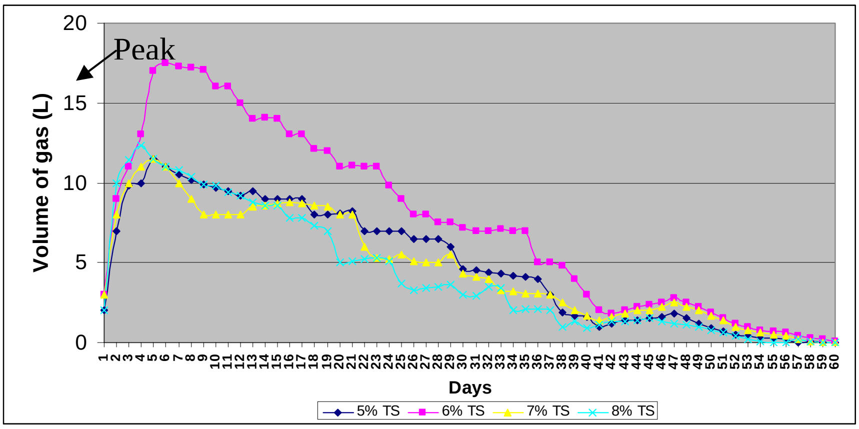

Figure 6 Comparison graph, showing volume of gas (L) against day

This comparison graph shows that the production of gas started on the first day and the maximum gas production was 17.5 L for 6% TS on the sixth day. The highest value of all percentage of TS was experimental within two to seven days. After 60 days it was clearly identified that the rate of gas production for all percentage of TS was near to zero except 6% TS. Comparatively the gas production of 6% TS is higher than other percentages of TS. For the period of digestion, at any temperature, the gas production was increased day by day at first and finally it was reached maximum rate- plateau at the day at six and after that the rate of gas production decreased.

Total Gas Production for Different Percentage of TS

The following graph shows the total gas production in 60 days for all percentage of TS.

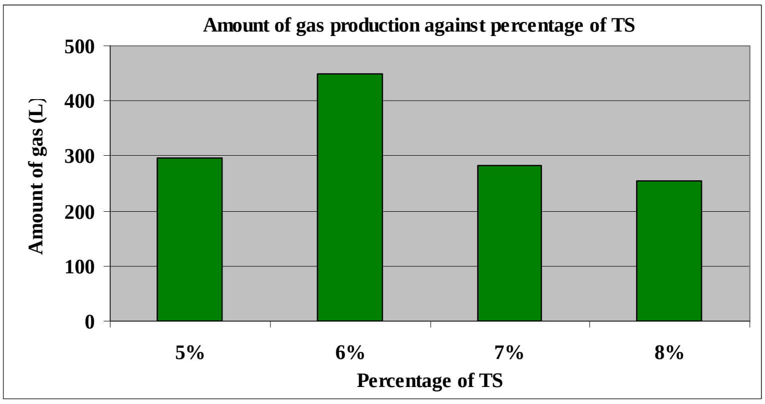

Figure 7 Total amount of biogas production against percentage of TS in 60 days

The graph shows that the maximum gas production is for 6% TS (at temperature 22^0c to 27^0c). But 26^0c to 30^0c temperature is suitable condition for microbial growth and it is directly involved in the decomposition of the organic DSW. So, by the anaerobic digestion of DSW, 6% percent is better for maximum gas production than other percentage of TS. But it may vary depending on the temperature as well as composition of DSW.

Gas Flow Rate Calculation

The average flow rate for 6% TS can be calculated by the following ways:
The total gas production for 6% TS =448.4 L
The TS value for 15.5 Kg solid waste=1.98865 Kg
We know that, 1,000 L=1 m^3
So, 448.4 L =1 / 1,000*448.4 m^3 =0.4484 m^3
For 1.98865 Kg TS the gas production is =0.4484 m^3

So, for 1 Kg TS the gas production is =0.4484 / 1.98865 m3/ Kg TS =0.23 m^3/Kg TS
Gas flow rate =0.23m^3/ Kg TS

CALCULATION OF TOTAL BIOGAS PRODUCTION

Amount of biogas (A) generated from DSW

A (m^3) = Amount of raw materials (Kg) × Total solid content (%) × gas generation rate per unit of solid waste (m^3/ Kg TS).
Here, the amount of domestic solid wastes (Kg) = 5,07,825 Kg /day (92.5% of averaging 549 tons)
Total solid content of DSW waste = 12.83%
Gas generation rate per unit of solid waste = 0.23 m^3/ Kg TS
Amount of biogas (A^3/day) will be generated from DSW.
= 507825*12.83 / 100*0.23 m^3 / day = 14,985.407 m^3 / day

Energy from Biogas

$\mathbf{E_1}$ (kJ) = A (m^3) x (%) of methane x LHV (kJ/m^3)
Where, A =14,985.407 m^3/day
Methane content = 55-75% (in an average 65%)
Lower heating value (LHV) = 20,580 kJ/m^3
So, $\mathbf{E_1}$= 200459789.4 kJ / day
= 200459.78 MJ / day

Electricity Generation from Biogas

Total Electricity generation is
E_2= (kWh / day) = E_1 (MJ) x Generator efficiency ÷3.599884 MJ. (1kWh =3.599884 MJ).
Where,
E1 =200459.78 MJ / day
Generator efficiency = 41.183%
So, E_2 = 22,932.78 kWh /day

Analysis of Bio-Fertilizer

Nutrient constituents of bio-fertilizer are shown in the Table 3 and chemical characteristics of bio-fertilizer are shown in the Table 4.

Table 3 Nutrient Constituents of Bio-fertilizer

Nitrogen (N) %	Phosphorus (P) %	Potassium(K) %
2.70 – 2.81	0.94 – 1.28	0.89

(Source: Laboratory experiment, (2008)

Table 4 Chemical characteristics of bio-fertilizer

Chemical constituents	Percentage (%) by weight
Carbon (C)	8-50
Nitrogen (N)	0.4-3.5
Phosphorous (P)	0.3-3.5
Potassium (K)	0.5-1.8

The bio-fertilizer has a great potentiality to keep balance the soil nutrients. The DSW based biogas plant that modifies the residue as bio-fertilizer. The bio-fertilizer has the characteristics of increasing organic content of the soil, moisture retention capacity, improves aeration at the root zone, soil texture, and soil fertility, and replenishes micro-nutrients in soils that provide the sustainable ecological condition.

CO_2 Saved by Biogas Technology

Various types of gas emits from solid waste land site, such as Methane (CH_4), Carbondiooxide (CO_2), Oxygen (O_2), Nitrogen (N), Hydrogen (H_2), Carbonmonooxide (CO), Ethane, Ethene, Acetaldehyde, Propanes, Butanes, Helium, Higher Alkanes, Unsaturated hydrocarbons, Halogenated compounds, Hydrogen Sulphide (H_2S), Organosulphur compounds, Alcohols, etc (DoE, 1989). According to Gendebein *et al.* (1991), Theoretically 372 Nm^3 landfill gas is generated from per tonne of solid waste. Among this amount CH_4 comprises 50-55%, followed by CO_2 which makes up the remaining volume. If the wastes degraded slowly after five years, the production trend of CH_4 and CO_2 will be more or less same. Therefore, it can be calculated the emission of CO_2 in equivalent to CH_4.

Theoretical Calculation Of CO_2 And CH_4 Production

Here the production of CH_4 = 372 x 63.8/100 (63.8% of averaging 372 Nm^3/tonne, considered high) = 237.33 Nm^3 /tonne

But the production of CH_4 = 372 x 55/100 (55% of averaging 372 Nm^3/tonne, it is considered more typical) = 204.6 Nm^3 /tonne

Now the production of CO_2 = 372 x 45/100 (45% of averaging 372 Nm^3 /tonne)
= 167.4 Nm^3 /tonne

With GWP of 21 for CH_4, CO_2 equivalent of 204.6 = 204.6 x 21 Nm^3 /tonne
= 4296.6 Nm^3 /tonne

Total production of Carbondioxide, equivalent per tonne = (167.4 + 4296.6) Nm^3 /tonne
= 4464 Nm^3 .So, total production of CO_2 equivalent/ tonne = 4464 Nm^3.Finally about 24, 50,736 Nm^3 CO_2 equivalent can be saved per day.

CONCLUSIONS

Khulna City Corporation produces a significant amount of domestic solid wastes (549 tons per day) from its population of 1.5 million. Apparently the waste seems a discarded materials, but scientifically it has a significant market value. Other than recycled and reused materials, all biodegradable substances could possible to make it biogas and bio-fertilizer. This process is environmentally friendly, ecologically sustainable, and lucratable for the possible carbon-credit marketability in global climate situation. The research findings say “Own produces biodegradable kitchen waste from individual family could possible to supply its own needs- the energy, biogas and precursor for organic agriculture-the bio-fertilizer.” Moreover, by this approach the large amount of DSW could be managed, by maintaining the environmentally friendly condition, because the process was produced biogas and bio-fertilizer, which means ultimately produce no wastes at the end and moving towards the sustainable resource recovery option from the DSW. Thus, the environment will get rid of the hazardous impact from the solid wastes. Only needs it possible into-practice – the motivation and technical supports. Government, NGOs and CBOs, can do this easily. If so, one day –the country at least able to self sustainable from its present –energy crisis and fertilizer war situation.

RECOMMENDATIONS

Designed for a better resource recovery system from DSW in KCC area, following recommendations are to be suggested:

- The production of wastes should be reduced, by formulating goal based on waste weight, volume and composting and to induce separation to facilitate waste recycling and reuse.
- DSW based biogas plant can be installed that will be low cost, locally available, sustainable and environmentally friendly.
- It is necessary to source separation of organic wastes along with other valuable substances through recycling, reusing and other method before to carry out the wastes into the land fill site. An appropriate (Nine fixed dome / floating cover) biogas plants can be installed in the land fill site depending on the amount of the organic wastes.
- Within a community a large size biogas plant can be installed depending on the demand of biogas as well as amount of organic solid wastes that generating from themselves based on the community based management system.
- For better gas production, a strong, degradable enhancer such as-*Trichoderma hargianum*, (Rafi) and *Trichoderma virens* (Ilias, *et al*., 2006), is very much necessary.
- Depending on the generating solid waste and gas requirement of the family, small scale biogas plant can be installed.
- Public education and awareness programmes are needed to promote the use of recycled products.
- Encouraging governmental and non-governmental organizations-including community based organizations and women, youth and public interest group.

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An Integrated Model for Sustainable Waste Management System in Municipalities

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ABSTRACT

Solid Waste Management (SWM) is considered like a critical issue for immediate and serious environmental problems, confronting urban local governments in the developing countries. Municipal waste is one of the most intractable of all troubles associated with all urban squalor and diseases. If proper SWM system is not taken for the growing cities and towns, it will cause degradation of the urban environment due to severe environment problem. To get to the bottom of this problem an integrated system should be built up which will meet all the steps to manage solid waste. A proper SWM system has different steps like, collection, transfer and transport, treat and disposal. This paper is an effort for the investigation of a mechanism of proper SWM. Different approach should be taken for different steps of an integrated SWM system. Community base waste collection system, then waste transfer and transport and a scientific and sustainable disposal through municipal body will be the part of this system. A GIS base database can be produced to locate suitable places for secondary waste dumping point, and a network analysis will be fruitful to connect these points in a route. Finally, sanitary land filling, incineration and composting will be a sustainable disposal system. Proper management of these three steps can make this system economically profitable and sustainable for environment. So, this integrated system can be a model for local government of municipalities.

INTRODUCTION

Protection to environment to protect the eco-system which is essential to sustain life on the planet should therefore be of paramount importance to all. Humans are exclusively responsible for exploitation of environment and eco-system despite the fact that they are most vulnerable to the changes in the ecological balance. At the same time it is the humans only who have capacity to repair damage to the environment & eco-system. Pollutants to the eco-system are Physical, Chemical, Biological, & Radiological. Quantum of waste is directly proportionate to population and changing life style (consumerism), hence growing in quantity and complexity by the day. Waste is end product of an activity which has no further use. However this concept is based on inability to find waste management solutions, and is not in accordance with the concept of 'Zero Waste'. It must be understood that waste of one activity may be resource for another. Waste in any form is damaging to the environment & impacts human health adversely. Waste can be broadly classified into three main categories, namely municipal solid & liquid waste, bio-medical solid& liquid waste, and industrial waste (including E-waste). In essence all these are damaging to environment and cause pollution; thus compromising human health. In the whole world there is a trend of rapid urbanization and it should be addressed accordingly. So, local governments in the cities are facing different challenges to provide the basic services to the city dwellers. Among the services one of the major components is solid waste management.

This paper aims to study about sustainable waste management system of municipalities. To fulfill this purpose, Khulna City Corporation has been taken as a case study.

TALE OF KHULNA CITY CORPORATION

Khulna city is reported to generate some 200-455 tones of solid wastes daily, per capita per day generation variously quoted lying between 0.22 kg and 0.75 kg. The city has a population of about

1.5 million. In Dhaka, per capita waste generation per day is 0.52 kg. Assuming the same value for Khulna, daily waste generation should be more than 750 tones. There have been some 6 studies by various consultants on Khulna city solid waste till 2005 on record. As mentioned above, per day generation varies from 200 tones to 450 tones. The approximate percentage composition by sources is domestic 79%, institutional 5%, commercial 10%, street 1%, hospital 2%, drain 2%, others 1%. (Banerjee and Ahmed, 2005)

Present Disposal Arrangement

KCC has 505 conservancy staff and 42 supervisory personnel. The cleaners accumulate the wastes at the road- and drain sides. Once the street sweeping and drain cleaning have been done, the cleaners collect the wastes in cane baskets and hand carts to dump them at the nearest collection point or dustbins. City dwellers dump their household wastes at the nearby KCC dustbins. These wastes are then collected by KCC trucks for the final disposal at the landfill /low lying areas. The solid waste is dumped at these locations without taking any pollution control measures and treatment option. The leachate produced from open waste produced in rainy season has extremely high pollution potential and causes surface water pollution around the dumping sites. As waste management support facilities, KCC provides 1250 dustbins (pucca), 56 demountable container, 3 covered trucks, 56 demountable garbage trucks, 12 open trucks, 76 hand drawn carts. Out of 71 garbage-carrying trucks 36 are road able at present (PREGA, 2005). With an annual budget of Tk. 21 million (KCC Budget Book), conservancy services of KCC are visibly unsatisfactory because 50% of the listed trucks are not road able.

Estimation of the Present Waste Quantity

The total amount of wastes carried by KCC trucks is 217.91 tones per day. According to KCC officials and interview with some NGOs and other stakeholders, KCC trucks handle KCC support facilities are grossly insufficient to cope with the situation and as such 30 – 50% of the waste generated in the city. The waste generated per day in the city therefore lies between 463 tones and 726 tones, the average being 595 tones. The population of Khulna Statistical Metropolitan Area (KSMA) was 1.34 million in 2001 with a compound growth rate of 2.96% over the period 1991 – 2001. Assuming the same growth rate, the population now stands at more than 15 million and the per capita waste generation per day based on the above population stands at 0.40 kg which is less than that of Dhaka (0.52 kg). The variation of per capita generation from 0.22 kg to 0.75 kg quoted in the literature arose from area and season specific surveys; in the affluent areas and during the wet season the value will be high, while in the slums and during dry season it will be low.

Future Projection of Solid waste Quantities

Table 1 Projection of population growth and attendant waste generation (2001-2021) of Khulna Statistical Metropolitan Area

Year	Waste/day/capita (kg)	Population (million)	Total waste/day (tones)	Total waste/year (tones)
2010	0.46	1.74	800	292000
2011	0.47	1.80	846	308790
2012	0.49	1.81	907	331055
2013	0.50	1.90	950	346750
2014	0.51	1.96	1000	365000
2015	0.53	2.02	1071	390915
2016	0.54	2.08	1123	409895
2017	0.56	2.14	1198	437270
2018	0.57	2.20	1254	457710
2019	0.59	2.27	1339	488735
2020	0.61	2.33	1421	518665
2021	0.62	2.40	1488	543120

(Source: PREGA, 2005)

Assuming an annual GAP (Gross Area Product) of 4% and 70% of the additional income going into consumption, waste generation growth factor may be taken as 4 x 0.7 = 2.8%. It is seen that waste generation attendant on both population (2.96%) and economic growth (4%) will reach over 1488 tones in 2021. (PREGA, 2005)

INTEGRATED SUSTAINABLE WASTE MANAGEMENT IN MUNICIPALITIES

The Dimensions of ISWM

The concept of Integrated Sustainable Waste Management (ISWM) recognizes three important dimensions in waste management: (1) the stakeholders involved in waste management, (2) the (practical and technical) elements of the waste system and (3) the sustainability aspects of the local context that should be taken into account when assessing and planning a waste management system.

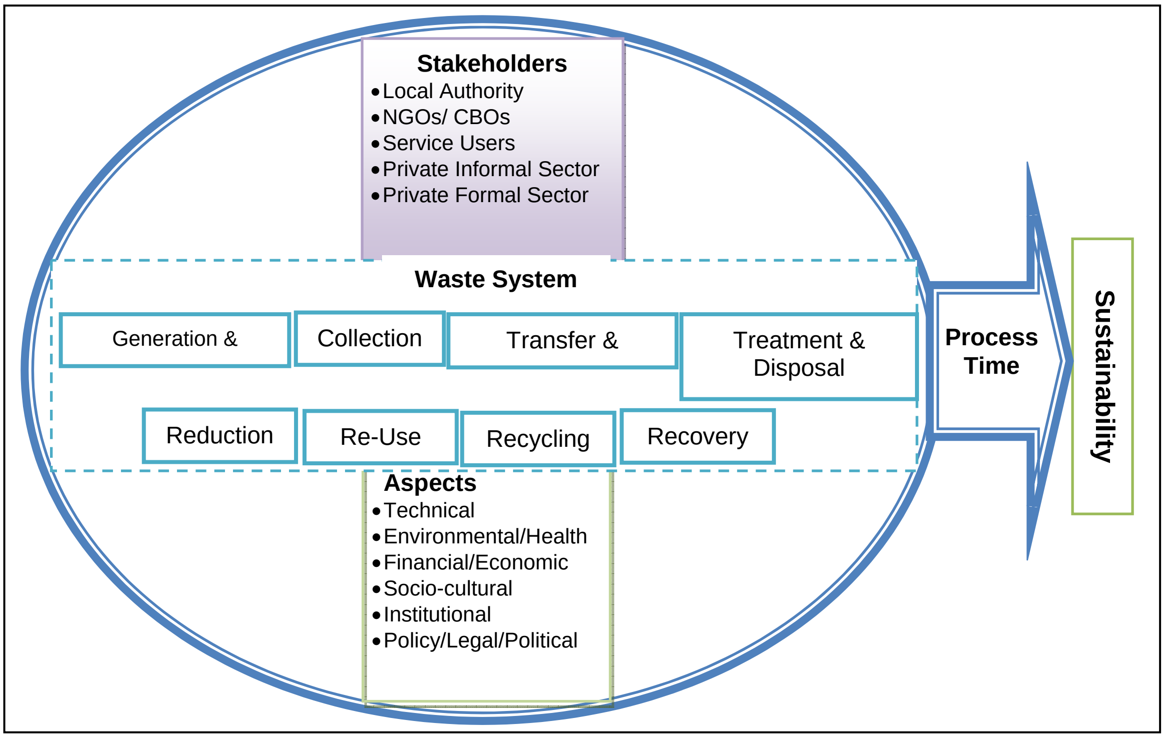

Figure 1 Integrated sustainable waste management

Stakeholders, the First ISWM Dimension

The first ISWM dimension is the stakeholders. A stakeholder is person or organization that has a stake, an interest, in –in this case- waste management. A number of potential stakeholders are listed in below. However, stakeholders in waste management differ in each city, so they need to be identified in the local context. Stakeholders may vary in the intensity or breadth of their roles and interests in relation to waste management, but they can co-operate for a common interest. In addition, the stakeholders in a particular city or region share a common social and geographic context, and may be bound together by other systems in addition to solid waste1. Some typical stakeholders in ISWM are: local authorities, community groups, NGOs, CBOs, local, regional or national institutions, such as schools, hospitals, trade unions, the military, government departments, national parks; tourism associations, recycling industries, private waste management companies and their clients, social and religious groups, activists and lobbyists. For example: clan, caste, ethnicity, professional affiliation, religion, school or university background, commercial relationship, kinship, sport, politicians, private sector industry and commerce and the associations or trade industry lobbyists that represent them; small and micro-enterprises and entrepreneurs, other self-identified parties and individuals with a stake in the urban environment in general, and solid waste in particular.

Waste System Elements, the Second ISWM Dimension

The waste system elements are sometimes referred to as the technical components of waste management. Most waste system elements are also stages in the life cycle of materials. This life cycle movement, or flow, begins with extraction of natural resources, and continues through processing, production and consumption stage towards final treatment and disposal. The waste system elements generally form the “back end” of the life cycle.

Many countries have prioritized these waste management activities into the so-called waste management hierarchy, which varies between an operational policy guideline and an injunction that is part of a national environmental law. This waste management hierarchy is shown in Figure 2.

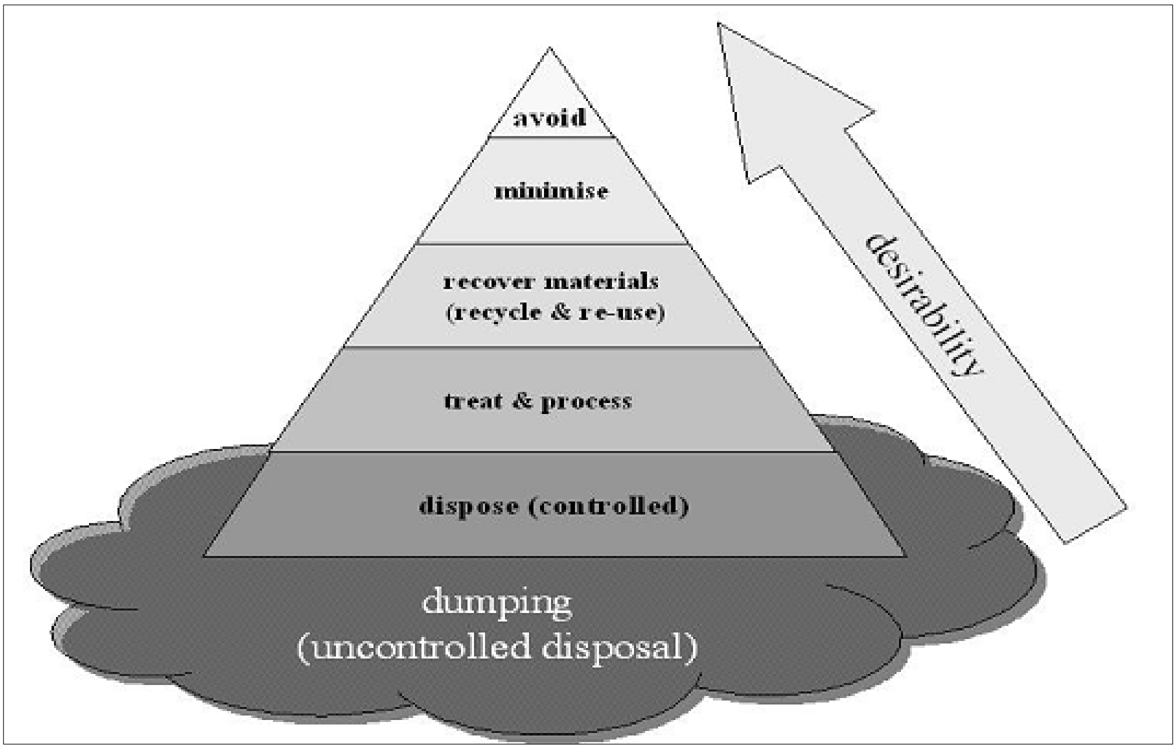

Figure 2 The waste management hierarchy (UWEP, 2004)

THE MAJOR WASTE SYSTEM ELEMENTS CONSIDERED IN THIS STUDY

Waste Prevention and Minimization

Waste prevention and minimization is the simplest but the best elements of waste management. For this purpose, reuse and repair should be encouraged. This has to be practiced from the household level.

Collection

In Bangladesh the main responsibility of solid waste management system in urban areas is on the municipal authorities. The first part of the waste management is to collect waste. There are two types of solid waste collection and transportation to the disposal site in Bangladesh: conventional system and participatory system.

Conventional collection system

Waste is generated in the home and usually stored until a small amount has been accumulated. In the conventional system it is the responsibility of the householders to carry their wastes to the nearest solid waste bins or similar facilities which are provided by the city corporation and deposit wastes there. The city corporation is responsible for the transfer of this waste from the roadside bins to the final disposal site.

Participatory or community base waste collection system

Participatory or Community-based management of services backed by measures to strengthen local institutions in implementing and sustaining solid waste management programs, is one of the guiding principles in international declarations such as New Delhi Consultation in 1990 and reconfirmed in Agenda 21 (Ahmed and Rahman, 2000). Participatory management is an approach that seeks to make the best use resources available within the community with support from government or any NGO or organization. In communities or user groups, take on more tasks and responsibilities, relieving agencies of routine solid waste management and maintenance duties through and learning approach by promoting changes of prevailing attitude, behavior, norms, skills and procedures.

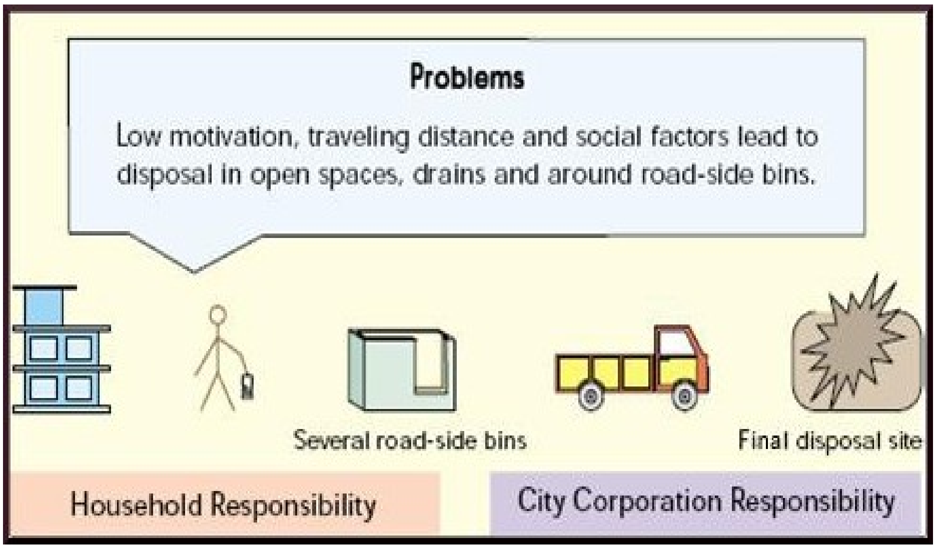

Figure 3 Conventional waste collection systems in KCC (WSP-South Asia, 2000)

In municipality wards can be divided into small areas called primary collection blocks. These should be consist of approximately 500 households which will all served by one rickshaw van. Waste generated in the home is stored in a bin, basket or bag and collected everyday by a primary collector who transports the waste to nearby transfer points, normally in a rickshaw van. This is primary collection and is the responsibility of the community. Transfer points are places where waste is unloaded from primary collection vehicles to be taken away by secondary transport. Several primary collection blocks are served by a transfer point. The waste is then collected from the transfer points and taken to the final disposal point by a large truck. This is secondary collection and is the responsibility of the city corporation.

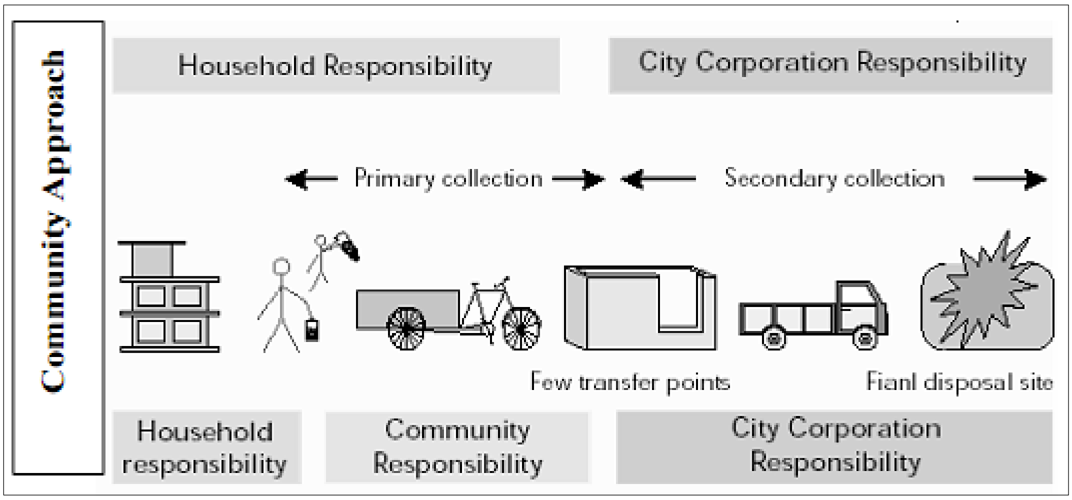

Figure 4 Community based waste collection system. (after Khalequzaman et al. 2004)

In Khulna City Corporation there are 31 wards. Among these wards in 29 wards (except 22 and 29 no. ward) seventeen NGOs are working for Primary collection. These NGOs are working in participatory waste collection system. List of different organizations involved in Khulna City Corporation for solid waste management is given below:

But the NGOs are not the most suitable for this purpose. CBOs can be the better options for community base waste collection. CBOs can be more economically affordable for the people. These CBOs can be a committee organized with the representatives from municipal authorities, political leaders and different social strata. These CBOs can be conducted by the contribution of community people or by monthly charge of recipient of this service.

Along with this, waste should be should be segregated from household level, which will make the process easier.

Table 2 Name of organizations involved in solid waste management

Name of Organizations	Ward No.
Prism Bangladesh	Ward No: 3, 31
Prodipon	Ward No: 6, 12, 24, 27, 28
Society Progress Organization (SPS)	Ward No: 9,15,16
Muktir Alo	Ward No: 21, 23
Rustic	Ward No: 17, 18
Rupayan	Ward No: 19, 20
AOSED	Ward No: 25, 16
Shabolombi	Ward No: 10
Prosanti	Ward No: 30
Protisruti	Ward No: 22
Nobarun Sangsad	Ward No: 24 (Part)
Goti	Ward No: 20, 25 (Part)
BRIC	Ward No: 4, 5, 7
Centre for Human Resources Development (CHD)	Ward No: 16 (Part)
Commitment	Ward No: 11
World Vision	Ward No: 18
Khulna City Corporation (KCC)	Ward No: 22, 29

Transfer and Transport

Transfer and transport is the second stage of waste management. Though it is a simple stage, it demands more concentration. Because, the conservancy department of municipalities is paid huge budget to the transport the waste. But a scientific approach can solve this problem. Suitability analysis through GIS for selecting the location of dumping sites and transfer points and a network analysis to connect these points in a route will be fruitful. For this purpose, a spatial database has to be produced. Several researches have already been done, which will be very helpful to complete this purpose.

Without this, for an environmentally sustainable waste transport system authorities have to ensure covered vehicles, loading waste in a proper way, maintain the capacity of the vehicles and make a proper schedule for waste transport avoiding congestion time.

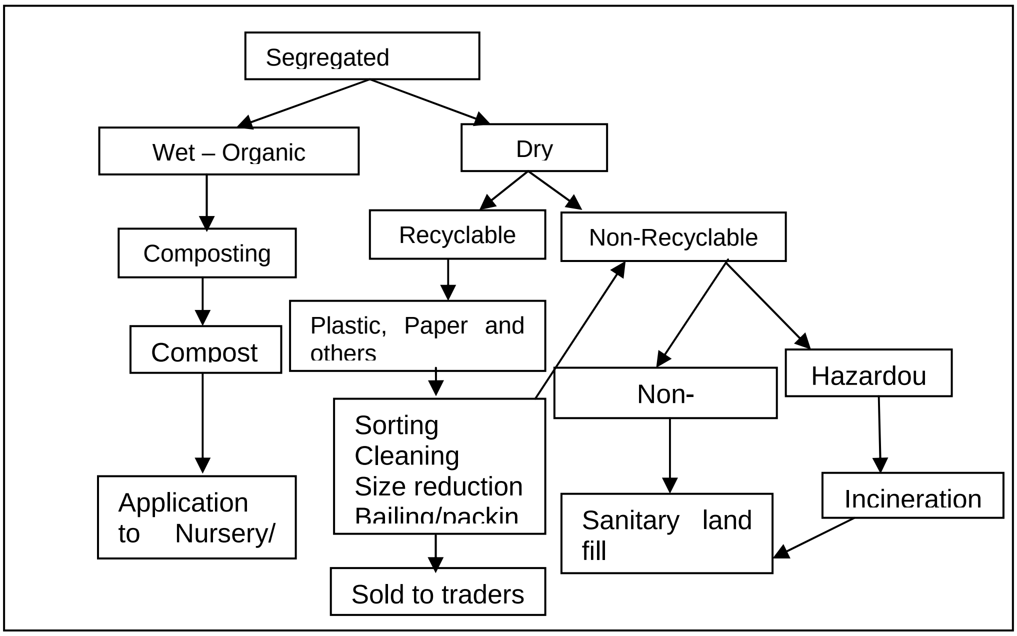

Figure 5 Flow chart of waste treatment operations

Treat and Disposal

There are so many way to treat and dispose waste. But the suitable process will vary with the type and quality of waste. Again all of the treatment or disposal methods are not economically affordable at the developing country like Bangladesh. Recycle sanitary land filling, incineration and composting will be a sustainable disposal system.

STRATEGIC APPROACH

The community-based approach is working well for the SWM in our current working areas; a strategic approach for SWM needs to be developed. The strategic approach should follow these essential aspects:

- Development of a policy framework, which will realistically incorporate the SWM, need for all social, economic and geographical sectors.
- The sustainability consideration of SWM should not benefit the high-income class at the cost of the poorer section.
- Policy decisions need to be taken on
    1. paurasava Act.
    2. municipal Taxation Policy.
    3. public Health Policy.
- Waste disposal should be viewed in an integrated manner that would arrange disposal of the following
    1. solid waste
    2. waste water
    3. clinical Waste
    4. toxic Waste
    5. radioactive waste
- Finally the guarantee of community based SWM is the awareness, eternal vigilance, united action and participation of the community people themselves. Any SWM program should have the built in process of ensuring the elements mentioned in the preceding lines. (Rahman,2000)

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Hazardous Waste Management

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Appropriate Treatment Technology for Hazardous Biomedical Wastes - An Indian Case Study

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ABSTRACT

Biomedical wastes from the hospitals, nursing homes and clinics include a variety of wastes; some of these contain harmful organisms and disease causing agents. This paper focuses on the fact that the reuse of discarded syringes/ needles without disinfection can transmit lethal diseases like AIDS and Hepatitis. Similarly, indiscriminate recycling of used cotton, clothes and medicines can pose a host of health hazards. It points out that there is no option but to ensure that the wastes of different categories are to be properly segregated and rendered to harmless through physical separation, disinfection, disposed in secured landfill and incinerated depending on the nature of the wastes. This paper examines the characteristics of the hazardous biomedical wastes generating from hospitals and assesses their impacts on the environment .It discusses the Regulatory Notification for Biomedical Waste (Management and Handling) Rules under the Environmental Protection Act. Physico-chemical and biochemical approach for handling and safe disposal of hazardous biomedical wastes generated from hospitals are discussed. Site selection and incinerator design for a chosen hospital has been evaluated on the basis of literature and data collected. It examines that improper incineration of wastes; particularly chlorinated organic compounds can result in noxious emissions including dreaded dioxins. The design of the incinerator has been made on the basis of combustion efficiency, mass balance, energy balance, moisture content etc. The designed parameters are compared with those of the standard values provided in the literature. The stack height of the incinerator, generation of the ash was determined and quantification of the ash generated has been made. Ash produced from incineration of the waste has been analyzed and design of pit for their safe disposal has been ascertained. A strategy has been developed for handling and safe management of hazardous biomedical wastes.

INTRODUCTION

Wastes generated by hospitals include infectious and noninfectious materials, hazardous wastes and chemicals, and other non-hazardous wastes. Biomedical waste is often considered to be a subcategory of hospital waste and indicates ‘potentially’ infectious waste that is produced from healthcare facilities (Frank Kreith.1994). It is infectious and it acts as an agent in the infections’ transmission. This is because it contains microorganisms (bacteria, viruses, fungi etc), which can be communicated by invasion followed by multiplication in body tissues. The so transmitted pathogens can cause disease or diverse health impacts to human .The hazards arising from generation of wastes have generally been of great concern to environmental health engineers in developing countries. Biomedical wastes from the hospitals, nursing homes and clinics include a variety of wastes such as hypodermic needles, scalpel blades, surgical gloves, cotton, bandages, clothes, medicines, blood and body fluids, human tissues and organs, body parts, radioactive substances and chemical etc.(Rao and Garg 1994) Some of these contain harmful organisms and disease causing agents. For instance, reuse of discarded syringes/ needles without disinfection can transmit lethal diseases like AIDS and Hepatitis. In the process of health care, waste generated usually includes sharps, human tissues or body parts and other infectious materials (Baveja, et al. 2000), also referred to as ‘‘Hospital solid waste’’ and ‘‘Biomedical solid waste’’ (Patil and Kotail 1998). The Government of India (Notification: Biomedical Waste Management and Handling Rules, 1998) specifies that Hospital Waste Management is a part of hospital hygiene and maintenance activities. Storage of the waste needs to be in areas which are disinfected regularly and which are maintained at appropriate temperatures particularly if wastes are being stored prior to treatment.

Indiscriminate disposal of hospital wastes is indeed one of the major sources for spread of pollution and infection (Singh and Mahajan 1998). Similarly, indiscriminate recycling of used cotton, clothes and medicines can pose a host of health hazards (Howard et.al 1985). Also improper incineration of wastes, particularly chlorinated organic compounds can result in noxious emissions including dreaded dioxins (Pawel and Fred 1987). Hence, there is no option but to ensure that the wastes of different categories are to be properly segregated and rendered harmless through physical separation, disinfection, disposed in secured landfill and incinerated depending on the nature of the wastes (Basu 1996). Biomedical waste management is a special case wherein the hazards and risks exist not just for the generators and operators but also for the general community (Sandhu and Singh 2003). The sound management of hazardous/infectious waste is the first step in health risk reduction With this view a fact finding survey has been conducted to evaluate the appropriate treatment technology for the safe management of hazardous biomedical waste and attempts are made to search out an appropriate treatment technology.

CATEGORIES OF BIOMEDICAL WASTE

Biomedical wastes are generated as a result of diagnosis, treatment, and immunization of humans or animals. Some states include wastes generated as a result of biomedical research and the production and testing of biologicals. Unfortunately, there is no one common *specific* definition of what constitutes medical waste so each facility must determine this based on applicable federal, state, and local regulations (Anon 1996). Because disposal of waste from health care facilities is driven by differing regulations, it is useful to categorize the overall waste stream into the following four categories:

- general trash
- regulated Medical Waste or Infectious waste
- hazardous waste
- low-level radioactive waste

The rates of waste generation vary widely. One study of overall hospital waste found a range from 4 to 22 kg/bed/ day, with an average of 12 kg/bed/day (Samwel 2004). For other types of health care facilities, it has been reported the following overall waste generation rates:

- physicians' office — 5 lbs/patient/day (2.3 kg/patient/day)
- nursing home — 3 lbs/person/day (1.4 kg/person/day)
- laboratory — 0.5 lbs/patient/day (0.2 kg/patient/day)

As per the Biomedical waste (Management and Handling) Rules, 1998 the waste is categorized into ten categories. In these parameters moisture content and heating value plays the important role.

STATUS OF BIOMEDICAL WASTE IN INDIA

There are about 1.6 million health care workers at approximately 27,500 health care facilities in India (Shah et al. 2001). Biomedical waste management has become a critical issue as it poses potential health risks and damage to the environment, which has taken a central place in the national health policy and is attracting a considerable international interest (Patil and Pakhrel 2005). Environment (Protection) Act 1986 (EPA) was formed under the Ministry of Environment and Forests, which is the most comprehensive Act on the Indian Statute Book relating to Environment Protection (Jaswal and Jaswal 2000). In July 1998, the Government of India Environment (Protection) Act 1986 (Rule 29 of 1986) issued a Notification on Biomedical Waste (Management and Handling), Rules 1998(Notification 1998). It defines ''Biomedical waste'' as any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities pertaining thereto or in the production or testing of biological, and including categories mentioned in Schedule I (1998).

The term "hazardous waste" means a solid waste or a combination of solid wastes, which because of its quantity, concentration, or physical, chemical or infectious characteristics may (1) cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness or (2) pose a potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.

Generators of Biomedical waste (BMW) are those producing more than 23 kg of regulated BMW per month. For generators who manage their waste by shipping to offsite disposal facilities, they are supposed to separate, package, label, mark, and track the waste according to regulations. The biomedical waste management (BMWM) efforts in India have emerged as a result of strong awareness on effects from the BMW in terms of human health and the need to protect our environment. The Ministry of Environment and Forests (MOEF) and WHO conducted a survey in the year 2000 to study the management of the syringes and needles used during immunization programs in India. This was followed by a similar survey on the management of all BMW types in 2001. From these two studies, it was established that hospitals did not have proper means of managing BMW. It contains different items making it a special type of mixed waste. If not properly sorted, its handling becomes even more difficult. It can contain soiled or blood soaked bandages, culture dishes and other glassware, discarded surgical gloves and surgical instruments (like scalpels). Needles (used to give shots or draw blood), cultures, stocks and swabs used to inoculate cultures are the most common items in biomedical waste and well known to the health-care staff. Waste from operation theaters will also contain removed body organs (like tonsils, appendices, limbs etc.), which renders the biomedical waste scary, and nuisance. Biomedical waste will also contain lancets (the little blades with which the doctor pricks finger to get a drop of blood). Thus, if the waste is not segregated properly at the point of generation it will be a mixture of all these items with kitchen waste, office waste and floor wastes which do not arise as a result of patients being attended (Srivastava, 2000).

Currently, a new parameter for biomedical waste generation has been developed, putting into consideration of the number of hospital beds in a given hospital as indicated by the National Health-Care Waste Management Plan (NHCWMP, 2003). The rate of waste generation at a given hospital increases with the number of beds available and the occupancy rate. The occupancy rate is defined as the percentage of occupied beds to the available beds in hospitals. The psychology and pediatric sections give the least amounts of waste. Such an overview will assist the hospital management to direct their waste management resources in the critical areas.

The actual biomedical waste management situation in the democratic developing country like India is grim (Lakshmi 2003). The leading national newspaper of the country reports that even though there are Rules stipulating the method of safe disposal of Biomedical Waste (BMW), hospital waste generated by Government Hospitals is still largely being dumped in the open, waiting to be collected along with general waste. The study conducted by the Central Pollution Control Board (CPCB), an apex pollution monitoring body on incinerators in Delhi Hospitals, concludes that the incinerators were found to spew a high level of deadly residues and toxic emissions such as cancer-causing dioxins and furans besides chemicals which cause neonatal abnormalities, reproductive and skin disorders, endocrine disruption and suppression of the immune system reports Krishna (Krishna 2004).

For the waste to be infectious, it must contain pathogens with sufficient virulence and quantity so that exposure to the waste by a susceptible host could result in an infectious disease. However, the terminology problem is complicated, because different terms are used to describe infectious waste, e.g. infectious, pathological, biomedical, bio-hazardous, toxic, and medically hazardous, with a possibility of difference in the meaning.

Based on the type of waste, domestic waste takes a large proportion of the waste volume, so that such waste is not mixed with patient derived waste and it can be easily handled. However based on infections, it is important for healthcare staffs to take precaution on handling sharps and pathological wastes, which comprises only about 21% of the total infectious wastes (Manohar, et. al 1998). Different classifications will give different results. For example, it has been reported that 60% of the biomedical waste is infectious while 40% is non-infectious, depending on the classification used (Sandhu and Singh, 2003). The sound management of hazardous/infectious waste is the first step in health risk reduction. When the infectious waste cannot be minimized or eliminated at the source, it must be treated .The objectives of effective infectious waste management program are to indentify the infectious waste to protect human health and the environment from hazards posed (Singh and Mahajan 1998). Proper management must ensure that the waste is handled in accordance to well established procedures from the time of generation through treatment of the waste (to render it noninfectious) and its ultimate disposal. The primary burden of infectious waste management falls upon the generators and handlers. Hospitals and other infectious waste generators must have ongoing management strategies.

BIOMEDICAL WASTE TREATMENT

Before dealing with the technical and economic issues relating to non-incineration technologies, it is crucial to select the use of non-incineration technologies in a broader context (Singh and Mahajan

1998). The decision to select an alternative technology must encompass a strategic framework dealing with various aspects of biomedical waste management as shown in Figure 1. Doing so ensures that the maximum environmental, occupational safety and economic benefits of non-incineration technologies can be achieved. In the past, many hospitals simply dumped all their waste streams together—from reception area trash, cardboard boxes, and kitchen waste to operating room wastes, contaminated sharps, and lab waste—and burned them in their incinerators. There were no incentives to separate, recycle, or reduce waste. A commitment to public health and environmental protection, regulatory compliance, and the need to reduce costs require a new framework for dealing with hospital waste. The underlying elements of a strategic framework are waste minimization and segregation. Different components of the waste stream must be kept separate from each other. Specifically, potentially infectious waste, regular trash, hazardous waste, and low-level radioactive waste must be segregated from each other (Sharma and Mathur 1989). Every effort must be made to minimize each of these waste streams and each must be disposed of properly. The infectious waste that remains can then be treated using an alternative (non-incineration) technology. (Note: Some facilities incinerate waste that had already been treated by a non-incineration technology, thereby defeating the purpose of using an alternative.) Other elements of a strategic framework include: developing a safe and effective collection, transport, and storage system; waste management and contingency planning; protecting the health and safety of workers; and proper sitting of the non-incineration technology (Pathak, 1998).

Waste minimization is the reduction to the greatest extent possible, of waste that is destined for ultimate disposal, by means of reuse, recycling, and other programs. The potential benefits of waste minimization are: environmental protection enhanced occupational safety and health, cost reductions, reduced liability, regulatory compliance, and improved community relations. The recommended waste minimization techniques are segregation, source reduction, resource recovery and recycling, treatment and proper disposal.

Non-Incineration Technologies

Non-incineration treatment technologies can be classified in many ways—such as according to size, purchase price, types of waste handled, or market share. The technologies can be categorized based on the fundamental processes used to decontaminate waste. The four basic processes are:

- Thermal processes
- Chemical processes
- Irradiative processes
- Biological processes

The majority of non-incineration technologies employ the first two processes listed above (Singh and Sharma 1996). Presented below is each of these processes, as well as mechanical processes which supplement the four fundamental processes.

Thermal processes are those that rely on heat (thermal energy) to destroy pathogens in the waste. This category is further subdivided into low-heat, medium-heat, and high-heat thermal processes. This further sub-classification is necessary because physical and chemical mechanisms that take place in thermal processes change markedly at medium and high temperatures. Low-heat thermal processes are those that use thermal energy to decontaminate the waste at temperatures insufficient to cause chemical breakdown or to support combustion. In general, low-heat thermal technologies operate between 200°F to about 350°F (93°C –177°C). Medium-heat thermal processes take place at temperatures between 350 to 700°F (177°C-370°C) and involve the chemical breakdown of organic material. These processes are the basis for relatively new technologies. They include reverse polymerization using high-intensity microwave energy and thermal depolymerization using heat and high pressure.High-heat thermal processes generally operate at temperatures ranging from around 1,000°F to 15,000°F (540°C-8300°C) or higher.

Chemical processes employ disinfectants such as dissolved chlorine dioxide, bleach (sodium hypochlorite), peracetic acid, or dry inorganic chemicals. To enhance exposure of the waste to the chemical agent, chemical processes often involve shredding, grinding, or mixing. In liquid systems, the waste may go through a dewatering section to remove and recycle the disinfectant. Besides chemical disinfectants, there are also encapsulating compounds that can solidify sharps, blood, or other body fluids within a solid matrix prior to disposal. One developing technology uses ozone to treat medical waste, and others utilize catalytic oxidation.

Irradiation-based technologies involve electron beams, Cobalt-60, or UV irradiation. These technologies require shielding to prevent occupational exposures. Electron beam irradiation uses a shower of high-energy electrons to destroy microorganisms in the waste by causing chemical dissociation and rupture of cell walls. The pathogen-destruction efficacy depends on the dose absorbed by the mass of waste, which, in turn, is related to waste density and electron energy. Germicidal ultraviolet radiation (UV-C) has been used as a supplement to other treatment technologies. Irradiation does not alter the waste physically and would require a grinder or shredder to render the waste unrecognizable.

Biological processes employ enzymes to destroy organic matter. Only a few non-incineration technologies have been based on biological processes.

Mechanical processes—such as shredding, grinding, hammer-mill processing, mixing, agitation, liquid-solid separation, conveying (using augers, rams, or conveyor belts), and compaction – supplement other treatment processes. Mechanical destruction can render the waste unrecognizable and is used to destroy needles and syringes so as to minimize injuries or to render them unusable.

Incineration

Incineration is an environmentally and technically superior method of waste disposal. At the same time, it is highly controversial and expensive (Montague 1998). The typical Medical waste incinerator process flow diagram as depicted in Figure 1.

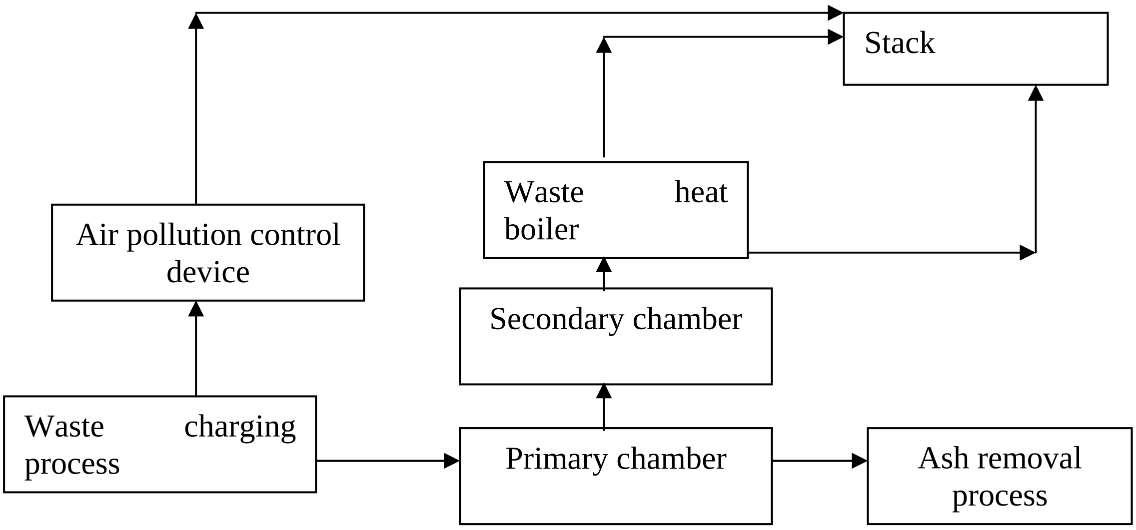

Figure 1 Medical waste incinerator process flow diagram

In previous decades, landfills were primarily used for waste disposal, allowing nature to take its course, eventually reducing the end volume toxicity of the wastes. However, because of increasingly stringent environmental regulations concerning air quality, landfills, and groundwater contamination, along with the decreasing availability of land for the encapsulation of wastes, incineration has become the desired disposal method for municipalities and industries. Yet, even incineration technology is constantly undergoing revisions in order to meet tougher environmental standards (Singh and Sharma 1996). These technological advances include those that increase efficiency, and those that use emissions control apparatus. Incineration thermally decomposes matter through oxidation, thereby reducing and minimizing the wastes, and destroying their toxicity (Thornton et. al1996). It can be applied to industrial, municipal, and hazardous wastes, provided that they contain organic materials. Since they are primarily organic, substances can undergo and sustain thermal degradation (Anon 1972).

To provide secondary treatment for environmentally unsafe compounds, so that they can be released to the atmosphere at suitable concentration levels. Various types of incinerators are currently manufactured. The choice of an incinerator depends on the wastes' combustibility and its characterization as liquid, sludge, solid, or gas (Anon 1980). The wastes' combustibility characteristics, such as ignition temperature, flash point, and flammability limits determine the necessary operating temperature, O_2 concentration, and residence time for greatest waste minimization. The proper incinerator types can then be identified based on the waste specifications. The following are the types of incinerators used:

- Rotary kiln
- Fluidized bed
- Liquid injection

- Multiple hearth
- Catalytic Combustion
- Waste-gas flare
- Direct-flame

Of these, rotary kiln, fluidized bed, and liquid injection are the most, prevalent in industry because of their, applicability to large scale use and, and their versatility. Consequently, it will concentrate on, these three kinds.

Rotary kiln characteristics:

- Rotate wastes in cylindrical container, enabling thorough mixing with air
- Operating temps. from 1500-3000^{o}C
- Has greatest resistance to high temps.
- Can handle liquid, sludge, solid, or gases in very large quantities
- Can operate in batch mode, allowing more flexibility than continuous mode
- Can be mobile to allow onsite treatment
- Can accept entire drums of waste, a unique feature

Fluidized bed characteristics:

- Vessel contains inert granular material that expands and acts theoretically as a fluid when gases are injected up through the material bed from nozzles
- Operating temps from 1400-1800^{o}C
- Can handle liquid, sludge, solid, or gases
- Waste enters through nozzles
- Offers nearly isothermal operation
- Can't handle wastes that melt and form slag, disrupting fluidization

One other characteristic that all two types of incinerators (rotary kiln and fluidized bed) share is that they can all be operated in a Pyrolysis or oxygen starved mode. Wastes with high caloric value that is capable of releasing great heat content are most appropriate for this kind of operation.

Multiple hearth incinerators consist of vertically shaped hearths, and are primarily utilized for sewage sludge. They are operated from 760-980^{o}C catalytic combustion, waste-gas flare and direct flame incinerators are all for gases. Catalytic combustors use a catalyst and are designed for low organic concentration wastes. Waste-gas flares are used for non-hazardous waste that has high organic content. Direct flame incinerators operate from 540-815 ^{o}C and are used when waste gas contains particles.

On a final note, one very controversial form of incineration that presently has been banned in the United States, but is used in Europe is ocean incineration. For this, two incinerators are mounted on a huge ship that carries the wastes out to the middle of the ocean and burns them out there. The ideal wastes for this kind of disposal are toxic and hazardous wastes such as chlorinated matter and organometallics. Ocean incineration is perfect for these wastes because the acids produced can be neutralized by the huge buffering capacity of the ocean. This eliminates the need for scrubbers and other secondary treatment to detoxify the combustion products and make them more environmentally acceptable.

STUDY AREA PROFILE

The two Patliputra Medical College Hospitals are:

- Patliputra Medical College & Hospital, Court More, Dhanbad
- Patliputra Medical College & Hospital, Saraidhela, Dhanbad.

A 600-bed Hospital and Medical College Center, Dhanbad, is divided into two parts. One is located at Saraidhela and the other are located at Court More. These two hospitals are spreaded over 10 acres of land and situated on the Dhanbad– Koyla Nagar road which leads to NH-32. It is one of the well equipped hospitals in this region of Dhanbad, Jharkhand State that has all basic specialties including General Medicine, General Surgery, Orthopedics, ENT, Gynecology, Pediatrics and Psychiatry. The multi-specialty teaching hospital is claimed to be meticulously build, planned, painstakingly designed using modern scientific knowledge-based technology. The Generation of Waste (infectious & non-infectious) in different departments in Kg/day for two months and the calculated percentage values along with number of beds as presented in Table 1.

Table 1 Generation of waste (infectious & non-infectious) in different departments in Kg/day for two months and the calculated percentage values along with number of beds. Standard deviation is given in parenthesis.

Department	Average waste generated in Kg		Percentage (%)
	For one day	*For two months*	
GYNECOLOGY OT-I	2.688 (± 1.56)	161.30	12.82
GYNECOLOGY OT-II	1.939 (± 0.96)	116.35	9.24
GYNECOLOGY DUTY ROOM	1.201 (± 0.72)	72.08	5.73
ENT OT	1.379 (± 0.84)	82.73	6.57
EYE DUTY ROOM	1.059 (± 0.72)	63.51	5.05
EYE OT	1.405 (± 0.89)	84.29	6.70
LABOR ROOM	1.562 (± 0.86)	93.71	7.75
CENTRAL CASUALTY	1.418 (± 0.64)	85.10	6.76
PEDIATRICS	0.993 (± 0.69)	59.56	4.73
PATHOLOGY	1.361 (± 0.60)	81.65	6.49
OT OF ORTHOPEDICS	1.913 (± 1.37)	114.75	9.12
OT OF SURGERY	2.268 (± 1.36)	136.10	10.81
DUTY ROOM OF ORTHOPEDICS	1.382 (± 0.75)	82.90	6.59
BLOOD BANK	0.410 (± 0.36)	24.60	1.95
GRAND TOTAL	20.978	1258.63	Approx (100%)

Quantitative Determination of Waste by Using Standard Method

The following steps were involved in the determination of the biomedical waste generated from different places in the study center:

- The supporting staff of each ward/laboratory/department was briefed over the nature of assistance and support that was needed in determining the quantity of wastes during the study period.
- The sampling buckets were placed in each and every department with properly labeled for collection of the waste to facilitate in tracing the source of waste generation for the data collection.
- Solid waste of both types (infectious and non-infectious) was weighed individually on a suspension spring scale (±50 Kg) with the assistance of the staff and the weight was recorded from each and every department.

The amount of non-infectious and infectious average waste generated in kg/day in each department was determined and recorded for each day over a period of two months, it is clear from the test results that gynecology OT contributes a lot to the solid waste generated from the two hospitals.

$$\sigma_{n-1} = \sqrt{\frac{\sum x^2 - \frac{\left(\sum x\right)^2}{n}}{n-1}}$$

The values given in parentheses are the sample standard statistical deviations, which are calculated by using the above formula. The arithmetic mean "x" was determined as (Σx)/n, where "n" is the number of days (Gupta 1998). The percentage of non-infectious and infectious types of waste generated from various blocks has been made.

DESIGN OF THE INCINERATOR

Treatment by incineration, and disposal of the resultant ash by land filling, is an attractive option for managing medical waste (Delinger et al.1986). A major benefit of incineration is the destruction of pathogens (disease-causing agents), which occur as a result of the high temperatures achieved in (Biomedical Waste incinerators) BMWI's. Another benefit is the significant reduction of the weight and volume of waste material to be land filled. BMWI's typically achieve better than 90 percent burn down. In addition, converting waste to ash results in a more aesthetically acceptable material. One of the major objectives of incineration is to generate acceptable ash for land disposal.

In these units, sequential combustion operations are carried out in two separate chambers. The primary chamber accepts the waste, and the combustion process is begun. Three processes occur in the primary chamber (Anon 1986). First, the moisture in the waste is evaporated. Second, the volatile fraction of the waste is volatilized, and the volatilized gases are directed to the secondary chamber. Third, the nonvolatile combustible portion (fixed carbon) of the waste is burned. The typical operating temperature range for primary chambers is 650° to 760^{o}C, but the temperatures can range from 400° to 980 ^{o}C. Combustion gases containing the volatile combustible materials from the primary chamber are directed to the secondary chamber. Here the gases are burned with excess air, and at least one auxiliary fuel burner is used, as necessary, to maintain temperatures. According to most manufacturers, typical operating temperatures for secondary chambers range from 870° to 1100 ^{o}C . The combustion gases from the secondary chamber are then vented through the stack to the atmosphere. Medical waste incinerators have the potential to emit a variety of air pollutants (Aun Melamed and Susan Wilburn 2001)

Destruction and removal efficiency (DRE) = 99.99% should be attained on each principal organic hazardous constituent (POHC) in the feed waste where:

$$DRE = \frac{(W_{in} - W_{out})}{W_{in}} * 100$$

Where: W_{in} = mass feed rate of the POHC in the waste stream fed to the incinerator, and

W_{out} = mass emission rate of POHC in the stack prior to the release to the atmosphere.

Particulate emission Maximum: 120 mg/m^3

No waste is to be fed into the incinerator:

Final Design of the Incinerator for the Chosen Hospital

The biomedical waste incineration process can be described in terms of the following steps: waste charging, primary chamber combustion, solids movement though the primary chamber, secondary chamber combustion, combustion gas handling, and ash removal (Anon 1972). Figure.1 is a process flow diagram that illustrates how these steps relate to each other in the incineration system.

For the analysis of biomedical waste incineration theoretical estimations have been carried out for mass balance, heat balance and flue gas generation. Theoretical results show extra amount of air is required to keep the combustion chamber temperature below the operating temperature limit of

760^{o}C. The calculations also show generation of HCl above the levels set by the law. In all the calculations it has been assumed that only paper, cotton and plastic burn and contribute to flue gas. The following describes in brief the various estimations for medical waste incineration of the PMCH:

Incineration at Stoichiometric Conditions

For theoretical estimations of medical waste incineration, it is important to know the chemical combustion formula for various components of the waste. It is assumed that only paper, cotton and plastics take part in combustion. One main reason for this assumption is, because paper, cotton and plastic are the major components of biomedical waste generated by the PMCH. The other three components, namely metal, glass and miscellaneous items account for less than 10% of the total medical waste generated at the PMCH, hence they are neglected for the purpose of calculations. Plastics found in BMW are further characterized into seven sub-groups based on resin type. The energy released during the reaction is 10036 Btu/lb of cellulose.

Turbulence is an expression relating the physical relationship of fuel and combustion air in the furnace. A high degree of turbulence is desirable. Burning efficiency is enhanced with increased surface area of fuel particles exposed to the air. Fuel atomization maximizes the exposed particle surface. Good turbulence exposes the fuel to air in a rapid manner, helping to promote rapid combustion and maximizing fuel release. A burner requiring no excess air and producing no smoke is said to have perfect turbulence (a turbulence factor of 100%). If, for instance, 15% excess air is required to achieve a no smoke condition, the turbulence factor is calculated as:

$$Turbulencefactor = \frac{Stoichiometricair}{Totalair * 100\%} = \frac{1.00}{1.15} * 100\% = 87\%$$

Combustion does not occur instantaneously. Sufficient space must be provided within a furnace chamber to allow fuel and combustible gases the time required to fully burn. This factor, termed as “dwell time, residence time, or retention time”, is a function of furnace temperature, degree of turbulence and fuel particle size.

Mass Balance

The flow weight into an incinerator must equal the flow of products leaving the incinerator. Input includes waste fuel, air and supplementary fuel. The flow exiting the incinerator includes moisture and dry gas in the exhaust as well as ash, both in the exhaust as fly ash and bottom ash (Walker and Cooper 1992).

Problem of the hospital	
Wet feed, lb/h	46
Moisture, %	17
Ash, %	20
Heating value of the volatile fraction	7500 Btu/lb

Heat Balance

Heat, like mass, is conserved within a system. The heat exiting a system is equal to the amount of heat entering that system. The result of the heat balance is a determination of the incinerator outlet temperature, outlet gas flow, supplemental fuel requirement, and total air requirement. The total heat into the incinerator was calculated in the mass flow computations. By determining how much of the total heat produced is present in the exhaust gas, the exhaust gas temperature can be calculated. If the calculated exhaust gas temperature is equal to the desired exhaust gas outlet temperature, the process is autogenously and supplemental fuel is not required. If the desired temperature is lower than the actual outlet temperature, additional air must be added (or additional water) to lower the outlet temperature to that desired. This condition is also autogenously burning since supplemental fuel is not added to the system. For the case where the actual outlet temperature is less than the desired outlet temperature, supplemental fuel must be added. The products of combustion must include the products of combustion of the supplemental fuel. Dry flue gas properties are assumed to be identical to those of dry air.

Ash generated is 9.2 lb/h, from the mass flow calculations. The heating value of the ash can be calculated by the equation:

$$Q = C_p(T - 60)$$

Where, Q = Heating value
C_p = Ash specific heat= 0.24 Btu/lb. ^oF
T = Ash discharge temperature
Say, at 2000^{o}F, Heating value Q =0.24 (2000-60) = 465.6 Btu/lb.
The heat loss through ash discharge is therefore (9.2 * 465.6) = 4283.52Btu/h= 0.00428352 MBtu/lb.

Radiation: the heat lost by radiation from the incinerator shell can be approximated as a percentage of the total heat of combustion.

Therefore, the total calculated enthalpy is:

At 1900^{o}F	0.1899 MBtu/h
At 2000^{o}F	0.1924 MBtu/h
At X^{0}F	0.3435 MBtu/h

By extrapolation, the exhaust-temperature "X" is 2112^{o}F.

With these designing parameters the batch incinerator is designed to accommodate the hospital waste. In this system, the incinerator is charged with a single batch of waste, the waste is combusted, the incinerator is cooled, and the ash residue is removed; the cycle is then repeated. When the unit is loaded, the incinerator is sealed, and the incineration cycle then continues through burn down, cool down, and ash removal without any additional charging. Depending on the size of the batch MWI, batch units may operate on a 1- or 2-day cycle. Ash is removed either one day or two days after the initial batch charge of waste. In this unit, the primary and secondary chambers are vertically oriented and combined within a single casing. Figure 2 is a schematic of a batch-duty MWI. This unit's combustion chambers are rectangular in design and are contained within the same casing.

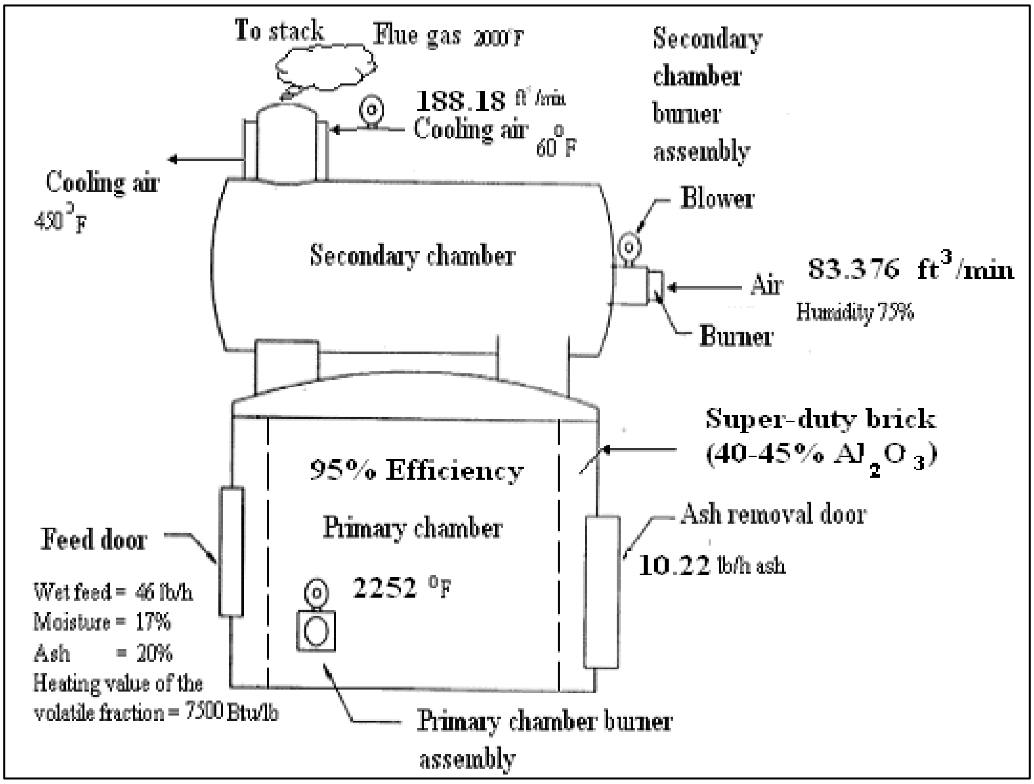

Figure 2 Batch-duty incinerators for the chosen hospital waste

Inclinator Ash Management

A large amount of solid waste is generated in the hospitals during diagnosis and treatment of diseases. The solid waste may contain human organs, bandages, needles, syringes, test tubes, blood tubes, tissue cell culture and other plastic materials. The incinerator is an effective and hygienic method for disposal of hospital waste. Bottom ash constitutes 20- 30% of original waste and is typically composed of aluminosilicate phase and contains significant amount of heavy metals. These residues are generally in a wet condition when disposed, adding up to 25 to 50% to the weight. Consequently, disposal of ash residues imposes a substantial increment to the total cost of operation of a WTE facility. The presence of significant amount of toxic metals in the incinerator ash may be of serious concern for its disposal. In India, Ministry of Environment has issued guidelines for Bio medical waste management in 1998.

Handling and disposal of ash residues must not cause contamination of the environment by fugitive dust or by leaching into the environment or water supplies (Barbeito and Saprio 1977). Dusting is minimized by keeping the residues in a moist condition.

Stored ash residues must be properly managed to prevent unacceptable discharge of dust or leachate. Runoff and leachate must be collected, supervised, and properly disposed of so that soluble metal compounds and salts do not contaminate the environment.

Scoring of ash allows chemical reactions to take place, which bind the metals, reducing leaching potential. Rainwater percolating through the pile cleans the ash by slowly leaching out the available (soluble) metals.

Ash containers must be drainable to recover leachate, and watertight to prevent leachate from running off into the environment.

Transportation of ash residues must be in covered containers to prevent dust from escaping into the environment. Containers, vehicles, and roads must be washed if contaminated with ash. The wash water must be disposed of properly or recycled back to the ash quench tank.

Ash was collected weekly once from incinerator of BCCL central hospital, Dhanbad. About 1 kg of ash was collected and dried at room temperature. All the visible metals and glass objects were removed. Ash samples were then pulverized and passed through –200 mesh (75 micron) sieve. Whole sample was mixed properly using a blender and the blended samples were taken for analysis. The concentrations of Co, Cr, Cu, Mn, Ni, Zn, Pb metals were determined by GBC AVANTA. 0.5 gm of ash from each sample was taken for digestion in 5 ml HNO_3 and 1 ml $HClO_4$.Digestion is done until the color of the flask contents turns to white. Then some more HNO_3 is added to the flask and placed for the digestion. After the contents of the flask changed to white color, flask is cooled to room temperature. Then the contents of the flask are dissolved in 1% HNO_3 solution and the volume is made up to 50 ml. Then the solution was preserved for metal analysis in an Atomic Absorption Spectrophotometer.

The concentration of trace elements varies according to the incineration conditions of incinerator. Zinc concentration is higher in hospital all the samples, probably due to burning of teeth, bones and plastic material. The high concentration of is due to burning of considerable amount of plastics. Proper disposal of incinerator ash is therefore important to minimize environmental pollution. Land filling of incinerator residue is the best way of disposal, as the mobility of heavy metals inside landfill is very low. The complete wash out of metal may require thousands of years or more. Recycling may also be a way to reduce the loss of heavy metals to the environment. Hence the proper disposal of incinerator ash would require regular analytical monitoring to ensure that the concentration of trace elements is within permissible limits.

Landfill of untreated ash is the simplest means of disposal. Ash residues have been co-disposed with municipal solid waste (MSW), but for various reasons it may be preferable to place ash residues in separate or dedicated cells. Ash residues have been used to cover MSW as daily cover or as final cover. Placing ash residues in ash fills has the advantage that a solid, relatively impervious mass is created, over which trucks can drive as soon as it is placed. Efficient management of ash fills can increase the density of the ash to as high as 3300-lb/yd^3 or 122 lb/ft^3, as compared with about 1800 lb/yd^3 of uncompacted ash. Another benefit of compaction is the potential for reducing the permeability to as low as 1x 10^{-6} to 1 x 10^{-9} cm/sec. Ash fills are so impervious to water that only a small fraction of rain falling on the top surface is able to penetrate the fill; 90% or more will runoff, without leaching much of the soluble materials in the ash. It is important to provide effective runoff collection systems since the water may be significantly contaminated, especially when the ash fill is in the process of being filled, prior to capping. Ash residues have been used as lining materials for landfills, in lieu of costly clay liners. To prepare the ash for use as a landfill liner, Portland cement can be added at the landfill at 6-10% plus lime at 6-7% by weight. The leachate from the ash fills may be discharged or trucked to wastewater disposal plants if found to be acceptable, or it may require treatment before such disposal. The salinity of leachate is measured by electrical conductivity. Soils producing leachates that have an electrical conductivity greater than 16 mhos/cm are classified as saline, causing interference in the uptake of water by plants. So the soluble toxic metals are only slowly released due to the presence of alkaline materials that provide powerful buffering against MSW produced acids and the low quantity of weak acids in acid rain.

CONCLUSIONS

Biomedical wastes from the hospitals, nursing homes and clinics include a variety of wastes; some of them contain harmful organisms and disease causing agents. The study reveals that incineration can be considered as an environmentally and technically superior method of biomedical waste treatment. It has been observed that improper incineration of wastes, particularly chlorinated organic compounds can result in noxious emissions including dreaded dioxins. For appropriate treatment of biomedical wastes of different categories are to be properly segregated and rendered harmless. PMCH is one of the well-equipped hospitals in the region chosen for the study of biomedical waste and development of appropriate treatment technology. On the basis of composition and quantity of waste generated an incinerator has been designed and combustion efficiency, mass balance, energy balance, moisture content etc have been evaluated. The primary combustion chamber temperature was estimated to be at 1233 ^{o}C. At this temperature super-duty refractory bricks were suggested with 40-45% Al_2O_3.The designed parameters are found to be comparable with those of the standard values. The ash generated for the 90% efficiency of the incinerator has been found to be 5kg/h. The strategy developed for the handling and safe management of biomedical waste has formed a guideline and may be used on an industrial scale for various sites.

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Clinical Waste Management in Khulna City

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ABSTRACT

The current practice of waste disposal was to dump all types of wastes in the nearest Khulna City Corporation (KCC) bins or adjacent low-lying areas. Hazardous wastes are openly burnt in some hospitals without any air emission and temperature control. Wastes are collected by the municipal waste-collection service, and are transported for final disposal with municipal wastes. Most wastes were disposed of in municipal waste dumps along with municipal solid wastes. The hospital staff, professionals, and the general people were not aware of the hazards of hospital wastes. Wastes were not segregated at any hospitals. As a result, mixing of wastes led to contamination of potentially-recyclable components of general wastes and high risk of occupational exposure of workers. This paper illustrates the classification of different types of clinical wastes and their adverse impacts on human on environment and on human health. The paper also highlights the existing clinical waste generation pattern of different hospitals, Clinics in KCC area and about the present dumping system for it. This study also identifies the risk associated with health hazards of the general people and the people involved with the present clinical waste management system. Eventually, the paper provides some options and guidelines for sustainable clinical waste dumping and management for Khulna City as well.

INTRODUCTION

In Bangladesh, clinical waste is a new subject within uncountable elements of environmental pollution. Especially Dhaka, the capital and other major cities of this country it is now a serious anxious case. According to study of World Health Organization medical wastes generated from human and animals in clinic and pathological laboratory etc for the purpose of diagnosis of diseases, thesis, treatment or immunization on them. 15% to 20% of these medical wastes are harmful and vulnerable for infection and different types of diseases. With the increasing population in Bangladesh different types of diseases, accidents, sufferings are increasing. For these reason clinics, hospitals, medicals are also escalating. In these types of institutions vast amount of treatment and test equipments are used. There are different types of medical wastes such as pine, blade, blood, cough, glass, godge, bandage, tube, dust or filth of human and animals. These medical wastes are gathered at the side of clinics and medicals and are causing serious pollution with other home and industrial wastes. An anxious matter is in residential and commercial area most of the clinics and hospitals are situated. For this clinical waste is causing serious health problem and different types of diseases.

Khulna, the third largest metropolitan city of Bangladesh, stands on the banks of the Rupsha and the Bhairav rivers. Clinical waste is one of the vital problems in Khulna City. Establishment of various health care centers, clinics and hospitals has made difficult for management of different wastes, as there are poor waste management systems in this city. In order to prevent health hazard, proper Hospital Waste Management and codification of its operational directives are required to be formulated without delay. The present study took an attempt to discover the present clinical waste management system of Khulna city and to measure the level of risk for environmental health due to mismanagement of clinical waste.

OBJECTIVES

- to identify different types of clinical wastes in Khulna City

- to clarify the impacts of wastes on environment and human.
- to identify the total amount of clinical waste generated from different health center of Khulna city.
- to find out the existing management and dumping system of the clinical waste.
- to recognize the risk of health hazards of general people and the people who are involved in waste collection and disposal system.
- to present some environmentally responsive alternatives for improved management and dumping system for clinical waste this would be suitable for Khulna city.

SCOPE OF THE STUDY

- in present world environmental protection is a growing concerned matter both in developed and developing countries. Environmental hazards in urban in urban areas caused by clinical waste is a matter of concern.
- through this study it will be possible to recognize different types of waste produced by different hospitals, clinics, medicals and pathology centers.
- it will be possible to measure the amount of clinical waste produced per day from KCC area.
- the study will present the over view of clinical waste management system in KCC area.
- the study will provide the prospects to identify the basic problems in managing the hospital wastes appropriately.
- it will be helpful for different governmental and non-governmental officials, planners, environmental engineers and policy makers who are concerned about environment management system to make healthy, friendly, welcoming and pleasant environment.
- it will be cooperative for doctors, nurses and different personnel and employees who are working in different institutions.

RATIONALE OF THE STUDY

Unhygienic waste disposal by many hospitals, clinics and healthcare centers in Khulna are posed serious health hazard to the city dwellers in general and to the people living within and in the surrounding area of the hospitals in particular. Almost all of these hospitals are disposing every kind of wastes such as: hazardous, non-hazardous, infections, sharps etc. in nearby municipal dustbins without any pretreatment whatsoever.

An injurious, unhealthy and harmful environment exists in every governmental medical facility that affecting patients, hospitals staff and other people and around governmental and non-governmental facility. The medical wastes are disposed on the road and also here and there. Scavengers who collect waste from dustbins are at risk from sharps, pharmaceuticals and chemicals and from direct contact with infectious materials. General peoples also are affecting more as these waste are disposed directly in the environment.

To protect the citizens from lethal diseases that may occur by inappropriate disposal of medical waste, a joint effort by NGOs and GOs is immediately required to create awareness amongst the people of medical and para-medical profession and citizens. Moreover, government should enact necessary laws and policy without further delay. We are cover behind our neighboring country India, which has by now enacted necessary law for clinical waste management.

LOCATION OF THE STUDY AREA

Khulna is the third largest city in the country and is located in the south-west part of Bangladesh (At 22° 49 north latitude and 89e 34 east latitude). Khulna the port city of south Bengal is surrounded by river named Rupsha and Bhairab. Khulna became glorious for the presence of the seaport named Mongla and Mangrove forest named Sundarbans. There is an economic dominance of Khulna on national economic development. Khulna is established as a regional center for trade and commerce. it is the administrative headquarters for Khulna district and division and the regional center for higher education. Existing health facilities category within KCC boundary according to functions are:

Table 1 Different type of existing health facilities in Khulna city

Type of facilities	Number of facility	Percentage
Clinic	34	13.70
Hospital	15	6
Maternity center	3	1.20
Family planning center	21	8.60
Pathological center	12	4.80
EPI center	124	50
OPO	39	15.70
Total	248	100

(Source UCF-IP)

METHODOLOGY OF THE STUDY

It is very difficult to explore data from direct field survey. Thus the study was based on the available data and information from secondary sources. At first conceptualization was made for developing clear understanding about what is intended to do in the study. Conceptualization earned by helpful literature review and studying different books, seminar paper, report, magazine which focus on the issue related to the research topic, a clear concept about different of the report were developed. The study area was Khulna City Corporation. The study area was divided into 7 groups for purpose of data collection. In order to get a view of the nature of the study area a reconnaissance survey was conducted in KCC area at the early period of the report preparation. It helped to prepare a framework for the study and the photographs were also taken which helped very much to identify the clinical waste and its management system. Then data was collected from the field by survey team. Different groups went to different area and collected data from the filed. Data also collected from the secondary sources and KCC. After discussion with all groups the final data were summaries. In this stage all the collected data were classified through tabular form according to objectives. Data after editing were processed and analyzed using statistical tools and after that final report was produced.

FINDINGS AND ANALYSIS

Clinical Wastes

Clinical wastes are all kinds wastes generated from the clinics, hospitals and other centers. But waste papers, dust, etc generated from clinics are not treated as clinical waste. Usually following types are found as clinical wastes.

- gauge. Bandage, cotton etc
- saline bag
- chemical reagent, blood, urine, stools, test tube etc from pathological lab.
- plasters
- foil or packet of medicine
- any part of human body amputed in Operation Theater
- abortioned ambrio
- syringes and needles
- stool, urine, cough, spit, blood etc.
- dead body is also treated as clinical waste.

The following data were collected from filed survey from different hospital. From every large and medium size hospital has different data about clinical wastes. But most of the small clinics have no data about their collection and disposal system and amount of waste generate from them. There are no people involve in waste management.

Table 2 Waste generated from small sized clinics and hospital (Number of bed is less than 20)

Name of the centre	Number of bed	No. of people involved in waste management	Daily generated waste from activities (KG)			
			Medicine	Surgery	Maternity	Total
Khulna nursing home	4	1	1	—	—	1
Nibedita Sheba sadan	15	3	1	1	.07	2.07
Naama clinic	5	2	2	.07	2	4.07
K clinic	12	2	.45	1	.5	1.95
All clinic	6	2	1	.5	1	2.5
Arogya niketon	12	2	1	1	.1	2.1
City nursing home	17	3	3	2	.45	5.45
Al amin	15	2	.3	.175		.175
Green maternity hospital	10	3	4	4	6	14
Matrirnongol clinic-u Shasthya Kendra	10		1	.175		1.175
Niramoy clinic	4	1	.3	.06	.01	.37
Total	110	21	15.05	9.98	10.18	35.16

Source: Field Survey'2002 and Prodipon

Table 3 Waste generated from middle scale hospitals (number of bed between 20 &100)

Name of the centre	Number of bed	No. of people involved in waste management	Daily generated waste from activities (KG)			
			Medicine	Surgery	Maternity	Total
Sheba clinic	20	6	8	5	2	15
Uposhom private hospital clinic	20	3	2	.5	.5	3
Cure home general hospital	20	6	1	1	.1	2.1
Nurgis memorial	26	4	4	.175	-	4.175
Nahar clinic	30	4	.5	1	2	3.5
Pongu hospital	20	-	5	5	-	10
Garab-e-newaz clinic	38	15	9	2	1	12
Total	174	38	29.5	14.67	5.6	49.775

Source: Field Survey' 2002 and Prodipon

Table 4 Waste generated from large-scale hospitals (number of bed more than 100)

Name of the centre	Number of bed	No. of people involved in waste management	Daily generated waste from activities (KG)			
			Medicine	Surgery	Maternity	Total
Khulna surgical and medical hospital	100	14	20	5	4	29
Khulna medical college hospital	250	36	20	10	15	45
Khulna general hospital	150	20	15	15	15	45
Total	500	70	55	30	34	119

Source: Field Survey'2002 and Prodipon

People Involve in Clinical Waste Management

From Table 2, 3 and 4 it is seen that total 129 people involve in different medicals and clinics at waste management in Khulna City. In small medium, large size health facilities have 21,38, 70 people in management.

From the study it is also found that average amount of waste disposed from a small scale hospital is 3.23 kg/day, 7.11 kg/day for medium scale and 39.3 kg/day for large scale hospitals respectively. Everyday in Khulna City more than 800 kg clinical wastes dispose from various hospitals and clinics. But dumping system of this waste is not satisfactory. The following table shows syringe and neddle use scenario in different hospitals and clinics in KCC areas.

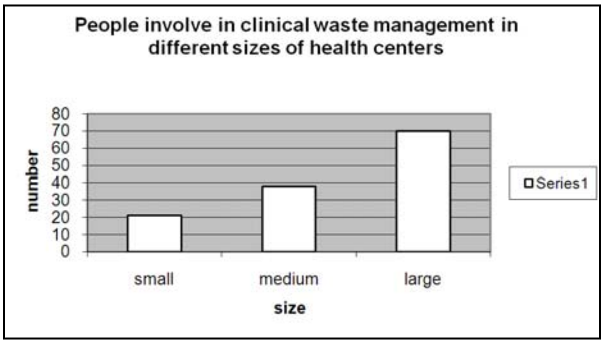

Figure 1 Involve of people in different clinics

Table 5 Syringes and Needle Disposal Scenario from Various types of Hospitals and Clinics

Types of health facility	No. of daily disposed needless (Average)	No. of daily disposed syringe (average)	Disposed in dustbins (%)	Sold (%)
Large hospital	450	400	100	-
Medium clinic and hospital	50	50	97	3
Small clinic and hospital	25	25	90	10

(Source: Field Survey,2002)

From the survey it has been observed that a large number of needles and syringes are used in hospitals and clinics. None of them destroy these needles before throwing them into the municipal dustbins. This practice helps recycling contaminated needles and syringes increasing the chances of needle born diseases. Some of the hospital and clinics sell these needles anti syringes themselves. About 90 percent of them dispose the syringes and needles in the nearby dustbins together with other waste and 10 percent of them sell it to some parties together with other materials, which have a chance to be reselling. Every small and medium scale hospital or clinic dispose about 30-40 needles and syringes everyday in an average in Khulna City (Field survey 2002) If the total number of health center is 248, its 10 percent is 34.8. So about 35x34 = 1190 syringes and needles are sold to various parties for recycling every day. On the other hand Tokai also collects large number of needles and syringes from the dustbins. Large hospitals like Khulna Medical Collage hospital, Khulna General Hospital and Khulna Surgical and Medical Hospital, each of them dispose about 400 needles and syringes every day.

City Khulna in the Context of Developed Countries

The quantities of different categories of hospital wastes in Khulna city are estimated on the basis of the data collected from selected hospitals/clinics from an intensive survey. These wastes we recollected 3 times a day. The average generation rate (kg/bed/day) of total hospital waste was about 1.2, which is much lower than that of 4.5 in USA, 2.7 in Netherlands and2.5 in France. However, the average hospital waste generation rates are in the range of 1–4.5 kg/bed/day in Latin American countries like Chile, Brazil, Argentina, Venezuela, (Monreal 1991). But the percentage of hazardous waste in Khulna city (15.5 per cent) is much higher than that of Netherlands (5 per cent) and Sweden (9 per cent), and is lower than that of Denmark (25 percent) and USA (28 percent), and is very close to the rate of generated in Germany (14 per cent). The indicated difference may be due to geographical location, living habits and standards, avail-ability of different treatment facilities, and perhaps to the ways in which solid wastes are categorized in different countries. Sweepers of the hospital collect garbage from these spots inside the hospital premises and then throw them in the roadside dustbins. Disposable syringe, needles, blood soaked.

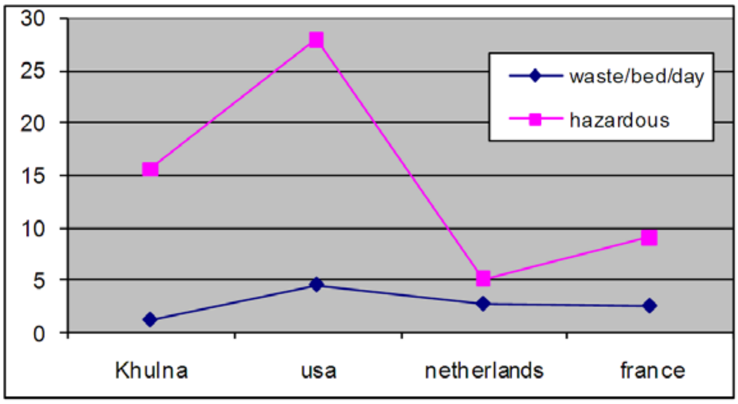

Figure 2 Comparative analysis between Khulna and different cities (*Source: Field Survey, 2002)*

WASTE COLLECTION AND DISPOSE SYSTEM

The main observation in clinical waste collection and disposal system in Khulna city is that, maximum of the hospitals & clinics is not collect, and dispose all the waste separately. They throw it to the municipal dustbins or roadside—dumping site, which is collected and disposed later by City Corporation together with other urban domestic solid waste.

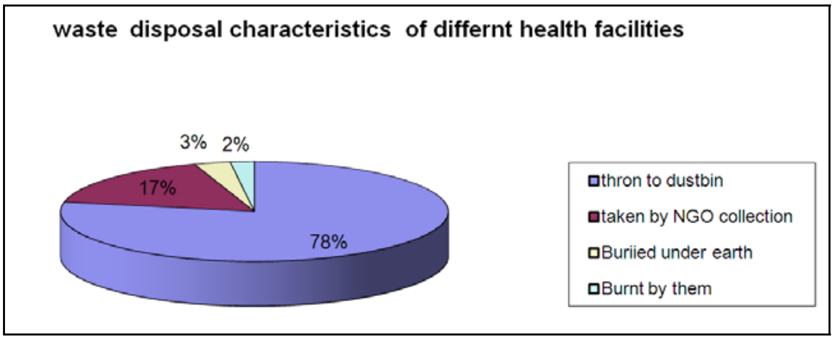

Figure 3 Waste disposal characteristics of different health facilities (*Source: Field Survey, 2002)*

Some Case Studies in Collection System

Most of the health centers collect their waste in outdated system. Only Garib-E Ncwaz clinic and Khulna Surgical and medical Hospital are exceptional in this respect. In Garib-E Newa clinic every cabin have some modernize dustbins. These dustbins have a device on which pressure is created by leg and the cover is opened and the waste is disposed inside it. There is a central dustbin beside the main garbage where all the waste is disposed in three shifts per day. Waste picker from PRODIPAN comes twice a clay and take the waste from the main dustbin. In Khulna surgical and Medical hospital, there is a pipe 1)1 wide diameter made of stainless steel which connects all the words and cabin of each floor. All the waste comes to a large bucket through the pipe. This bucket is placed besides the hospital building and from here a waste collector take up the waste in two shifts per day. In every government hospital there are exists a good collection system of recycle waste like saline bags, ampoule or foil of medicine etc. Every ward boy, aya to the store, collects these. When the recyclable waste fills up the store, then it is sold by auction. Certainly it is a good practice, which can reduce the volume of urban solid waste.

Role of City Corporation in Management System

For waste collection and disposal main responsibility goes to City Corporation or Paurashava of a city. Khulna City Corporation is also trying its best for proper collection and disposal of urban solid waste as well as clinical waste.

But the endeavor is not sufficient for its various constraints. Conservancy department of KCC has various problems like: *Shortage of fund, Shortage of manpower, Shortage of vehicles etc*
There also existence improper administrative system in the department. Through they have an wish to make separate collection and disposal system of clinical waste (which exist in developed countries), they are not able to do that at present for the shortage of fund and man power. *(Conservancy department of KCC)*

Role of NGO's

Waste disposal of a city is a very big task, which cannot be done by only one authority. Only a collective endeavor can achieve the goal in this respect and there is a hope that, already some NGO's have come forward to shave the responsibility with Khulna city Corporation. Pradipan and Muktir Alo are mentionable name of two NGO, which are dealing with urban solid waste management. Recently PRADIPAN has gone for a contractual arrangement with KCC to share the responsibilities of managing clinical wastes. PRODIPAN will establish an waste composting plant and an incinerator in near future with the financial support of World Bank.

Occupational Health

According to Dr. Zia-Ur-Rahman {Assistant Professor of Surgery, Dhaka Medical College Hospital (DMCH)}, they are not provided with gloves while the treatment takes place, which might be infectious to them. They are open to the diseases of the patients, as the public hospitals do not provide them with proper equipment and facility. The nurses, sweepers and cleaners are not aware of taking any precautionary measures while disposing the hazardous hospital/clinical waste. The scavengers outside the hospitals are exposed to the hospital/clinical waste, as the waste is disposed into the KCC dustbin. Studies have not been carried out on the health effects of the community those who are exposed to the hospital/clinical waste in Bangladesh. Mainly people at risk to hospital/clinical waste in Khulna City are:

- cleaners
- sweepers
- nurses
- scavengers

Types of Hazards

Exposure to hazardous health-care waste can result in disease or injury. The hazardous nature of health-care waste may be due to one or more of the following characteristics:

- it contains infectious agents
- it is genotoxic
- it contains toxic or hazardous chemicals or pharmaceuticals
- it contains sharps

Persons at Risk

All individual exposed to hazardous health-care waste are potentially at risk, including those within health-care establishments that generate hazardous waste and those outside these sources who either handle such waste or are exposed to it as a consequence of careless management. The main groups at risk are the following:

- medical doctors, nurses, health-care auxiliaries and hospital maintenance personnel
- patients in health-care establishments or receiving home care
- visitors to health-care establishments
- workers in support services allied to health care establishments such as laundries, waste handling and transportation
- workers in waste disposal facilities (such as landfills or incinerators), including scavengers

The hazards associated with scattered, small sources of health care waste should not be over looked; waste from these sources includes that generated by home-based health- care, such as dialysis and that generated by illicit drug use.

Hazards from Infectious Waste and Sharps

Infectious waste may contain any of a great variety of pathogen micro-organisms. Pathogens in infectious waste may enter the human body by a number of routes:

- through a puncture, abrasion or in the skin

- through the mucous membranes
- by inhalation
- by ingestion

Impacts of Infectious Waste and Sharps

For serious virus infections such as HIV/AIDS and hepatitis B and C, hospital workers-particularly nurses-are at greatest risk of infection through injuries from contaminated sharps (largely hypodermic needles). Other hospital workers and waste management to operators outside hospitals are also at significant risk, as are individuals who scavenge on waste disposal sites (although these risks are not well documented). The risk of this type infection among patients and the public is much lower. Certain infections spread through other media or caused by more resilient agents may pose a significant risk to the general public and to hospital patients. Individual cases of accidents and subsequent infections caused by the hospital waste are well documented. For example; a hospital housekeeper in the USA developed staphylococcus bacteria endocarditic after a needle injury.

RECOMMENDATIONS

- Large no of people should he involved in overall management process of clinical waste for the city.
- Disposable syringes and needles should be separately collected and handled carefully. It should be recycled or crashed by a reliable organization so that it can not come in contact with people.
- An incinerator should be established by I<CC either in large scale or small scale whether it may be economically profitable or not, because human cost is undoubtedly higher than any other cost.
- Non-biodegradable portion of clinical waste should be separately collected and recycled. In this way waste volume will be reduced and resource will be conserved.
- Measures should be taken to improve understanding of the doctors, nurses and other hospital staffs about the health hazards of clinical wastes, safe handling and disposal.
- Make aware and educate the city dwellers about the ill effects of poor hospital waste management.
- Development of environment friendly clinical waste management.
- KCC should start a separate collection and disposal system for clinical waste.

CONCLUSIONS

Khulna City Corporation should give guidelines and rule to the hospitals/clinics of Khulna. They should start grading the hospital/clinics to improve hospital waste disaster. They should also involve the Non-Governmental Organizations to upgrade the waste disposal system. They should stop this disaster and consider the international principles as their guideline. Strict law policy should be made or should improve the old system. Ministry of Health should also take interest. The authority should stop this recycling of hospital waste, which takes place through the scavengers. Strict measures should be taken to improve the hospital/clinical waste situation now. People should be involved to combat this hospital waste menace. The above article shows the adverse situation of hospital waste management in Bangladesh.

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Waste Mismanagement and Health Hazard Using GIS Techniques in Khulna City of Bangladesh

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ABSTRACT

This study has been intended to focus on the mismanagement system and its health hazards related with generation and management of Municipal Solid Waste (MSW) in Khulna City. Around 520 tons of MSW is generated per day considering all the sources and the generation rate is 0.60 Kg/capita/day on an average. Domestic wastes are the main sources of MSW in Khulna City. There are potential risks to health and environment from improper handling such as collection, storage, recycling and disposal of MSW. Unplanned management of solid waste in Khulna City causes significant environmental hazard and serious threat to surface water ground water soil and air. Mainly the workers working in Solid Waste Management (SWM) system are facing problems due to the unmanaged solid waste besides the city dwellers also confronting these problems. By considering the present scenario of the problem associated with MSW in Khulna City required proper SWM approaches that would be financially suitable. The Geographical Information System (GIS) can provide an opportunity to integrate field parameters with population and other relevant data or other associated features, which help in SWM. The management procedures can benefit from the appropriate use of GIS. The use of GIS in selection process will reduce the time and enhance the accuracy.

INTRODUCTION

Solid wastes are the useless, unwanted and discarded materials considering the place produced mainly by the anthropogenic activities. With the rapid growth of population and technological activities amount of waste is also increasing (Alamgir et al. 2005). At present in many instances solid waste are collected in mixed state and being dumped in environmentally very sensitive places like road sides, marshy lands, low lying areas, public places etc. causing numerous negative environmental impacts such as ground and surface water pollution, air pollution. Although peoples are being affected with this unmanaged solid waste mostly the people who are directly contact with it such as workers who involve with the SWM. The dumping of solid waste in open places directly related to the breeding of mosquito and other vectors of fatal disease. But this essential service of Khulna City Corporation (KCC) is not efficiently and properly performed by the local bodies. Finally, the study will search for initiatives to develop the efficiency of existing management system which can build up a friendly environment for inhabitants in KCC. Present population of Khulna City is more than 1.5 million according to City Corporation but report (BBS, Khulna 2009) says that the total population of KCC is 863603. The growing population is generating solid waste, but disposal of this solid waste is not improved. Approximately 52% solid waste collected from the generated solid wastes. Rest 48% is disposed in vacant land, low laying areas, ponds, road sides, drains and ditches. Uncontrolled disposal of solid waste has contributed localized flooding through closing of drains, because Khulna City is located about to same level of Bhairab River. Although the main dumping places of Khulna City is Rajbandh but they are dumping here and there. The system of SWM of KCC is unregulated and insanitary, resulting the adverse effects like degradation of water quality, attraction of disease carrying insects and rodents and overall degradation of environment. Besides these, the people of Khulna City do not participate with solid waste management of KCC. They are not only throwing waste here and there but also throwing it out side of the dustbins. If proper SWM plan is not taken for the growing metropolis of Khulna, it will create severe degradation of urban environment. So SWMS is one of the key aspects for urban cleanness and for better environment. It is, therefore, highly desirable to study SWMS of KCC area for better planning and management of solid wastes from environmental point of view.

OBJECTIVES

The prime objectives are as follows

a) To review the present scenario of solid waste management in KCC;
b) To find out the problems associated in management system;
c) To find out the health hazards of people from mismanagement of solid waste; and
d) Deliberate some guidelines for overcoming the problems.

MATERIALS AND METHODS

Khulna is the third largest metropolitan city in the country as shown in Figure 1 in between $21^{0}38^{\prime\prime}$ & $23^{0}1^{\prime\prime}$ north latitude and $89^{0}8^{\prime\prime}$ & $89^{0}58^{\prime\prime}$ east longitude and is 12 ft above mean sea level. The present area under its jurisdiction is 45.65 square kilometer divided into 31 wards with population 8,63,603 (*BBS 2009*). Primary data for this work were collected by field surveys through direct interviews of respondent that were necessary to perceive the real condition of different subject-matter of the study area. Secondary data were collected from various sources like NGOs, CBOs, researchers publications, books, newspapers, journals, seminar papers, reports, training guides, internet searching and unpublished research works, fair foundation offices, thesis papers, Statistical Bureau (BBS) Khulna Center, conservancy office of KCC etc. That survey was conducted through stratified random sampling and direct observation. As the number of population is approximately 60000 (household) and a house hold sometimes contain more than one family. So for the convenience stratified random sampling procedure was chosen. From each word 40 households were considered randomly for survey. Thus 1240 samples were taken from 31 wards of KCC. The data collected from the questionnaire survey the secondary sources were interpreted and processed for the analysis of the study.

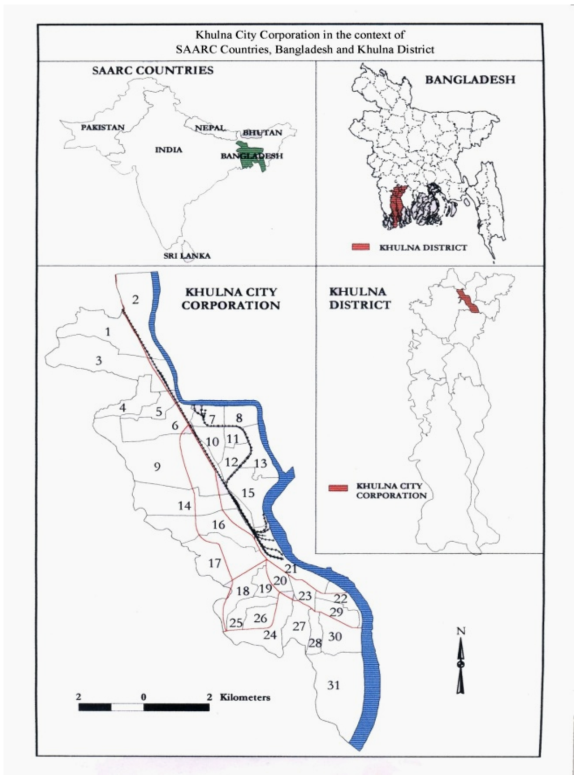


Figure 1 KCC in the context of SAARC countries, Bangladesh and Khulna Division

RESULTS AND DISCUSSIONS

Solid Waste Management System in KCC

Solid waste management system includes waste collection, storage, transport, treatment and final disposal governed by KCC. Conservancy office plays a vital role in solid waste management. Accept KCC govern body, different NGOs and CBOs also contribute in solid waste management. Total generated waste is estimated by calculating the rate of generation and multiplying the rate by the total population. According to the field survey the household sector is the primary source of Municipal solid wastes in Khulna city. Household wastes covering almost 76% of solid waste. Per day waste generation rate in different source are showing in Figure 2. Before final disposal of wastes are stored primarily in a bin on house and in dustbin near house, secondarily the waste is storage in a common place where wastes are gathered from different places by waste collectors. Primarily the generated wastes are storages in house or dustbin. Where door to door collection facility exists mainly they are storing their waste in a bin insite their house and where this facility not exists they store their waste in nearest dustbin. This is handed over to the waste collector in a regular basis usually once daily. The total number of dustbin is 1200. Maximum of them are open dustbin. There are few numbers of demountable containers which is generation point is carried to the secondary disposal site either by the households themselves or by the city corporation man power in terms of door to door solid waste collection system. Mainly wastes are collected from housesholds, dustbins, drains, streets and different open places. Khulna City Corporation (KCC) performs the key responsibility for collecting wastes from the secondary disposal points and transfers it to the ultimate disposal point. Wastes are generally collected once daily from the primary disposal points. For the collection and transport of solid waste KCC have different types of vehicles. For collecting wastes KCC cannot support all wards for its limited manpower and economic support. So KCC permit some NGOs to collect waste from different wards.

Table 1 Household solid waste generation rate in different wards, 2009

Ward no.	No. of household survey	Per capita Waste production	Population	Total waste in kg
1	40	0.36	22720	8179.2
2	40	0.4	21035	8414
3	40	0.37	25732	9520.84
4	40	0.38	15908	6045.04
5	40	0.5	17121	8560.5
6	40	0.49	23472	11501.28
7	40	0.43	16555	7118.65
8	40	0.39	20733	8085.87
9	40	0.4	38698	15479.2
10	40	0.41	20703	8488.23
11	40	0.4	21687	8674.8
12	40	0.42	58176	24433.92
13	40	0.4	22314	8925.6
14	40	0.43	29564	12712.52
15	40	0.36	28759	10353.24
16	40	0.54	40115	21662.1
17	40	0.6	33936	20361.6
18	40	0.46	18743	8621.78
19	40	0.41	31663	12981.83
20	40	0.5	25198	12599
21	40	0.47	27932	13128.04
22	40	0.56	24185	13543.6
23	40	0.4	20495	8198
24	40	0.55	48048	26426.4
25	40	0.46	30305	13940.3
26	40	0.48	20221	9706.08
27	40	0.51	35204	17954.04
28	40	0.55	25047	13775.85
29	40	0.59	22842	13476.78
30	40	0.44	40054	17623.76
31	40	0.38	36438	13846.44
Total	**1240**	**Average: 0.4529**	**863603**	**394338.5**

Source: Field survey, 2009 and KCC 2009

Door to Door collection is performed by KCC and different NGOs such as Prosanti, Shium, Goti, Nagorik Forum, Nabarun sangsad, Muktir Alo, Rupayan, Rustic, Shamadhan, Commitment etc. The study shows that about 18.55% of households are included in door to door collection system. And mostly 14.19% of the wastes are collected from dustbin. A part of street waste are collected daily that is approximately 15%. Treatment of solid waste is important in solid waste management. All the trucks start there journey to start collecting waste from the city corporation vehicle garage. Each individual truck has a separate route for collecting waste estimated 12 in number according to KCC authority. Without proper treatment solid waste can create harm for the people. An actual treatment of solid waste also provides us energy or it can be the source of money. Wastes are processed mainly in three ways at the final disposal site in KCC those are; Land filling, Recycling and Incineration. Land filling is one of the common procedures for processing of solid waste. This type of treatment processes used in almost all countries in the world. It is a safe technique in low cost for maintenance the solid waste. KCC mainly use this technique from the beginning. About 75% of solid wastes in KCC are used in land filling. Almost 20-30% of MSW contains materials which could be recycled. A special type of recycling is done by the poorest of the poor of the city which people collect recycling materials. People who do not sale or reuse these types of things normally throw these in the dustbin along with other kitchen waste. Those persons which are commonly recognized as “Tokai” collect these recyclable materials either from secondary disposal point or from ultimate disposal site. They daily sale it to the permanent recycling shops and earn average 70 taka per day. The ultimate disposal site can be converted into sanitary landfill. In KCC the final disposal site is situated in Rajbandh. It is at the western side of Khulna City and the distance is 9 km from the city. The area of Rajbandh is 25 acres. Now it is include in Batiaghata thana near Kaia Bazar. It is situated beside the road. Khulna City Corporation itself is the owner of the site. No scientific or modern technology is used for ultimate disposal in KCC. All wastes are disposed here manually.

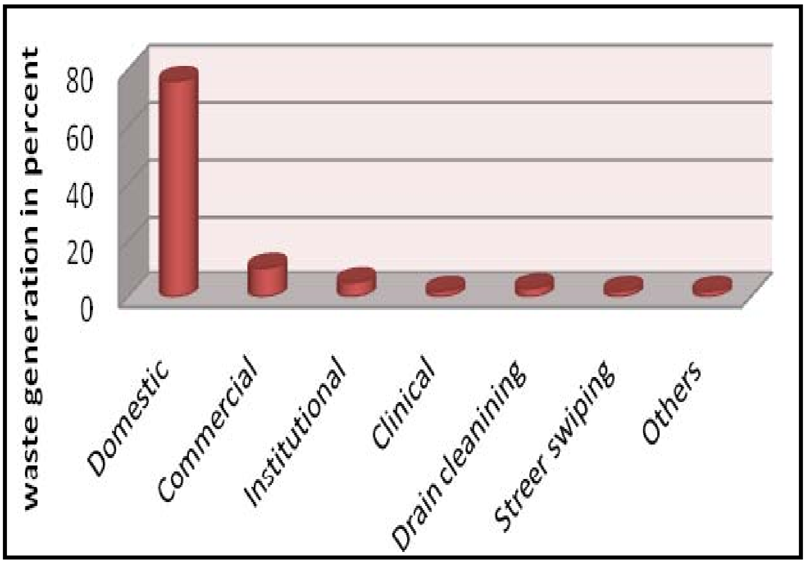
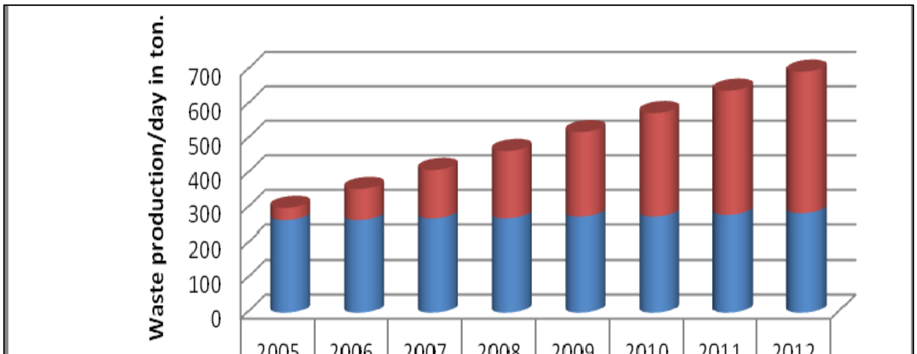


Figure 2 Per day waste generation rate from different sources

SOLID WASTE MISMANAGEMENT SCENARIO

The mismanagement of solid waste is not uncommon in KCC. Unconsciousness of public, lack of their participation in waste management facility, scarcity of manpower in management facility, irresponsibility of KCC and different factor are responsible for waste mismanagement in KCC. In KCC solid wastes are being collected in different stage from waste generation to final disposal. But by this present waste collection system the city dullards do not satisfy. They encountered some acute problem such as odor pollution in residential area, local flood due to drainage congestion with waste, water pollution, river pollution due to industrial effluent disposal into the river. Besides they encountered some disease such as Vomiting due to odor, Diarrhea, Cholera which is occurred by flies, but flies born in dust bin and other mismanagement of waste disposable system. From the field survey it is found that the workers who handle solid waste they suffer from various types of chronic and acute diseases, such as Skin disease, Diarrhea, Dysentery, Cholera, Hepatitis and Physical injury from hazardous wastes. In Khulna city, Khulna City Corporation is responsible to manage waste collection and disposal system. But from the field survey it is found that many wards there are no waste management system. As a consequence they deprive from the facilities of waste management system of KCC. Lack of management they are bound to dispose their waste into open place, street, drain, dead pond and other places. The mismanaged dumping of solid waste all over the wards as shown in Figure 3. Institutional wastes, industrial solid wastes, hospital and clinical wastes contain different type of material such as papers, glass, metals and some toxic chemicals. These waste are needed properly separation, but there is no measuring steps to mitigate this issues. All wastes are disposed in a common place named Rajbandh. At Rajbandh though it is found that separation of waste into different materials are being occurred but these are not satisfactory. Some waste such as plastic, glass, batteries and metals which can be used as a recycle material, do not separated from the mixed waste. As a result KCC loss not only the potential sources of revenue but also loss their reputation for mismanagement of waste.



	2005	2006	2007	2008	2009	2010	2011	2012
Unmanage waste	35	90	140	195	245	300	360	410
Manage waste	265	265	270	270	275	275	280	285

Figure 3 Production of MSW per year

The production rate of waste per year was increasing but the management facility is not with this increasing solid waste as shown in Figure 3. Therefore the mismanagement is increasing day by day. For this cause environmental health is decreasing day by day. If the proper initiative will not take, KCC will face a serious problem within some years. Waste mismanagement mostly occurs in primary storage as shown in Figure 4. For the lacking of dustbin, proper awareness of people, insufficient manpower, irresponsibility of KCC etc is increases the mismanagement. Problems are described below. At the very beginning of waste generation some wastes are discarded and thrown where and there. Lack of knowledge and proper awareness about the management of waste, they cannot percept the consequence of disposal of waste into wrong places. Sometime city dwellers throw their generated waste into open place due to dame care or lack of any law for waste disposing into wrong places. Besides Industries, Institutes, Hospital, Clinic and other institutes, they produce huge amount of waste, but maximum has no onsite management system. All the wards are not similarly affected by solid waste. There are several wards which has proper management facility such as, 7, 18, 22, 29 whereas several wards are confronting the problems of solid waste such as 12, 16, 24, 30, 31. The condition of mismanagement scenario as shown in Figure 6 and the amount of mismanaged solid waste of every ward as shown in Figure 5.

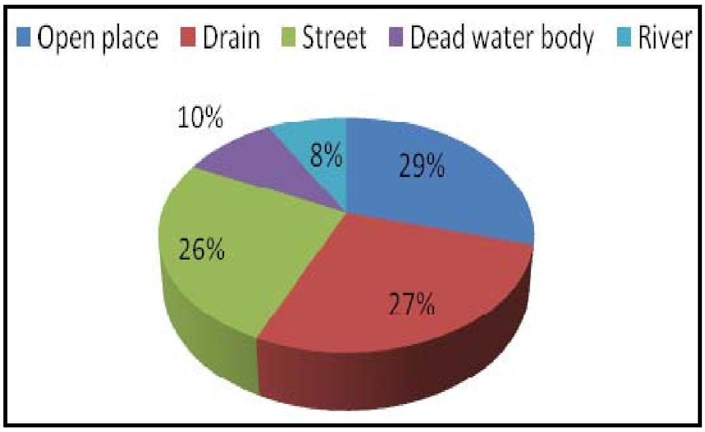


Figure 4 Mismanagement scenarios in waste in primary disposing

Mismanagement in Waste Storage

Lack of proper knowledge and irresponsibility is the main cause of mismanagement in KCC. Wastes are stores day after day but those are not collected by collectors in different wards of KCC. This cause people are not go further to keep their waste and through it street, road side and drain. Generally dustbin constructed on the basis of house hold number. But the number of dustbin according to the number of household does not sufficient. The wards which have insufficient number of dustbin are, 1, 2, 3, 7, 8, 13, 21, 31, and 30. As a result city dwellers which have insufficient dustbin facility they throw their maximum waste where and there. As a consequence they suffer from various types of environmental problems and health hazards. For collection of waste from household on any other premises, KCC provides three types of dustbins exist in Khulna City; these are cover dustbin, open dustbin and ring dustbin and the total number of dustbins 1200 and 12 demountable container.

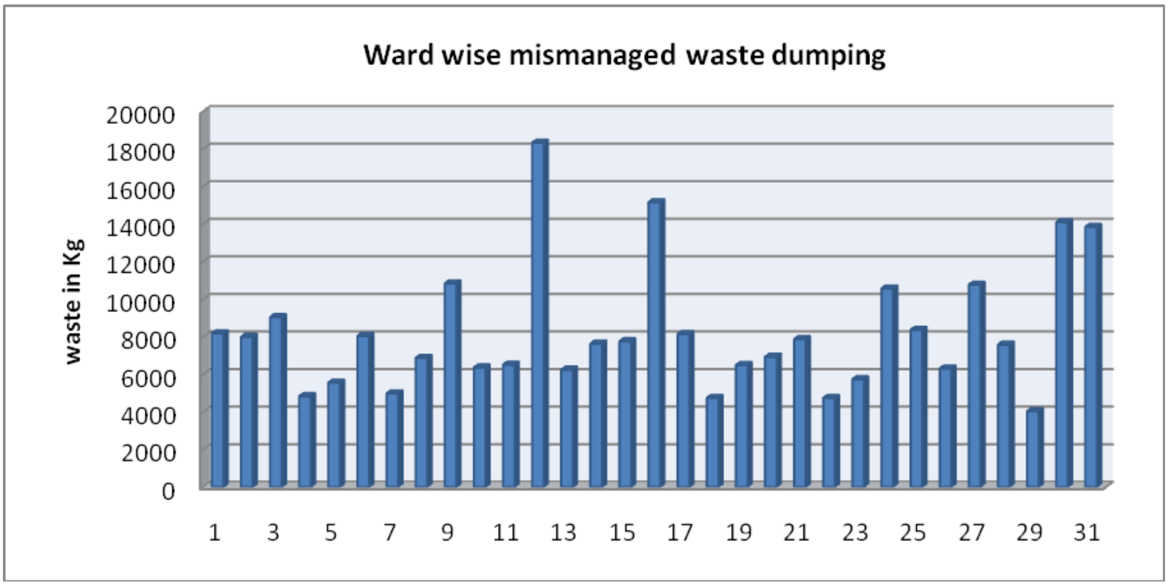


Figure 5 Mismanagement of solid waste in different wards

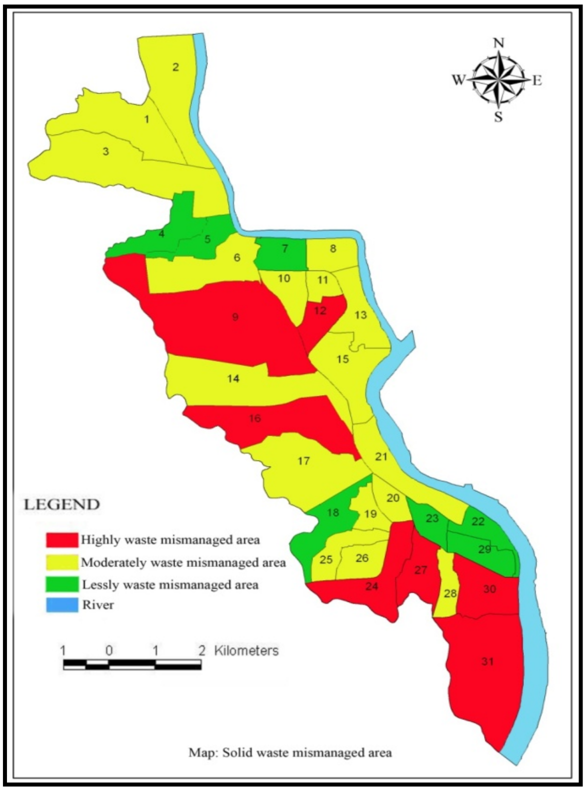


Figure 6 Map of solid waste mismanagement in KCC

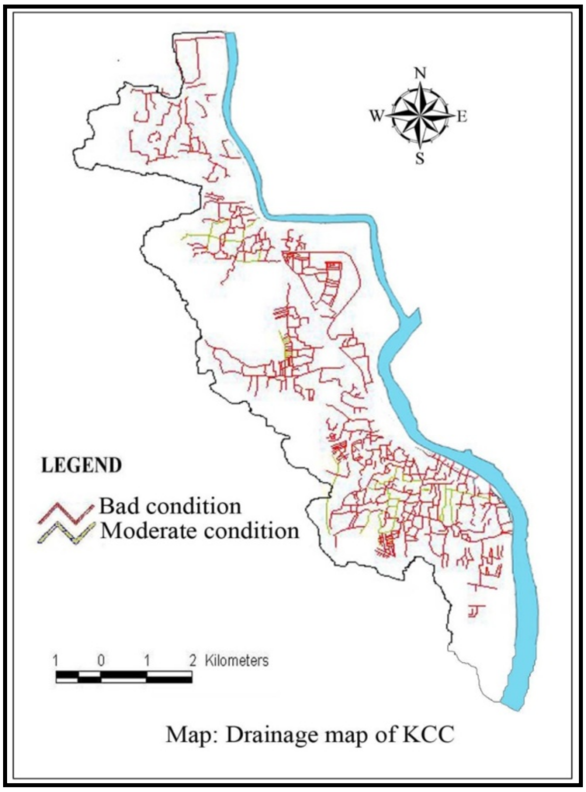


Figure 7 Drainage condition of KCC

Besides odor pollution are occurred and people do not able to go near the dustbin to dump their waste properly. Therefore an annoying condition occurred beside the bin. During rainy season the bin filled with water and then the scope of dumping waste into the dustbin is lost. Except these, Flies and mosquitoes grow in it. For bad condition of dustbin waste are haphazardly scattered by the animals like cow, dog, cat, hen, rats etc. And many diseases carrying insects are growing up there.

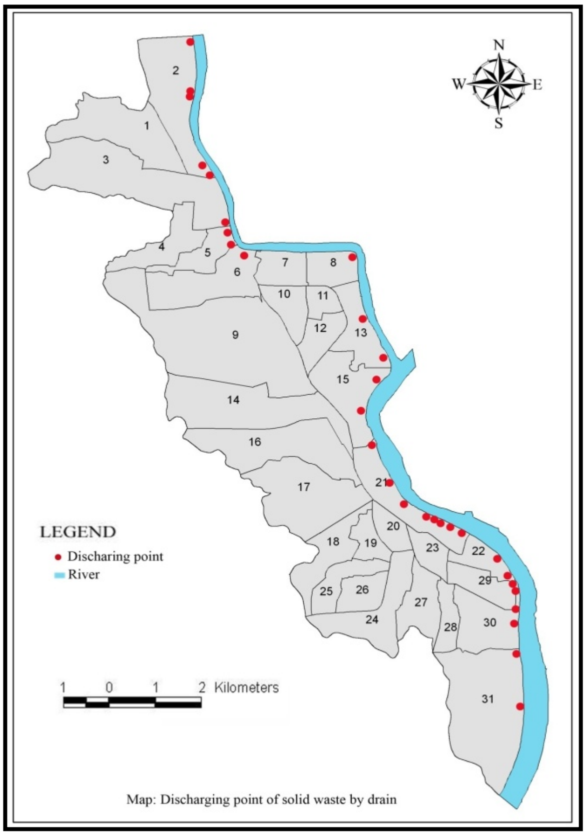


Figure 8 Discharging point of solid waste into the river by drain

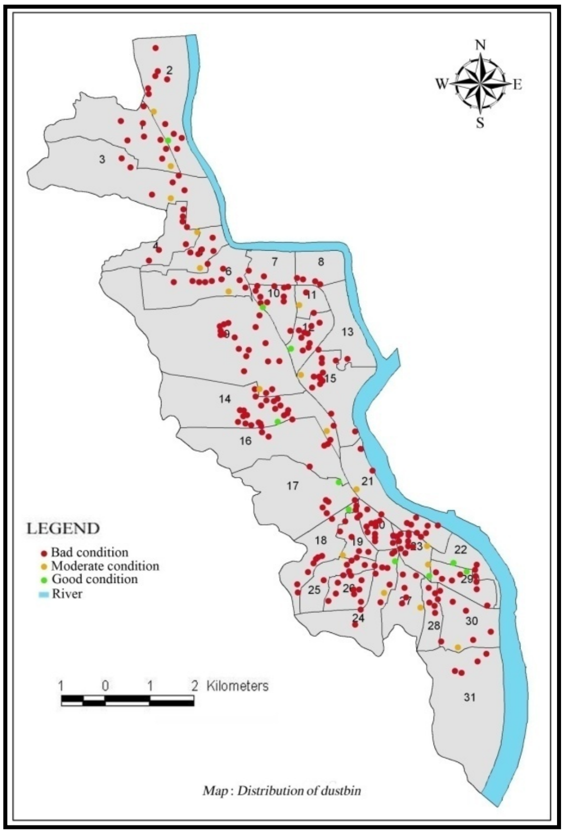


Figure 9 Condition of dustbin in KCC

Field survey reflects that 75% of total dustbins are in bad condition for proper repairing 20% moderate and 5% well condition. (Figure 9) shows the condition of dustbin. Otherwise the drainage condition is not well. Those are not properly cleaned in short interval. (Figure 7) shows the present drainage condition. As a result the drains are filler with solid waste, and it carries solid wastes through Voirab River and pollutes it. (Figure 8) shows the discharging point of solid waste into the Voirab River. The management authority has no headache about this. People who live beside the dustbin are suffering unbearable aesthetic and health problems. For dumping different types of waste, such as organic waste, hazardous waste, plastic materials, radio active materials, developed and some developing countries maintained different types of colorful bins. Each color of bin refers a distinct type of waste that can be dumped into that bin. By maintaining of color code wastes are automatically separated. In KCC from the field survey it is found that there is no maintenance of color code. As a result all wastes are dumped into the same dustbin and occurred a hazardous condition.

Waste Mismanagement during Collection

It has found that in KCC two types of collection are being made, one is from dustbin and another is door to door collection. For door to door collection dwellers have to pay some charge. But there are some errors which are occurred during collection. Actually proper Solid Waste management System depends on the field level workers. The present workers do not work systematically because they are insufficient for the management. Working pressure is too high on them so that they are not working well. The present manpower is not sufficient for better solid waste Management, it is the main cause. There is lack of sincerity of KCC staffs and lack of proper staff supervision. As a result waste collection does not occur properly. Lack of monitoring this becomes an acute problem. During holiday or other occasion day waste generation somewhat large in quantity than usual day, but there is no any special measuring step to assimilate this extra waste properly. Various types of gaps exist in the present organogram of Conservancy Department due to shortage of staffs and laborers. So it is another type of constraint of Conservancy

Labours are in significant in number in KCC. They are irresponsible for their duties due to improper guideline. So every stags of conservancy Department have great gap between Conservancy Officer and laborer. Transport equipment and man power is too much limited to continue the task. Three is no self loading and emptied equipment here that make the task easier. There is no compacting equipment here which can increase the load capacity of the truck. Most of the roads are too narrow to drive the trucks while collecting the waste. There are 52% waste are collected daily and rest of the 48% are not collected for lack of low trip number. The actual collected waste is 273 tons per day, where as 520 tons waste generated per day in the city. The uncollected waste scattered of roadside or any other places. This has occurred due to low trip number of vehicles. The best collection system of waste is door to door collection, because through this system the possibility of waste scattering is low into the surrounding environment. Due to the man power and economic constraint KCC does not able to provide this type of collection system among all wards. KCC provides only this type of facility to the ward, 5, 10, 22, and 29. Besides these some NGOs named C.B.O, S.P.S, Rustic, Prodipon etc. (Figure 10) shows the ward wise door to door collection facilities. Though some wards have waste management facilities but wastes are being collected partially. Except these there are some wards which have no door to door collection facility such as, 1, 2, 8, and 31. Door to door collection is a waste management system in which waste collectors collect the waste everyday from household**.** The monethly payment is 10 to 25 tk per household for this service. Although monethly payment is low, 36% of household do not accept this service and they throw their waste into the drain or other places.

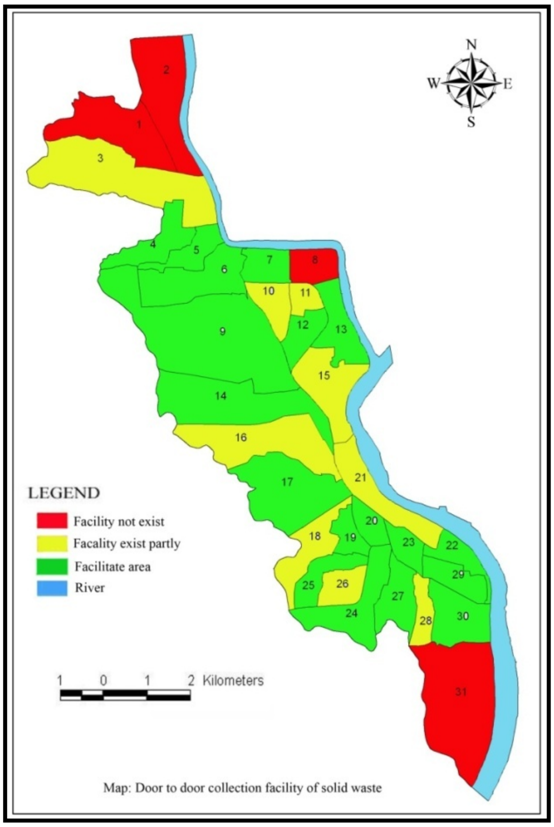


Figure 10 Door to door collection facility in different wards of KCC

Mismanagement in Transportation

Transfer and transport specifies the activities which cover the collection of waste for final disposal points by means of transportation facilities available of the city corporation. In KCC there are only 34 waste carrying vehicles are used for waste transportation which do not cover all 31 wards in a day. Besides vehicles trip number is low. In Khulna city the road condition of some wards is bad and big trucks are not able to transmit through it. Through the field survey it is found that the qualities of vehicles are not satisfactory. Almost the vehicles have no cover. As a result wastes are being scattered during transportation into the surrounding roads. Lack of repairing, maximum vehicles have lost their efficiency and wastes are being leached into the roads. Overload is one of the major problems for scattering of waste from vehicles also. Due to overload wastes fall down on the road during transportation.

Mismanagement in Waste Treatment

It is necessary to treat the collected waste before final disposal for a good environment. KCC disposed all city waste at Rajbandh for final disposal. But it is found that all waste remain without treatment. For environmental friendly ecology it is necessary to reduce the volume of waste, needed Duckweed treatment of waste, needed covered treatment plant. But these are not be used in Rajbandh. As a result at that place ecology are gradually decreased. Waste generation source is the main point to separate the wastes according to their nature and process used for treatment. Separation at this point is most economic and time saving than to other steps. City dwellers have very little knowledge about solid waste management. As a result any type of segregation or separation is not done at the waste generation point. Land filling is one of the ways to reduce the volume of waste. By the proper sanitary land filling biogas and leachate produce as a byproduct which can be used as a potential source of energy. Though there is a sanitary landfill at Rajbandh of KCC, but lack of proper maintenance the condition of this sanitary landfill is very poor. As a consequence various types of pollution occur such as air pollution, odour pollution, soil pollution, ecological disruption etc. Recyclable material such as like tin can, pet bottle, battery, glass, plastic made goods etc are not separated properly by KCC before final disposal. Though some people locally named “tokai” collect this type of materials for their self benefit from the waste. But this not refers the proper separation of recyclable material. This recyclable material can be the potential source of extra income of KCC. But lack of proper management KCC deprived from this opportunities.

Mismanagement in Disposal

The area of disposal site of Rajbandh is 25 acres. This landfill station situated just beside the Khulna- Satkhira road, but no landfill station can be situated near to any public construction, like road of transportation, residential area, market place etc. At Rajbandh landfill station surrounded by agricultural lands. As a consequence these agricultural lands are affected very much by leachate and other pollutant from landfill station. Through the field survey it is found that the disposal area does not sufficient. Considering all aspects of disposal site of Rajbandh, it is an ecologically vulnerable area and need to take urgent measuring steps. From the disposal site waste are instantly spread out by different types of animal. As a result the germ of diseases also spread out by them. These animals can be the potential source of hazrds. When decision is made for set up a plant, there are some factors to be considered, surrounding ecology is one of them. Through the field survey it is found that there is no consideration of ecology at Rajbandh waste disposal plant. As a result, odour pollution is being occurred, crop production hampered, water bodies are being polluted and this rate is high during Rainy season. Due to no consideration of ecology, ground water is also being polluted. Without considering ecology this disposal place is lost its efficiency gradually. Therefore at Rajband waste disposal plant needs EIA study.

HEALTH HAZARDS FOR MISMANAGED SOLID WASTE

Mismanaged solid wastes and health problems are closely related with each other. Waste describes unwanted residues that are usually perceived to be of negative value. Mismanaged solid waste can affect human health, children being more vulnerable to these pollutants. In fact, direct exposure can lead to diseases through chemical exposure as the release of chemical waste into the environment leads to chemical poisoning. Uncollected solid waste increases risk of injury, and infection. Waste dumped near a water source also causes contamination of the water body or the ground water source. In particular, organic domestic waste poses a serious threat, since they ferment, creating conditions favorable to the survival and growth of microbial pathogens. Direct handling of solid waste can result in various types of infectious and chronic diseases with the waste workers and the rag pickers being the most vulnerable. Waste treatment and disposal sites can also create health hazards for the neighborhood. Workers working with waste containing chemical and metals may experience toxic exposure. Disposal of health-care wastes require special attention since it can create major health hazards, such as jaundice, diarrhea, parasitic diseases, dysentery, stomach trouble, eye trouble, headache. Some time drain blocked and water logged by the solid waste. So it has an indirect impact on human health. Cholera, Diarrhea, Plague, stomach diseases are caused through the rats. The garbage in refuse attacks rats. Rats rely on readily available scraps of foods such as those, which are kept in open trash barrels. Inadequate collection and disposal of solid waste is a major factor in the spread of gastrointestinal and parasitic diseases, primarily caused by the proliferation of insects and rodents.

Health Problems of Municipal People

There are many causes of health problem of municipal people. Generally unhygienic condition is the main reason of health problem. Solid waste mismanagement is one of the unhygienic practices. Lack of proper knowledge and awareness about health are the main causes of solid waste mismanagement. Around 75% of the city dwellers faces problem for solid waste. Many types of health problem can be occurred, such as Diarrhoea, Dysentery, cholera, Typhoid, Hepatitis, etc. Through my field survey it is found that children and women suffer much than the male. Dustbin, blockage drain, waterlogged area are the suitable place for born and live on of mosquito which cause the fatal human diseases like Dengue’s, Malaria.

All wards have a serious mosquito problem and it is mainly caused by mismanaged solid waste. The treatment facility against mosquito is insufficient, the pesticides uses for mosquito are not sufficient or the facility not reaches in all sectors of people. Thus dengue, malaria, filarial and other diseases are spread out to the city people. Odour problem is the common problem to the people, they are felling discomfort during the passing time beside dustbin because maximum dustbin are not properly cleaned by KCC.

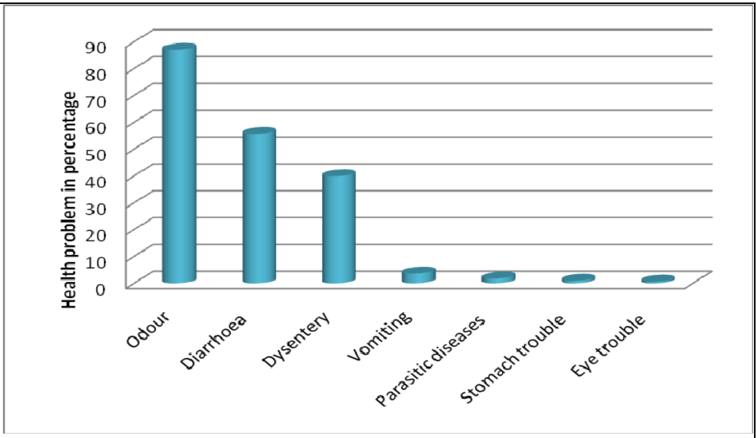


Figure 11 Health problem scenario of city dwellers for solid waste

Health Problems of Workers

The workers who are engaged for collection, storage, separation, disposal, processing of solid waste suffered from various types of acute and chronic diseases as shown in Figure 11. According to the report of World Health Organization (WHO), there are 40 types of human diseases are caused by the solid waste. Health problem can caused by Skin and blood infections resulting from direct contact with waste, and from infected wounds. Eye and respiratory infections resulting from exposure to infected dust, especially during landfill operations. Intestinal infections that are transmitted by flies feeding on the waste. Whether bone and muscle disorders resulting from the handling of heavy containers. Infecting wounds resulting from contact with sharp objects. Poisoning and chemical burns resulting from contact with small amounts of hazardous chemical waste mixed with general waste. Burns and other injuries resulting from occupational accidents at waste disposal sites or from methane gas explosion at landfill sites. Most of the workers involved in waste management service are not using any type of safe guard in KCC. Almost 96 % of workers are suffering in health problems. There is several numbers of examples of serious injuries. Moreover some are loosing there body part by injuries.

Causes of Problem

Illiteracy is one of the most common problems for worker. As a result they don't have any knowledge about health care. For this cause numerous diseases are creating net in their bodies. Only 14% of the worker has the facility of safe guard, rest 86% of the workers do not use safe guard. As a result different types of injuries are introduced among the workers. Field survey shows that about 88 % of workers facing different types of injuries like eye injuries, needle ingestion, cutting by blade, skin damages and such types of problem. Beside workers are not treated well because of low income level, also any type of health problem facility is not provided for the workers. For this cause they are suffering different types of disease such as gastric, diarrohoea, dysentery, vomiting, abdominal pain, eye trouble, hepatic problem etc.

RECOMENDATION

General Recommendation

- Increase public awareness about the importance and benefits of solid waste to resource recovery by KCC, NGOs and CBOs.
- Construction of clean, hygienic and well constructed covered dustbin with no odor sufficiently.
- Assurance of regularity in collection and transportation of solid waste from the households bins and primary dumping sides.
- Organic degradable waste should be more compost and also used as a fertilizer in the crop field and fisheries and in this way increase the awareness for reduction of solid waste generation.
- Increase awareness of people with the intention of nothing is disposable into the environment and everything should be used as a resource.

- Increase the knowledge about biogas plant by household organic solid wastes which can be used for generation of electricity that can be helped to meet the shortage of current electricity demand in households.
- It also necessary to install large recycling factories for availability recycling of solid waste due to sustainable waste-to-resource recovery.
- Increase the facility of house to house collection in all areas of KCC if possible.
- Establishment of sanitary land fill instead of open dumping if funds are available.
- Provide well constructed and well linkage of sewerage systems and drains every areas of KCC.
- Drain should be cleaned properly at short interval.

Recommendation for Workers Health

- Provide solid waste workers and waste pickers with clean drinking water and sanitation facilities.
- Prohibit children from waste picking and prohibit domestic animals from being fed with
- food waste which has been mixed with other municipal wastes.
- Provide annual medical examinations.
- Vaccinate solid waste workers for hepatitis A and B, tetanus, polio and typhoid.
- Provide education about personal hygiene, and the safe care/feeding of domestic livestock and pets to solid waste workers and waste pickers.
- Provide solid waste workers and waste pickers with protective clothing, shoes/boots and gloves.
- Provide solid waste workers operating waste processing equipment with protective eye
- Glasses and face masks.

CONCLUSIONS

From the management point of view, it can be concluded that the present system of SWM of KCC is not satisfactory. Moreover SWMS is in a hazard condition now. As such there is an urgent need for improvement in financial, institutional and technical aspects. Local NGOs and CBOs participation can illuminate the management system. Public awareness is one of the most important factors for proper management of MSW. They need to know about the adverse effect of solid waste in environment. Project from NGOs or KCC also need to develop the awareness for cleaning the environment to save ourselves. Workers are in vulnerable condition for solid waste, so by upgrading the technique and serving proper knowledge we can minimize this antagonistic effect on human. If the present waste generation rate and present management system will continue it would be very much alarming for the city area. So, only the sincerity about solid waste can remove this adverse effect from City Corporation. And a proper procedural framework of KCC could help to do this. The city has grown at an alarming rate during the last decade and ultimately results the various environmental disorders. Like other growing cities, it has already experienced solid waste management problem. Solid waste problem in the city is so extreme with time and population. If the problem is identified at the earlier stage and taken necessary preventive measures, the problem may be solved better.

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Medical Waste Management in Some Selected Metropolitan Cities of Bangladesh

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ABSTRACT

This paper demonstrates that now a day Medical Waste Management (MWM) has become a matter of major environmental concern due to the increasing growth of health facilities in both public and private sectors of Bangladesh and simultaneously the production of huge amount of Medical Waste (MW). Most of this MWM happens improper disposal that brings hazardous situation, which leads to contamination of nearby communities or wildlife and spread the occurrence of HIV, skin diseases, asthma, diarrhea, allergy, eye irritation and other bad impacts. The study has tried to find out a comparative analysis of MWM in the selected major cities of Bangladesh namely, Dhaka, Khulna, Chittagong, Sylhet, Rajshahi and Barishal. This research observed that MWM of some projects (such as PRISM and JICA based MWM) at Dhaka City are comparatively better than other cities. As Dhaka possesses a huge amount of hospitals and clinics, the rate of MW generation is highest there. The hygienic contamination and environmental pollution was found at peak in Barisal City where the MWM involved very poor handling and controlling activities. Khulna City authority has the responsibility for off-site transport of medical waste from the government hospitals to landfill at Rajbandh. 'Prodipon' involved in hospital waste management system from private clinics that used incineration process at Rajbandh. However, the research revealed that based on the selected MWM factors, the overall MWM system is non satisfactory in all cities. Based on the experimental results it can be concluded that all cities need to be more improvement in their respective MWM practices through the development of Risk and Safety Management and Training.

INTRODUCTION

Medical waste possesses serious threats to environment and health requires specialized treatment and management prior to its final disposal. Simply disposing it into dustbins, drains, and canals or finally dumping it to the outskirts of the city poses a serious public health hazard. Such disregard occurs due to lack of awareness of the people and institutions engaged in medical waste generation and disposal as well as due to lack of treatment facilities. The problem is getting worse with increasing in the number of hospitals and clinics in the city. Due to expansion of medical facilities in the country the environmentalists are becoming very much worried because of the hazards that lie behind the facilities of the establishment. Waste products from these clinics are not treated or destroyed properly, rather thrown into the dustbins thereby creating health hazards. These waste products pollute the environment.

One estimate shows that some 5.2 million people (including 4 million children) die each year from waste-related diseases. Globally, the amount of municipal waste generated will double by the year 2000 and quadruple by year 2025 (Akter et al. 1999; Nasima 2000). Concerned with this situation Agenda 21, adopted in the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June, 1992, set the following goals and targets with Regard to waste management in cities:

- All countries must establish waste treatment and disposal criteria and develop the ability to monitor the environmental impact of waste by the year 2000.
- By 2025, developing countries should ensure that at least half of the sewage, wastewater and solid waste are disposed according to national and international guidelines.
- By 2025, all countries shall dispose of all waste according to international quality guidelines.

Medical waste management has become a major issue in urban areas of all the countries of the world, especially in developing country like Bangladesh. As medical wastes are infective wastes it spreads diseases at a faster rate than others. So it is more significant than other wastes. But the present practice of medical waste management in Bangladesh is in very haphazard condition. In this aspect, the management standards that are found around the world are not been seen in any where of Bangladesh except one or two hospitals or clinics and 65-70% wastes are remain totally unmanaged.

OBJECTIVE OF THE STUDY

1. To identify the types and amount of medical waste generated in some selected metropolitan cites in Bangladesh.
2. To draw an overview the present medical waste management system in Bangladesh.
3. To asses the possible environmental consequences of improper disposal of MW in Bangladesh.

MATERIALS AND METHODS

Medical waste and its problem are growing rapidly as a direct result of rapid urbanization and population growth in major cities of Bangladesh. Medical waste poses serious threats to environmental health, requires specialized treatment and management prior to its final disposal. The study was conducted within some selected metropolitan cities in Bangladesh where peoples of all walks of life in and around the cities get medical services and facilities. Mainly medical waste management system was surveyed in Khulna City and the activities of PRISM Bangladesh in Dhaka City with collaboration with Dhaka City Corporation were observed here. The study was conducted from June, 2008 to December, 2008 in Dhaka and Khulna City of Bangladesh. Around 60 hospitals or clinics from Dhaka and 40 from Khulna were surveyed for the study. Primary data were collected through questionnaire survey and field visit and secondary data secondary sources of data were collected from different journals, books, NGO reports, websites and etc. Afterwards the collected data are presented in tabular and graphical forms for the sake of good interpretation.

Data Collection and Processing, Analysis and Interpretation

Data were collected from the two main types of sources; Primary data sources and Secondary data sources. Primary data were collected through questionnaire survey in the field. After collection of data, it was processed, analyzed and interpreted. Data analyses are performed with the help of statistical methods by the help of MS Office, graphical presentation as pie chart, bar diagram etc.

RESULTS AND DISCUSSIONS

Present Scenario of MWM in Selected Metropolitan Cities

To protect the urban environment of Dhaka City from the hazardous effect of medical waste which is generated as by-product of medical services, PRISM Bangladesh in collaboration with the Dhaka City Corporation has initiated the medical waste management program in Dhaka City. Dhaka City Corporation in collaboration with PRISM Bangladesh is operating the medical waste management to protect the urban environment from the hazardous effects of medical waste. Through their work necessity has been developed to work for environmental governance. In Khulna, Khulna City Corporation and the NGO Prodipan jointly engaged in MWM in the city. Prodipan works in different environmental issues in Khulna for a long time and MWM is one of them.

Types of Medical Waste

There are various materials generated and for better management option wastes are categorized:

Non Hazardous Medical Waste

Non hazardous medical waste in health care establishments are general waste that contains kitchen garbge, refuse of food materials, Fruits materials, vegetables, clothes, papers, packing materials, water bottle etc

Hazardous Medical Waste

Hazardous waste in the health care establishments is as follows:

- **Infectious waste**: Gauge, cotton, tissue, organs, human fetuses, dressings, bandages, sticking plaster, gloves, disposable medical items, waste of operation theater, pathological waste etc
- **Sharp waste**: Scissors, blade, needle (without syringe), broken glass etc.
- **Recyclable waste**: Syringe (without needle), saline bags, blood bags, bottle of medicine, plastics materials etc.
- **Chemical and radioactive waste**: Expired medicine, discarded chemicals usually from cleaning and disinfecting activities, medicine used in laboratory which are not reused and by product of radioactive materials used in identification of diseases, X-ray film etc.

Table 1 Inventory of different health care establishments (HCEs) of Khulna City

Name of the HCEs	No of bed	Indoor patient/ day	Out patient/ day	Total patients per day	Total waste G. Kg./day	Waste Generation rate	
						Kg. Waste/Bed/day	Kg. waste/Patient/day
KsaH	150	200	300	500	260	1.73	0.52
KMCH	250	350	300	650	340	1.36	0.52
KSH	213	180	300	480	150	0.70	0.3125
KC	15	10	5	15	8.5	0.56	0.56
NMSC	15	7	0	7	2	0.13	0.28
FHC	19	10	15	25	13.3	0.7	0.53
BNHD	10	6	10	16	11	1.1	0.68
IBHDC	40	40	60	100	60	1.5	0.6
ApCDC	10	4	13	17	8	0.8	0.32
KSMH	100	60	200	260	82	0.82	0.29
SH	15	5	25	30	13	0.86	0.37
CH	30	20	40	60	22	0.73	0.43
RMH	20	5	25	30	14	0.7	0.47
GCDGHC	35	12	60	72	26	0.74	0.36
HNH	10	7	15	22	7	0.7	0.32
SNH	10	5	0	5	3	0.3	0.6
SC	15	11	9	20	13.5	0.9	0.68
GHC	20	12	25	37	17	0.85	0.46
PDC	*	*	10	10	6.1		0.61
SDC	*	*	60	60	8		0.13
MDC (Mahanagar)	*	*	40	40	10		0.25
MDC (Medicare)	*	*	50	50	16		0..32
MC	20	15	30	45	7	0.35	0.15
NMH	25	15	15	30	10	0.4	0.33
Total	1022	974	1607	2581	1107.7	15.93	9.77
Average					0.41		

Source: Field Survey, 2008; * There is no fixed bed in Diagnostic Centers (KsaH=Khulna Sadar Hospital KSH=Khulna Sishu Hospital KC=Khalishpur Clinic NMSC=Nagar Matri Sadan clinic FHC=Fare Health Clinic, BNHD=Boira Nursing Home and diagnostic, IBHDC=Islami bank hospital and Diagnostic Complex, ApCDC=Apex Clinic and Diagnostic Complex, KSMH Pvt. Ltd. =Khulna Surgical and Medical Hospital Pvt. Ltd., SH=Specialized Hospital, CH=Cure Home, RMH=Rashida Memorial Hospital, IBHLCC=Islami Bank Hospital Lab and Consultation Center, HNH=Haq Nursing Home, SNH=Sibsha Nursing home, PDC=Padma Diagnostic Center, SC=Sapla Cinic, NMH=Nurgis memorial hospital, GCDGHC=Gorib newaj Clinic, Diagnostic and General Hospital Complex, KMCH=Khulna Medical College Hospital, SDC=Setu Diagnostic Center, MDC=Mahanagar Diagnostic Center, GHC=Good Health clinic, MDC=Medicare Diagnostic Center)

Generation of Medical Waste

Medical waste generated from the daily activities of patients, cleaners, sweepers, nurses, doctors, and administrators etc that are discarded as useless. Medical wastes are generated from wards, cabins, Operation Theater. Volume of waste mainly depends upon Number of beds and outdoor patients that represents the waste generation sources. The size of the hospitals and clinics are categorized into three groups for convenient as small, medium and large depending upon the number of facility bed in a particular health center. Health center having more than 50 beds are categorized as large facility. Facilities having 20-50 beds are categorized as medium while facilities having less than 20 beds are categorized as small.

Table 2 Number of Health Care Center covered by the PRISM by their project in Dhaka City

Total number of hospital, clinic and diagnostic centers	Coverage in 2005	Coverage in 2006	Coverage in 2007	Coverage in 2008	Coverage in 2009 up to May 2009
1000 (Approx.)	17	108	219	275	297

Source: PRISM Bangladesh, 2009.

Table 3 Average daily hazardous waste collection and management

Type of waste	2005	2006	2007	2008	2009 till date
Infectious waste	45 Kg	352 Kg	1290Kg	2450Kg	2625 Kg
Sharp waste	2 Kg	29 Kg	66 Kg	95 Kg	107 Kg
Recycle-able waste	6 Kg	42 Kg	105Kg	150 Kg	173 Kg
Other	3Kg	3 Kg	7 Kg	25 Kg	35 Kg

Source: PRISM Bangladesh, 2009.

Table 4 Amount of waste generated in average from different sized health facilities in Khulna City

Size of facilities	Generated Waste (kg/day) (app)	No of Hospital
Small	5-6kg	9
Medium	10-12kg	7
Large	100-200kg	4
Total		***20**

Source: Field survey, 2008;
**The value is excluding four diagnostic centers.*

The figure below shows the proportion of different types of clinical waste generated in the health centers of Khulna city. General wastes are about 79% of the total amount of waste. Among rest 10% percent are infectious wastes, 3% are sharp wastes and 8% are reusable wastes.

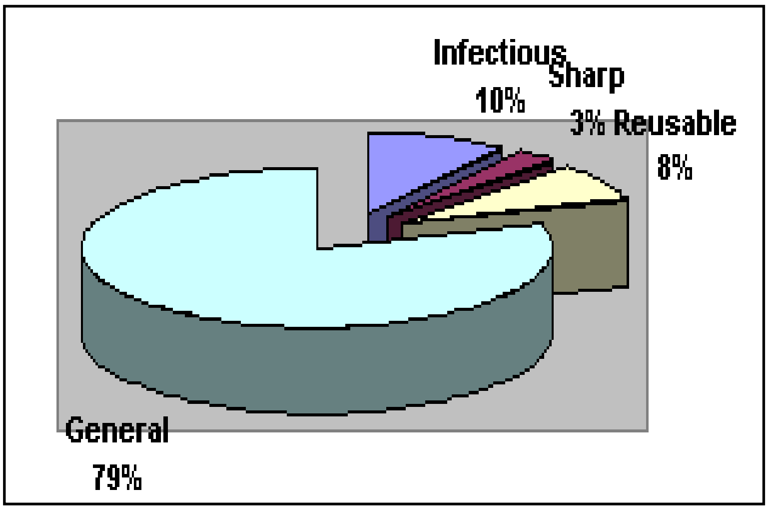

Figure 1 Percentage of different type of clinical wastes generated

Table 5 Waste generation rate per bed per day in different health care center in Khulna City

Type of health center	Rate of waste generation kg/bed/day	Mean
Government hospital	1.5	1.12
Private hospital	0.75	
Diagnostic center	*	
Total	2.25	

Source: *Field survey, 2008; * There are no fixed beds in private diagnostic centers*

Table 5 shows that the waste generation per bed per day is higher in government hospitals (1.55 kg) than the private once (0.75 kg) as in Government hospital number of patients is higher than the number of bed, as in Government hospital huge patients comes every day and huge guests comes also with patients to take care of them. So both the patients and their guests generate wastes everyday**.** Though the waste generation per bed per day does not fluctuate much among different health centers. The average waste generation per bed per day in the studied health care center of Khulna city has been found 1.12 kg. It is a lower than that of Dhaka, which was found 1.16 kg per bed per day (Shehab, 2004). It is 4.5 kg per bed per day in USA, 2.7kg in Netherlands and 2.5 kg in France (Morillon et al. 2002).

Onsite Handling of Hospital Waste in Khulna

Table 5 Frequency of onsite handling (patient's bed to storage place) of waste

HCEs	**Total respondents**		**Once per day**		**Twice per day**		**Irregular**		**Total**
	R	(%)	R	(%)	R	(%)	R	(%)	
Govt. H	65	34.21	12	6.36	35	18.42	18	9.47	34.21
PH	88	46.31	25	13.16	26	13.68	37	19.47	46.31
PDC	37	19.47	7	3.67	10	5.26	20	10.53	19.47
Total	190	100	68	35.57	48	25.02	75	38.91	100

Source: *Field survey, 2008*

HCEs=Health care Establishments, R=Respondents, Govt. =Government, P=Private, H=Hospital, D=Diagnostic, C=Center

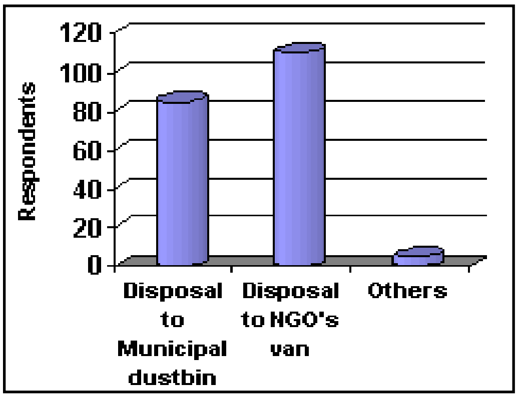

Figure 4 Collection system of medical waste in the study HCEs

In the studied government hospitals, sixty five (34.21%) respondents were reported in measuring on site handling (from patient's bed to temporary storage place) of generated hospital waste. At Government hospitals, the frequency of onsite waste handling was categorized as once per day, twice per day and irregular. The respondents were twelve, thirty five, eighteen and they were 6.36%, 18.42%, 9.47% respectively of the total respondents. At private hospitals the frequency of onsite waste handling was categorized as once per day, twice per day and irregular. The respondents were twenty five, twenty six and thirty seven and they are 46.31%, 13.16% and13.68% respectively of the total respondents. At private diagnostic centers the frequency of onsite waste handling was categorized as once per day, twice per day and irregular, respondents were seven, ten and twenty and they are 3.67%, 5.26% and 10.53% respectively of total respondents.

In the study 85 respondents disposed their waste in municipal dustbin, 110 respondents disposed their waste in NGO's van, and 5 respondents reported as others which were 42.10%, 57.89% and 2.63% respectively of the total respondents. The highest 57.89% respondents reported for NGO's collection System and the lowest 2.63% respondents reported as no isolation.

Private Organization Involved in Medical Waste Management

Prodipon, an NGO is the only private organization involved in clinical waste management in Khulna city. They started their clinical waste management service in May, 2000 with funding from Swiss development cooperation (SDC), UNDP and World Bank. At the same time they started their project with 20 health centers which has now risen up to 169.

Table 6 Health centers served by Prodipon in Khulna

HCEs	Total number	Served	Percentage (%)
Government	7	1	14.28
Private	241	168	69.70
Total	248	169	68.14

Source: *Field survey, 2008.*

Collection and Transportation

Prodipan's plan is to segregate waste at the source of generation. For this their program is to provide each health center with at least a set of four covered drums to dispose four types of wastes separately. The number of set drums may vary with the size of the health Center. But actually it has been found that many health centers have been provided with less than four drums. An auto van of 1.5 ton capacity is used for transportation of clinical waste from the health centers. Normally the collection starts in the morning every day from the same clinic and same time. Generally they start their collection from Khulna sadar Hospital every morning at 6.00 a.m.

Final Disposal Method

Safe disposal is the most important thing in the management of clinical wastes. The methods adopted by Prodipan for safe disposal of the waste are shown in Table 7.

Probability of Spreading Diseases and Environmental Pollution by Medical Wastes

Exposure to hazardous Medical waste can result in spreading diseases or injury. This can be generously proportioned when they are mixed with the large volume of general waste. The hazardous nature of health care waste have the characteristic i.e. contains infectious agents, chemical/pharmaceutical, and sharps and is also genotoxic, radioactive, etc.

All individuals exposed to hazardous medical waste are potentially at risk, those who are the waste generators, handlers and the people of the premises. Even small source of healthcare waste should not be overlooked /neglected. The main groups are the following

- Medical doctors, nurses, auxiliaries and maintenance personnel
- Patients and attendants
- Workers in support services i.e. laundry, waste handling and transportations
- Worker in disposal facilities i.e. landfills, incinerators, treatment plants, scavengers

Table 7 Disposal Method of Clinical Waste Adopted by Prodipan

Serial no	Waste type	Disposal method
1	Gauge, bandage, human organ etc	Burned after washing
2	Needle and all other sharp type material	Disposed in a concrete pit
3	Syringe, vial, ample, saline bags etc	Washed by bleaching powder and crashed in a shredder machine and disposed in a concrete pit
4	General waste(kitchen waste)	Open dumping, composting

Source: Field survey, 2008

Figure 5 concrete pits for disposal of syringes, saline bags and sharps and locally made burning pit.

Infectious waste may contains any of a great variety of pathogenic microorganisms and infection causes in human body by a number of routes e.g. through puncture, abrasion and cut of skins; mucus membranes, inhalation and injection; body fluids, illicit drug use etc. Examples of infections that can be caused by exposure to healthcare waste are listed in the Table 8.

Table 8 Examples of infections that can be caused by exposure to healthcare waste, causative organisms and transmissions vehicles

Type of infection	Examples of causative organisms	Transmission vehicles
Gastroenteric infection	Enterobacteria, e.g. *Salmonella*, *Shigella* spp.; *Vibrio cholerae;* helmenthis	Faeces and/ or vomits
Respiratory infection	*Mycobacterium tuberculosis*; Measles virus; *streptococcus pneuemoniae,*	Inhaled secretions, saliva
Ocular infection	Herpes virus	Eye secretions
Genital Infections	*Neisseria*, *gonorrhoeae*; herpes virus	Genital secretions
Skin infections	*Streptococcus* spp.	Pus
Anthrax	*Bacillus Anthracis*	Skin secretions
Meningitis	*Neisseria Meningitidis*	Cerebrospinal fluid
Acquired Immuno-Deficiency Syndrome (AIDS)	Human Immunodeficiency virus (HIV)	Blood, Sexual secretions
Hemorrhagic Fevers	Junin, Lassa, Ebola, and Marburg viruses	All bloody products and secretions
Septicaemia	*Straphylococcus* spp.	Blood
Bacteremia	Cogulaase-negative *Straphylococcus* spp. *Straphylococcus aureus, Enterobacter, Enterococcus, Klebsiella, and Streptococcus* spp.	Blood
Candidaemia	*Candida albicans*	Blood
Viral Hepatitis A	Hepatitis A virus	Faeces
Viral Hepatitis B, C	Hepatitis B, C viruses	Blood and body fluids

Sources: Safe management of health care wastes by WHO, 2000

Many of the chemicals and pharmaceuticals used in HCEs are hazardous (e.g. toxic, genotoxic, corrosive, flammable, reactive, explosive, shock sensitive etc). Chemicals residues may cause adverse affects on the operation of biological sewerage treatment plant or direct disposal causes toxic effects on natural ecosystem of receiving water. Similar problems may be caused by pharmaceutical residue, which may include antibiotics, drugs, toxic heavy metals, derivatives, disinfectants. Genotoxic and cytotoxic wastes are extremely irritant and harmful to local effects after direct contact with skin and eyes and they may cause sometimes dizziness, nausea, headache, dermatitis etc. Any discharge of genotoxic waste into the environment causes disastrous ecological consequences. The extent of exposure determines the type of diseases cause by radioactive waste. It can be headache, dizziness, vomiting or much more serious problem. The radioactive waste is also genotoxic and may effects genetic materials. Handling of radioactive source may causes serious injuries such as destruction of tissues, decussating, and amputation of the body parts and should therefore be undertaken with the utmost care. Healthcare workers or waste handling or cleaning personnel exposed to the radioactive are at high risk.

Existing Medical Waste Management in Dhaka

MW Source Collection

Safe Transportation of MW

Incineration of MW

Autoclaving of MW

Chemical Disinfection of MW

Sharp MW Disposal

Figure 6 Medical waste collection and treatment facility in Dhaka city

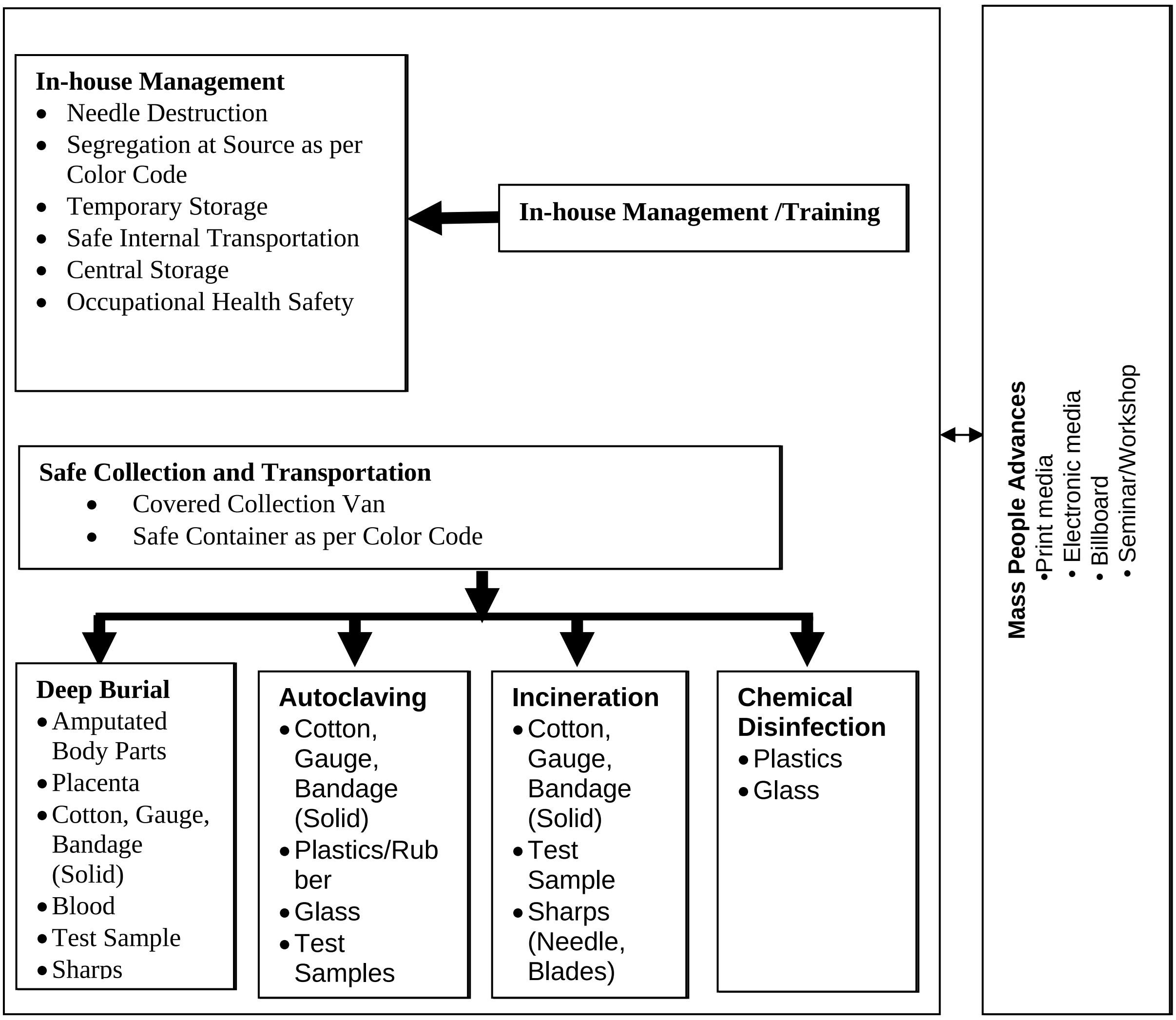

Figure 7 Flow diagram of existing medical waste management in Dhaka

Possible Environmental Consequences of Improper Disposal of Medical Wastes

From survey it was found that, Medical wastes in Khulna city are improperly disposed. This is due to lack of strong management system. Therefore the possible environmental impacts associated with the improper disposal of medical wastes in Khulna city could be the following:

- Pollutants from medical waste (e.g. heavy metals and PCBs) are persistent in the environment
- Accumulation of toxic chemicals within soil (proximity to agricultural fields, humans, soil organisms, wildlife, cattle)
- Ground water contamination, decrease in water quality.
- Bio-accumulation in organism's fat tissues, and biomagnified through the food chain
- Repeated and indiscriminate application of chemicals over a long period of time has serious adverse effects on soil microbial population reducing the rate of decomposition, and generally lowering the soil fertility.
- Pathogens lead to long term accumulation of toxic substances in the soil.
- Causes disease and illness in man, either through direct contact or indirectly by contamination of soil, groundwater, surface water, and air.
- Wind blown dusts from indiscriminately dumping also have the potential to carry hazardous particulates.
- With domestic animals being allowed to graze in open dumps, there is the added risk of reintroducing pathogenic micro-organisms into the food chain.
- Public nuisance e.g. odors, scenic view, block the walkway, aesthetics, etc.

- Improper sterilization of instruments used in labour room may cause infection to mother and child.
- Combination of both degradable and non-degradable waste increase the rate of habitat destruction due to the increasing number of sites necessary for disposal of wastes (degradation of habitat)
- Plastic-bags, plastic containers, if not properly destroyed may contaminate the soil and also reduces the chance for water percolation into the soil during precipitation
- Open air burning does not guarantee proper incineration, and releases toxic fumes (dioxin) into the atmosphere from the burning of plastics i.e., PCB's. (Nasima, 2000).

CONCLUSIONS

Now medical waste management has become a crucial issue around the world. As it is hazardous it is very much harmful for the environment. Recently, the management of medical wastes has received little attention despite their potential environmental hazards and public health risks. Using both the quantitative and qualitative approach, the report has attempted to quantify different medical wastes generated from different HCE, in the study area. The collected field data showed that all the surveyed HCE, generate pathological wastes, used syringes, broken bottles and glass, textile stained with blood and papers. They generate about 1107kg per day of wastes; the average waste generation rate for the surveyed HCE is 0.41 kg/patient/day in Khulna city and around 3000kg of MW in Dhaka city. The study reveals that medical wastes are not properly managed in almost all the HCE, in the study area. Some cleaners were found to be engaged to mishandle the generated wastes. They segregated the used sharps instruments (mainly the syringe-needles), saline bags, blood bags and test tubes from the kitchen and non-hazardous wastes for sale (resale) or reuse. It can be concluded that the existing system of Hospital waste management of studied HCEs is neither satisfactory nor adequate. Human resource development, adequate logistic support and above all political commitment are the basic needs for the development in the sector.

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Evaluating the State of Medical Waste Management System and its Possible Health Hazards in Dhaka City of Bangladesh

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ABSTRACT

The problem of medical waste and other toxic hazardous waste is growing rapidly throughout the world as a direct result of rapid urbanization and population growth. Fast increase of hospitals, clinics, diagnostic laboratories etc in Dhaka city exerts a tremendous impact on human health ecology and environment. The focuses of the study is an evaluating the state of medical waste management system and its possible health hazard in Dhaka city. The field survey of this research work has been done by following simple random sampling. Among the studied health care establishments (HCEs), medical waste generation rate was 2.66 kg/bed/day and 0.961 kg/patient/day. About 12% to 40% waste of the studied HCEs was hazardous. The highest amount (40%) of hazardous waste was generated by Popular Diagnostic Center and the lowest (12%) of hazardous waste from National Mental Health Institute and Hospital. The mean generation rate (gram/patient/day) of recyclable, sharp, infectious, general and chemical and radioactive waste was 39.35, 27.61, 49.84, 464.67 and 14.07 respectively. Among the studied HCEs 33.33% hospital disposed their waste in municipal dustbin and about 60% hospital disposed in NGO's covered bin. About 63.55% respondents reported that the existing collection is systematic and the rest 36.46% reported as non systematic. Dhaka City Corporation has the responsibility for off-site transport of government hospital's medical waste for final disposal or dumping. In the studied private HCEs the hospital waste has been treated by PRISM Bangladesh. In the studied HCEs, 75.65% staffs got training about the hospital waste management and the test did not get. Medical waste management is an integral part of health care, and creating harm through inadequate waste management that reduces the overall benefits of health care. In the studied government HCEs 2.34%, 3.27% and 3.74% respondents were infected by health hazard from sharp, infectious and chemical and radioactive medical wastes respectively. In private hospitals the health hazard problems were comparatively lower (0.935% by infectious waste) because of their sound medical waste management system. The study reveals that hospital wastes are not properly managed in almost all the government HCEs though some private HCEs follow hygienic management system. Most of the HCEs do not have any budgetary provision to manage their generated waste systematically. In order to arrange a proper and systematic medical waste management it is essential to follow specified regulations for collection, segregation, treatment and disposal of medical waste.

INTRODUCTION

Hospital is a service-oriented residential establishment that provides medical care facilities comprising of observational, diagnostic, therapeutic and rehabilitative services for persons suffering from or suspected to be suffering from any kind of disease or injury (Rahman *et al., 1999)*. Now a day's hospital waste is one of the ascension problems in Dhaka City. It has hazardous effect on the environment and its people. Establishment of various health care centers, clinics and hospitals has made this waste management difficult. Some wastes generated in a hospital are too hazardous to be treated negligently, and any carelessness in the management of these wastes in a hospital tends to spread infections and contaminate the entire living environment prevailing in a hospital. The delay in the recovery and overburden of medical waste endanger the patients' survival and may also generate health hazards to personnel working in and around the hospital environment. Although some degree of attention is given on the cleanliness of hospital wards, premises, laboratories, operation theaters, closets etc. and on the supply of safe drinking water in some hospitals/clinics in Dhaka but adequate emphasis is not given in most cases for the proper management of generated wastes and particularly the disposal of hazardous medical wastes. It was observed that the solid clinical wastes are being disposed off in the City Corporation's collection bins in and around the hospital premises. The waste is then collected by the City Corporation's Vehicles and transported to the open municipal dumping sites. For the management of medical waste requires its removal and disposal from the health care establishments as hygienically and economically as possible, by following the methods that all stages minimizes the risk to public health and to the environment.

Generally, medical waste is defined as the discarded or unwanted material or garbage or solid waste which is generated from the diagnosis, treatment, or immunization of human beings or animals, in research pertaining there to, or in the production or testing of biological materials (Lee, 1989). These have the potential to cause disease and are a health risk. It is a by-product of health care that includes sharps, non-sharps, blood, body parts, chemicals, pharmaceuticals, medical devices and radioactive materials (WHO, 2002). Health care establishments are one of the major producers of solid wastes which are hazardous in nature. Poor management of clinical wastes exposes to health workers, waste handlers and the community is the causes of infections, toxic effects and injuries (Ecoaccess, 2004).

OBJECTIVES OF THE STUDY

- To quantify the rate of medical waste generation in the studied Health Care Establishments;
- To investigate the existing management status of medical wastes in the study area; and
- To observe the health hazard associated with the current medical waste management system.

MATERIALS AND METHODS

The methodology for this study includes empirical field observation, site selection and field level data collection through inventory, questionnaire survey and interviews in formal and non-formal ways. The relevant secondary data for this research were mainly collected from the published and unpublished papers, journals etc. The data were analyzed to address the central issues of medical waste management with relation to the generation of wastes, opinions of the respondents from different sources as well as different point of views. In order to fulfill the objectives, the tasks were structured for data collection and data analysis.

RESULT AND DISCUSSION

The findings of the study are presented in three part of this chapter. The first part deals with generation of medical waste in different HCEs. The second part deals with management of hospital waste and the third part deals with the health hazard problem associated with the current medical waste management system.

Inventory of Different Health Care Establishments (HCES*)*

The rate of waste generation in the hospitals depends upon various factors such as the number of beds, types of health services provided, economic, social and cultural status of the patients and the general condition of the area where the hospital is situated (Askarian *et al*., 2004). Total 8670 patients were calculated in the studied HCEs including 2250 beds and 6420 outdoor patients. The study shows the average medical waste generation rate for the surveyed HCEs are 2.66 kg/bed/day and 0.691 kg/patient/day (Table 1).

The results of the study can compare with survey report of prism Bangladesh an NGO that works on medical waste management in Dhaka city. In their survey report the medical waste generation rate was 2.63 kg/bed/day and 0.56 kg/patient/day respectively (Survey report, 2004). This result is more or less similar to the present study. In different studies, the waste generation rate was reported as 2.71 kg/bed/day in hospitals of Tehran (Iran), (Mohammadi Baghaee, 2000) and the waste generation rate in Dares Salaam (Tanzania) hospitals was reported to be between 0.84 and 5.8 kg/bed/day (Mato and Kassenga, 1997). The WHO report regarding the waste generation shows the rate in general and university hospitals, which are 4.2-21.1 and 4.1-8.7 kg/bed/day, respectively (Pruss *et al,* 2004).

Table 1 Inventory of different Health Care Establishments (HCEs)

Name of HCEs	Bed Number	Out patients	Total patients per day	Total waste G. Kg/day	Waste Generation rate	
					Kg/bed/day	Kg/patient/day
NITOR	500	950	1450	1320	2.64	0.91
DSH	450	1252	1702	1127	2.50	0.66
NMHIH	150	75	225	227	1.51	1.01
NIKDU	250	718	968	593	2.37	0.61
Ibn S H	210	512	722	670	3.19	0.93
BMCH	350	845	1195	808	2.31	0.67
S H Ltd	95	250	345	225	2.37	0.65
CH Ltd.	95	214	309	241	2.54	0.78
NNH	70	230	300	211	3.01	0.70
EMCH	50	200	250	182	2.56	0.72
NSK	30	120	150	40	1.31	0.27
DDC	**	150	150	53		0.35
MDC	**	150	150	66		0.44
M DC	**	162	162	45.36		0.28
PDC	**	215	215	66.55		0.31
Total	**2250**	**6420**	**8670**	**5986.82**		
Average					**2.66***	**0.691**

* The value is excluding four diagnostic centers; ** There were no fixed beds in the diagnostic centers. HCEs= Health Care Establishments, NITOR= National Institute of Traumatology and Orthopaedic Hospital for Rehabilitation, DSH= Dhaka Shishu Hospital, NMHIH = National Mental Health Institute and Hospital, NIKDU= National Institute of Kidney Diseases and Urology, Ibn SH= Ibn Sina Hospital, BMCH= Bangladesh Medical Collage Hospital, SH Ltd. = Samarita Hospital Ltd., CH Ltd.= Central Hospital Ltd., NNH= Nibedita Nursing Home, EMCH= Eden Multi Care Hospital, NSK= Nagor Shashtha Kendra(Rayer Bazaar), DDC= Doctor's Diagnostic Center, MDC= Modern Diagnostic Center, MDC = Medinova Diagnostic Center, PDC= Popular Diagnostic Center.

Medical Waste Generation

Medical waste generated from the daily activities of patients, cleaners, sweepers, nurses, doctors, and administrators etc that are discarded as useless. Number of beds and outdoor patients were counted that represent the waste generation sources. This section deals with present situation of generating different types of medical waste from different. Various types of medical wastes are generated from health care establishments are classified as follows:

Non hazardous medical waste

Non hazardous medical waste in health care establishments are general waste that contains kitchen waste, refuse of food materials, fruits materials, vegetables, clothes, papers, packing materials, water bottle etc.

Hazardous medical waste

Hazardous wastes in the health care establishments are

- Infectious waste
- Sharp waste
- Recyclable waste
- Chemical and Radioactive waste

Figure 1 Different types of hospital waste generated in the studied HCEs.

The percentages compositions of hazardous and non hazardous medical wastes are shown by the following table:

Table 2 Comparative analysis of medical waste generation (%) in the studied HCEs

Name of HCEs	Hazardous waste (%)				Non hazardous waste (%)	Total (%)
	Recyclable waste	Sharp Waste	Infectious Waste	Chemical and Radioactive waste	General waste	
NITOR	7	3	14	4	72	100
DSH	6	2	11	1	80	100
NMHIH	6	1	3	2	88	100
NIKDU	7	2	5	4	82	100
Ibn SH	6	5	9	1	79	100
BMCH	6	2	6	1	85	100
SH Ltd.	6	2	7	3	82	100
CH Ltd.	4	2	7	2	85	100
NNH	8	3	9	2	83	100
EMCH	6	4	8	1	77	100
NSK	8	3	9	1	78	100
MDC	10	8	11	3	66	100
DDC	9	7	10	3	70	100
MDC	10	11	13	2	64	100
PDC	12	15	10	3	60	100

Among the studied health care establishments it was found that the Popular Diagnostic Center generated highest percent (40%) of hazardous medical waste and lowest percent (60%) of non hazardous medical waste followed by Medinova Diagnostic Center (36% and 64%), Modern Diagnostic Center (34% and 66%), Doctors Diagnostic Center (30% and 70%), National Institute of Traumatology and Orthopaedic Hospital for Rehabilitation (28% and 72%), Eden Multi Care Hospital (23% and 77%), Nagor Shashtha Kendra (Rayer Bazaar) (22% and 78%), Ibn Sina Hospital (21% and 79%), Dhaka Shishu Hospital (20% and 870%), National Institute of Kidney Diseases and Urology, Samarita Hospital Ltd (18% and 82%), Nibedita Nursing Home (17% and 83%), Bangladesh Medical Collage Hospital, Central Hospital Ltd. (15% and 85%), National Institute of Mental Health and Hospital (12% and 88%).

Medical Waste Management in the Studied Private Hospitals

Onsite medical waste management

The study reveals that the studied private hospital all types of waste was collected in a timely manner from the patient beds. Wastes from the Operation Theatre (OT) and Intensive Care Units (ICU) were collected more often, depending on the number of operations and cases attended in any particular day. For collecting the wastes in most of the studied private hospital except NSK Rayerbazer used color coded bin. For this reason source segregation of private medical waste are well developed. The bins used for wastes disposing are black, green, red, yellow, blue, brown and grey colored. Majority of the management concerned personnel and staff of studied private hospitals were trained on proper management of the waste according to the system. PRISM provided this training by a group of well trained professionals in the surveyed hospital. So the cleaners store the generated medical waste in the color coded bin according to their types. Then the wastes were store in a temporary storage site by the hospital cleaners.

Off-site medical waste management of private hospital

Safe collection and transportation

From the secondary storage the wastes were collected by different private company (Western Organisation, Prism, First Clean, RAKT, Nepcone etc) that are involved in collecting and managing the generated wastes from different HCE. Most of the studied private hospital prism is involved in collecting and managing the generated medical wastes. Waste collecting staff of prism were collected the wastes from every HCEs in due time. The staffs are well trained and provided with all logistics and safety wears for collecting the wastes. The collectors collect wastes from the HCEs premises with mechanized covered vans and individual colour containers for collection of wastes separately and carry the wastes safely from the premises. Necessary instructions and safety measures are strictly maintained during handling and transportation of wastes from HCEs to treatment plant. This NGO itself have a waste treatment plant at Matuail, near Dhaka city that is a one acre plot.

Figure 2 Collection of Medical Waste from HCEs by the collectors

Waste treatment and final disposal

Collected wastes were further resorted before sent to the treatment plant. The treatment processes of wastes according to their types are described below which were observed during the study period:

Table 3 Present disposal scenario of medical waste

Disposal place of Waste	HCES number	Percentage (%).
Disposed to Municipal Dustbin	5	33.33
Disposed to NGO's covered bin	9	60
Others	1	6.67
Total	15	100

Among the studied fifteen health care establishments five (33.33%) dispose their generated waste in the municipal dustbin. All the studied government hospital and a private hospital named Nagor

Shashtha Kendra (Rayer Bazaar) dispose their wastes in the municipal dustbin. Studied six private hospital and three diagnostic center total nine (60%) of the surveyed hospital dispose their generated waste in NGOs covered bin. This percent is comparatively high because most of the private hospitals follow this type of waste disposal. Only one diagnostic center does not follow any fixed procedure for waste disposal.

Table 4 Preferable Disposal place of waste in collection system

Preferable disposal places	**Respondents**	**Percentages**
Municipal open dustbin	37	17.29
NGO's covered bin	155	72.43
Others	22	10.28
Total	214	100

In the studied HCEs thirty seven respondents preferred municipal open dustbin for their waste collection and they are 17.29% of the total respondents, one hundred fifty five respondents preferred NGO’s covered bin for their waste collection and they are 72.53% of the total respondents and twenty two respondent had no appropriate comments and they are 10.28% of the total respondents. Medical waste should normally be collected everyday due to its hazardous nature. Frequencies of medical waste collection in studied HCEs are shown by the following table.

Table 5 Frequency of onsite handling (patient's bed to temporary storage place) of waste

HCEs	Total Respondents	Once per day		Twice per day		Irregular		Total
	R	R	(%)	R	(%)	R	(%)	
Govt. H	58	20	9.35	13	6.07	25	11.68	27.10
PH	100	30	14.02	25	11.68	45	21.03	46.73
PDC	56	18	8.41	16	7.48	22	10.28	26.17
Total	214	68	31.78	54	25.23	92	42.99	100

HCEs = Health Care Establishments, R= Respondents, Govt.=Government, P= Private, H=Hospital, D=Diagnostic, C= Center.

In the studied government hospitals, fifty eight (27.1%) respondents were conducted in measuring the onsite handling (from patient’s bed to temporary storage place) of generated medical waste. At govt. hospitals the frequency of onsite waste handling was categorized as once per day, twice per day and irregular. The respondents were twenty, thirteen and twenty five respectively and they were 9.35%, 6.07% and 11.68% respectively of the total respondents. At private hospitals the frequency of onsite waste handling was categorised as once per day, twice per day and irregular. The respondents were thirty, twenty five and fourty five respectively and they were 14.02%, 11.68% and 21.03% respectively of the total respondents. At private diagnostic centers the frequency of onsite waste handling was categorised as once per day, twice per day and irregular, respondents were eighteen, sixteen and twenty two respectively and they were 8.41%, 7.48% and 10.28% respectively of the total respondents.

Table 6 Frequency of onsite handling (temporary storage place to Municipal dustbin or NGO's van) of waste

Name of HCEs	Total Respondents	Once per day		Twice per day		Irregular		Total
	R	R	(%)	R	(%)	R	(%)	
Govt. H	58	32	14.95	17	7.95	9	4.20	27.10
PH	100	65	30.37	20	9.35	15	7.01	46.73
PD C	56	30	14.02	15	7.01	11	5.14	26.17
Total	214	127	59.34	52	24.31	35	16.35	100

HCEs = Health Care Establishments, R = Respondents, Govt.=Government, P=Private, H=Hospital, D=Diagnostic, C= Center.

In the government hospitals, the frequency of storage place to municipal dustbin was also reported through fifty eight (27.10%) respondents, in where thirty two (14.95%), seventeen (7.95%) and nine (4.20%) respondents reported as once per day, twice per day and irregular respectively. In private hospitals, the frequency of storage place to NGO's van was reported through one hundred (46.73%) respondents, in where sixty five (30.37%), twenty (9.35%) and fifteen (7.01%) respondents reported as once per day, twice per day and irregular respectively. In addition, in private diagnostic centers, the frequency of storage place to NGO's van was reported through fifty six (26.17%) respondents, in where thirty (14.02%), fifteen (7.01%) and eleven (5.14%) respondents reported as once per day, twice per day and irregular respectively.

Table 7 Timing of waste collection from secondary source to final disposal place

Timing of waste collection	Respondents	Percentages
Morning	69	32.24
Noon	95	44.39
Random	50	23.37
Total	214	100

From secondary source to final disposal place in the studied HCEs, sixty nine respondents reported that waste collection was at morning and they were 32.24% of the total respondents, ninety five respondents reported at noon and they were 44.39% of the total respondents and the rest fifty reported for random collection schedule and they were 23.37% of the total respondents.

Table 8 Systematic collection of waste in the HCEs

HCEs	Total Respondents	Systematic Collection		Non- Systematic Collection	
		Respondents	(%)	Respondents	(%)
Govt. H	58	9	4.21	49	22.90
Private H	100	80	37.38	20	9.35
Private DC	56	47	21.96	9	4.21
Total	214	101	63.55	113	36.46

HCEs= Health Care Establishments, Govt. =Government, H=Hospital, D=Diagnostic, C= Center.

In the studied HCEs, out of two hundreds and fourteen respondents fifty eight respondents were from government health care establishments and they were 27.1 % of the total respondents. In the government HCEs, nine respondents reported that the present collection system of waste was systematic and they were 4.21 % of the respondent, forty nine reported that the present collection system of waste was non systematic and they were 22.90 % of the total respondents. In private HCEs, one hundred respondents reported in where eighty respondents reported as systematic waste collection, they were 37.38 % of the total respondents, and twenty respondents reported as non systematic waste collection and they were 9.35 % of the total respondents. In private diagnostic centers, fifty six respondents were conducted in where fourty seven respondents reported as systematic and they were 21.96 % of the total respondents, nine respondents reported as the present collection system is non systematic and they were 4.21 % of the total. In the studied HCEs, 63.55 % respondents reported that the existing collection is systematic and the rest 36.46% reported as non systematic.

Islam *et al.* (1993) reported that most hospitals, clinics, and laboratories did not have any waste-management system in place. All wastes are collected together and are dumped in a common place, such as roadside, hospital surroundings, and dustbin of the Dhaka City Corporation. It was found that used saline bags, x-ray water, syringes, vials slides, empty packets, and bottles were collected and sold. Hospital authorities and cleaners collect the healthcare wastes and sell it to whole-sellers. PRISM Bangladesh, a national NGO was working in the studied private HCEs and there was systematic onsite handling, storage, collection, transportation and ultimate disposal system. Consequently, the over all management of hospital waste was positive.

Training and Awareness about Medical Waste Management

For the proper hospital waste management training and awareness of the concern people is very essential. During the field survey it was found that different level of awareness from different respondents. The management authority of HCEs and doctors got ideas about the medical wastes and its negative impacts. They point out that they are willing to manage the generated waste properly, but lacking of financial support and proper system, they are unable to do it. Nurses got their training on medical waste as a part of their professional training, but due to the lack of system, they are unable to apply their theoretical knowledge they gathered from their training. Some nurses told with little frustration that they are on the brink of forgetting the waste management system. In addition, most of the technicians, cleaners and ward-boys are not aware properly about the medical wastes and its risk issues. The patients were frightened about the infectious diseases and they were highly conscious about the present condition.

Table 9 Training issues for the respondents in HCEs

Types of HCEs	Got training		Did not get training		Total	
	R	(%)	R	(%)	R	(%)
Govt. Hospitals	10	8.70	25	21.74	35	30.43
Private Hospitals	65	56.52	0	0	65	56.52
Private Diagnostic Centers	12	10.43	3	2.61	15	13.04
Total	87	75.65	28	24.35	115	100

HCEs = Health Care Establishments, R= Respondents

In the measurement of getting training of the studied HCEs, 75.65% staffs got training about the hospital waste management and 24.35% staffs did not get training of the total respondents (Figure 4.17). In government hospitals ten respondents commented for getting training and they were 8.70% respondents of the total respondents. On the other hand twenty respondents reported as they did not get training about the hospital waste management and they were 21.74% of the total respondents. In the private hospitals all (sixty five) respondents commented as they got training and they were 56.58% respondents. In the private diagnostic centers twelve respondents got training, three respondents did not get training, and they were 10.43% and 2.61% respectively of the total respondents

Training Methodology

It was also investigated from field survey that almost all the respondents from all the surveyed HCE focused their opinion in favour of training concerning to the waste management. In connection with the training methods, about more than sixty of the respondents (63.55%) showed their interest in video and lecture, followed by video (18.69%), lecture (11.22%), and others (6.54%). In the govt. HCEs out of 27.10% respondent of the total 3.27%, 5.61%, 1.86% and 16.36% respondents opinioned for lecture, video, others and video and lecture respectively for training method. In the private hospitals out of 46.73% respondents of the total 4.21%, 7.94%, 31.76% and 2.80% respondents focused for lecture, video, lecture and video and others respectively for training method. In addition, in private diagnostic centers out 26.17% respondents of the total 3.74%, 5.14%, 15.42% and 1.87% respondent opinioned for lecture, video, lecture and video and others respectively.

Table 10 Respondents' opinion in suitable methodology for proper training in the HCEs

Name of HCEs	Lecture	Video	Lecture and Video	Others	Total
	R	R	R	R	
Govt. H.	7 (3.27%)	12 (5.61%)	35 (16.36%)	4(1.86%)	58 (27.10%)
PH	9(4.21%)	17(7.94%)	68 (31.76%)	6(2.80%)	100 (46.73%)
PDC	8 (3.74%)	11 (5.14%)	33(15.42%)	4 (1.87%)	56 (26.17%)
Grand Total	24(11.22%)	40(18.69%)	136 (63.55%)	14(6.54%)	214 (100%)

HCEs= Health Care Establishments, R= Respondents, Govt.=Government, P= Private, H=Hospital, D=Diagnostic, C= Center.

The voices of the respondents were mainly confined to the in-house waste collection procedure, segregation, incineration and safety dumping. Moreover, some respondents urged for reinforcement and imposing waste related laws.

Opinion about Existing Medical Waste Management

One hundred and four respondents stated as satisfactory of existing hospital waste management and they were 48.60% of the total respondents. In where eight, sixty five and thirty one respondents that recommended as satisfactory the existing management system were govt. HCEs, private HCEs and private diagnostic center respectively and they were 3.74%, 30.37% and 14.49% respectively. One hundred and ten respondents stated as unsatisfactory of existing hospital waste management and they were 51.40% of the total respondents. In where fifty, thirty five and twenty five respondents that stated as unsatisfactory the existing management system were govt. HCEs, private HCEs and private diagnostic center respectively and they were 23.36%, 16.35% and 11.68% respectively

Table11 Satisfaction rate of Existing waste management of HCEs

Name of HCEs	Number of Respondents	Satisfactory		Unsatisfactory	
	R	R	(%)	R	(%)
Govt. H	58	8	3.74	50	23.36
Private H	100	65	30.37	35	16.35
Private DC	56	31	14.49	25	11.68
Total	214	104	48.60	110	51.40

HCEs= Health Care Establishments, R= Respondents, Govt. =Government, H=Hospital, D=Diagnostic, C= Center.

The rate of unsatisfactory (51.40%) is more than satisfactory (48.60%). Both rates are approximately equal for sound management of private hospital waste. Comments of unsatisfactory came on the basis of various problems. The problems that faced by the patients, cleaners, nurses, technicians, doctors as well as administrative authority are: No environment friendly dustbin for waste disposal, no separate dustbin for separate medical waste collection, dustbin is not in a suitable location, waste collection system is unhygienic, irregular collection system, hazardous waste are spreading here and there due to lack of onsite treatment facility etc. These types of problems were mainly faced in the studied government hospital.

UNEP (1997) conducted another study at the Dhaka Medical College Hospital in 1995 and reported that there was also a lack of awareness on the consequences of unhygienic disposal of the hospital waste and absence of training facilities for the concerned staff. Besides, there was a shortage of supply of equipment and materials required for the disposal of hospital wastes. Most of the respondents showed their negative opinion in the present hospital waste management systems. Only a very few respondents mentioned the good in-house management of the waste segregation. It is noted here that private HCEs (as mentioned earlier) segregate the infectious waste for treatment and disposal. Govt. HCEs had no treatment facility. They mentioned that infectious waste could cause HIV/AIDS and Hepatitis. Moreover, they are presently facing stink and afraid of contaminating diseases from the infectious waste. They also mentioned here some probable steps that could overcome the problems:

- Use of apron, musk and gloves during handling the patients and segregating and disposal of waste;
- Use of WHO guided color-coded bins for segregated wastes;
- Training for awareness could be of great help concerning to this issue;
- Formulating, amendment, and imposing the relevant laws could prevent the improper management of clinical wastes.

Potential Health Hazards (Risks) Associated With Medical Waste

All individual exposed to medical waste are potentially at risk, including those within health-care establishments that generate hazardous waste and those outside these sources who either handle such waste or are exposed to it as a consequence of careless management. The main groups at risk are the following:

- Medical doctors, nurses, health-care auxiliaries and hospital maintenance personnel
- Patients in health-care establishments or receiving home care
- Visitors to health-care establishments
- Workers in support services allied to health care establishments such as laundries, waste handling and transportation
- Workers in waste disposal facilities (such as landfills or incinerators), including scavengers

Among the 58 respondents of government hospital 5 respondents are injured by sharp waste and they are 2.34%. In private diagnostic center 3 respondents are injured and they are 1.40% most of their injuries are hands cut by broken glass, legs damaged from needle injuries. In private hospital this type of injuries were not observed because of their systematic onsite handling, storage, collection, transportation and ultimate disposal system. Consequently, the over all management of hospital waste was positive.

Infectious Medical Waste Risk

Infectious hospital waste represents only a small part of total medical waste; yet, because of ethical questions and infection risks, it is a focal point of public interest. Infectious waste contains different kind of pathogens (bacteria, virus, parasites, fungus etc) or organisms that is potential for infection or disease if it is not properly disposed.

Table 12 Health hazard by the infectious medical waste

HCEs	Total respondents	Injured by infectious medical waste	
		Number of respondents	(%)
Govt. H	58	7	3.27
Private H	100	2	.935
Private DC	56	2	.935
Total	214	11	4.06

Among the 58 respondents of government hospital7 respondents are injured by infectious waste and they are 3.27%. In private hospital and diagnostic center 2 respondents are injured and they are .395% most of their injuries are various hepatitis.

Infected hospital waste can transmit diseases, especially if it finds portals of entry. “There is strong epidemiological evidence from Canada, Japan and the USA, that the main concern of infectious hospital waste is the transmission of HIV/ AIDS virus and more often of Hepatitis B or C virus (HBV) through injuries caused by syringes contaminated by human blood.” Other than these, there is potential risk of TB/ Throat infection, Typhoid, Dysentery, Diarrhoea, Bacterial/ Viral diseases, ARV (Rabies), VDRL (Sexually transmitted disease), UTI/ all C/S, and Leprosy etc. as the pathological laboratories do all these analysis to diagnose the diseases (Akter *et. al.,* 1998).

Hazardous Medical Waste Risk

This class of medical waste, while largely ignored, poses risk to workers handling them. Hazardous medical waste consists primarily of chemicals and discarded cytotoxin drugs.The pathological laboratories of medical center examine blood, stool, urine, and sputum. The chemicals used for the staining and preservation of slides and for the sterilization and cleaning of equipment and surroundings are potentially harmful to the laboratory technician and the environment. Most of the chemicals are poured down the sink and drain out next to the clinic. Children, adults, and animals all have the potential to come into contact with these chemicals. Xylene, phenol, methylene blue, hydrochloric acid, chlorine and carbol fuchsin are all used, and some can have very damaging effects (Akter et al. 1998).

Table 13 Health hazard by the chemical and radioactive medical waste

HCEs	Total respondents	Injured by infectious medical waste	
		Number of respondents	(%)
Govt. H	58	8	3.74
Private H	100	0	0
Private DC	56	5	2.34
Total	214	13	6.08

Other than these, a large number of chemicals also used in different diagnosis and treatment (e.g. chemotherapy). Some common hazardous chemicals, some of which are probable carcinogens or pose other health risks and effects.

Among the 58 respondents of government hospital 8 respondents are injured by chemical and radioactive waste and they are 3.74%. In private diagnostic center 5 respondents are injured and they are 2.34% of total respondent.

The main health risks of medical wastes are summarized below (modified from WHO, 1999).

- Contamination of drinking water. Possibility of leachate entering an aquifer, surface water or drinking water system.
- Non-biodegradable antibiotics, antineoplastics and disinfectants disposed of into the sewage system may kill bacteria necessary for the treatment of sewage.
- Antineoplastics flushed into watercourses may damage aquatic life or contaminate drinking water.
- Burning of waste at low temperatures or in open container results in release of toxic pollutants (e.g. dioxin) into the air.
- Carcinogenic waste such as heavy metals, chemical solvents and preservatives pose serious human health risks not only to workers but to the general public as well.
- Inefficient and insecure sorting and disposal may allow drugs beyond their expiry date
- Unprotected and insecure landfill may pose health hazard to the scavengers and inhabitants at the vicinity.

CONCLUSIONS

The collection, storage, transport, treatment and disposal of medical wastes are of growing environmental problem in Bangladesh, which needs immediate attention before it goes out of hand. In the studied government HCEs medical wastes are not properly managed. Most of the HCEs do not have any budgetary provision to manage their generated waste systematically. Highest amount (40%) of hazardous was generated from PDC and the lowest amount (12%) from NMHIH. In the studied HCEs, medical waste generation rate was 2.66 kg/bed/day and 0.961 kg/patient/day. About 31.78%, 25.02%, 42.99% of the total respondents informed for the transformation of medical waste from patient's bed to temporary storage place in once per day, twice per day and irregular respectively. Among the studied HCEs 33.33% mostly public HCEs disposed their waste in municipal dustbin and about 60% mostly private HCEs disposed in NGO's covered bin. About 63.55% respondents reported that the existing collection system of medical waste is systematic. The DCC has the responsibility for off-site transport of medical waste from government hospital's for final disposal or dumping. Medical wastes of these hospitals are disposed at Gabtoli, Mirpur dumping site. In the studied private HCEs the hospital waste has been treated and PRISM Bangladesh is working there. In the studied HCEs, 75.65% staffs got training about the medical waste management and 24.35% staffs did not get training of the total respondents. The rate of unsatisfactory (51.40%) is more than satisfactory (48.60%) for the existing medical waste management. Both rates are approximately equal for sound management of private HCEs medical waste management. Medical waste management is an integral part of health care. Because of the communicable diseases such as the AIDS/HIV and hepatitis B and C viruses, people are increasingly concerned over the disposal of medical waste. About 2.34%, 3.27%, 3.74% respondents were infected by health hazard from sharp, infectious and chemical and radioactive medical waste respectively in the studied government hospitals. In private diagnostic center 1.40%, 0.935%, 2.34% respondents were injured by sharp, infectious, chemical and radioactive medical waste. In the studied private hospital health hazard problems were comparatively lower (0.935% by infectious waste) because of their sound medical waste management system. Moreover, some respondents were facing stink and afraid of contaminating diseases from the infectious waste. It can be concluded that the existing system of medical waste management of the studied HCEs is neither satisfactory nor adequate. Insufficient vehicle, lack of manpower, technology and complex maintenance procedures obstruct systematic medical waste management.

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A Participatory Approach for Successful Clinical Waste Management in Khulna City

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ABSTRACT

The metropolitan cities in Bangladesh are presently facing massive challenge in managing the increasing amount of solid wastes especially the wastes generated from hospitals and clinics. In general, clinical wastes are collected and managed through the community bins along with domestic waste collection system. A specialized system has not been developed due to the technical and administrative deficiencies. On the other hand, most of the owners of clinics and pathologies are found to be reluctant in disposing their waste without any special care as it requires additional care, workers and money. In Khulna city, Prodipan (a local NGO) has developed a participatory clinical waste management service, which is being implanted successfully. Prodipan started the service with 20 clinics and pathologies out of 80 private clinics and pathologies in the city having successful dialogues with the related authorities. The organization developed the process with the consultation of various stakeholders who agreed to be a regular part of the project. Now, 68 clinics, pathologies along with 3 hospitals are covered with this service. The process includes three stages: separation at source, collection and transportation and systematic treatment and disposal of wastes. After collecting the clinical waste properly, Prodipan managed a sanitary disposal for safe and sustainable environment. This paper is a modest effort to explore the clinical waste management system taken by Prodipan in Khulna city. It also investigates the mechanisms that can be followed for successful clinical waste management in other cities of Bangladesh.

BACKGROUND

Infectious wastes have the potential of transmitting infectious agents to humans. Unintentional injuries may occur when the community is exposed to inadequately disposed waste (Turnberg 1996). According to WHO (2000), as a result of the re-use of non-sterilized syringes, 8-16 million hepatitis B, 2.3 to 4.7 million hepatitis C and80000 to 160000 HIV infections are estimated to occur every year. Many of these infections could be avoided if syringes were disposed of safely.

In many low-income countries, healthcare waste rarely receives special attention; rather, it is handled as part of the municipal waste stream. However, awareness of the potential and actual problems of handling and disposal of healthcare waste is now increasing. Whilst it is thought that poor management of healthcare wastes presents a higher risk to health than poor management of municipal waste, there is little guidance available on the actual extent of the risks involved (Monreal, 1991).

Due to expansion of medical facilities in the Khulna city, many hospitals and clinics are being established. But the environmentalists are becoming very much alarmed at such rapid growth of hospitals because of the hazards that lie behind the establishment of these facilities. Waste products from these clinics are not treated or destroyed properly, rather thrown into the dustbins thereby creating health hazards. These waste products mix with solid wastes from different households and are polluting the air, earth and water. Besides that viruses like sudomonus, staphylococcus, streptococcus, ecolyentercococus etc. are produced from these wastes products. Infections result from these viruses including infection of the liver, stomach, breathing infection, infection of the reproductive organs, meningitis, AIDS, STD, heamorrtetanus, diarrhea, tuberculosis, various skin diseases, etc.

The Existing Situation

Concerns are growing about clinical waste management globally including in the developing countries like Bangladesh to prevent the possible health hazards as well as the degradation of the environment. With recent rapid growth of private health sector, the need for safe and proper disposal of medical or clinical waste has become important not only for metropolis like Dhaka but also for other bigger cities in Bangladesh. Because, in many cases in these cities most of the hospitals and clinics both in government and private sector have either non-existent or out dated clinical waste management system. Khulna metropolis is one of the worst affected (by improper clinical waste management) cities.

Khulna is the third largest city of Bangladesh. The rate of urbanization is quite high in Khulna district where 50.1% of the population live in urban areas ranking third highest in the country. Khulna SMA is experiencing high rate of increase of population in the last few decades mainly due to in migration. In 1961, the population of Khulna City was only 1,27,970, but in 1974 it increased to 4,37,302, in 1981 it was 6,46,359 and in 1991 it went up to 10,01,825. It is estimated that the present population of Khulna city is about 1.3 million which has an area of about 45.65 square kilometers.

To meet the demand of this large and increasing population, a good number of health facilities have developed in Khulna. The nearby small districts also depend on Khulna for better treatment facilities. This regional importance has also initiated the growth of health sector in Khulna. Besides, couple of large government hospitals, many private clinics, some NGOs and KCC is providing health care facilities in Khulna. There are about 248 health centers in Khulna and the number is growing fast (Khandaker, 1999). According to a report in the daily "Prabartan" on the 11th November 2002, there are about 150 clinics and diagnostic centers in Khulna. These are mainly located within or around the central city area. Only 15% of them are concentrated in Khalishpur area, 5%in Daulatpur and 7% in Fulbarigate area; the rest are located in the "Sadar Thana".

Location of the Hospitals in Respect of Khulna City

In Khulna City the hospitals and clinics are increasing rapidly to cope with the demand of the people. As the hospitals growing rapidly there need to give attention of hospital's locational characteristics.

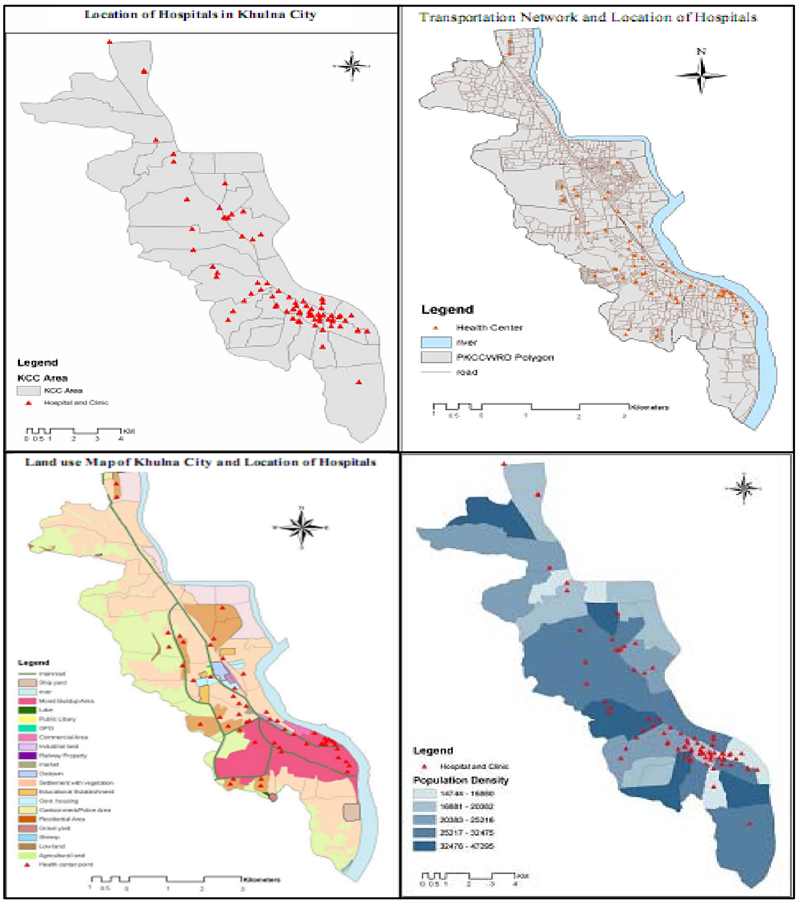

Figure 1 Location of the Hospitals

But the authority of the hospitals do not concern about the locational pattern of the hospitals and build up hospitals where they can. In Khulna City the location and site characteristics of hospitals were observed that, most of the hospitals in Khulna City are located close to the main transport routes and located in the residential area in the city, some are located in the mixed used area, the three main services that are electricity/ telecommunications, public transport, water and sewerage are available in the hospitals in Khulna City.

These maps shows that most of the hospitals in Khulna City are clustered in an area and nearly all the areas are residential area. The level of accessibility of the hospitals and clinics are very good as they located beside the main and important roads. The hospitals often discharge toxic materials in the road side or other open space which are seriously harmful for the residents. Clinical wastes are easily mixed with the other kitchen waste. Nearly all the hospitals are situated in the less density populated areas. There are a few numbers of hospitals which are located medium populated areas. The hospitals are very close in distance. They are gathered in some particular areas. So the distributions of health facilities are not equal in the city area.

RISK OF HEALTH HAZARDS BY CLINICAL WASTE

It was observed that existing hospital waste collection, handling and disposal practices of all the hospitals involved transport of wastes by ward boys, maid nurses and other employees from the point of generation to initial storage points in each unit. Waste normally collected from small bowl or plastic bin, provided for each bed in a hospital or clinic and put them either in a large size bucket. These wastes from buckets are then put in a pushcart or directly carried to the nearest municipal bins for dumping. While some hospitals takes the service of Prodipan. The municipal bins are normally placed either in hospital premises or outside the hospital. Wastes from Operation Theater, laboratory and hospital kitchen are also dumped into municipal bins. KCC trucks carry them to the landfill area for final dumping.

Absence of Protective Materials in Handling Clinical Waste

In most of the hospitals and clinics of Khulna city, nobody use protective gear in handling clinical waste. Sweepers collect and dispose wastes with bare hand and foot. K.C.C and Prodipan only provide plastic shoes, shovels and spades to the waste pickers. About in 35% hospitals and clinics use protective gear. The practice of using protective materials by the waste handlers in the hospitals and clinics are very poor. Only 3% use glove and apron, 25% use gloves and 60% are not use any protective materials (Mukta, 2008).

Risk of Health Hazards for Collection and Disposal of Waste

Preliminary disposal of waste is the first step in the waste management procedure. The disposal pot is usually kept beside the bed of the patient. All types of waste are collected from wards, cabins and O.T. with bowl, basket or bucket. Waste are collected together not separating them and kept to a central dustbin. Then this waste is taken by NGOs or City Corporation or thrown to nearby roadside dumping sites or dustbins. Very few of the clinics or hospitals burn or bury the waste themselves. A large number of needles and syringes are used in hospitals and clinics. None of them destroy these needles before throwing them into the municipal dustbins. Some of the hospital and clinics sell needles and syringes themselves. About 90% of them dispose the syringes and needles in the nearby dustbins together with other waste and 10% of them sell it to some parties together with other recyclable materials, which have a chance to be reselling. Every small and medium scale hospital or clinics dispose about 30-40 needles and syringes everyday in an average in Khulna City (Mukta, 2008).

Segregation of waste is compulsory for proper management of waste. The segregation work classified into five categories. No segregation (one pot), needle/syringes segregated (two pots), syringes and saline bags segregated (two pots), infectious and general wastes segregated (three pots), four types of waste segregated (four pots). Waste generated from about 63% of the beds in public hospitals is either not segregated or practices very limited segregation, 37% beds of the public hospitals are segregated their waste in three pots, no beds in public hospitals are segregated their waste in fore pots. But in case of 31% beds of the private hospitals, all four types of wastes are segregated.

In case of waste collection 85% hospitals use open bucket or bowl for transportation of waste. Only 10% hospitals carry the waste in covered containers, 5% hospitals use open wheel cart. On-site transportation is carrying of waste from the point of origin to the place, where the waste is stored before final disposal.

More that 50% hospitals store their waste in a covered drum before final disposal. Prodipan has supplied covered drums to the hospitals. The waste collector of Prodipan collects the waste from the drum each day. About 20% hospitals and clinics do not have any practice of storing the waste; they directly dispose the waste in the bins, drains or rivers from the initial disposal pots like bowls and buckets. 10% hospitals store their waste in large open buckets and 10% throws the waste in the burning chamber and it remains there until it is burnt. Only 10% hospitals do a better practice stores the waste in a room. Among them about 74% of the hospitals dispose their hazardous waste once a day, 16% dispose their hazardous waste twice a day, 5% stored their waste in a room without any treatment and another 5% directly stored in burning pit.

Risk of Health Hazards for Final Disposal of Wastes

In Khulna city there are 57% of the infectious wastes and 42% of the sharps finally disposes in the city corporation bins with other wastes. It clearly reflects the worseness of the condition. About 31% of the infectious waste and 39% of the sharps are handled by the NGO- Prodipan. Some hospitals have their own burning pits. 12% of the infectious wastes and 19% of the sharps are burn such pits. But the situation is worse in case of syringes and saline bags as almost 84% of them are taken by the ward boy or ayas for selling or sold by the authority itself. Only 13% of the disposed syringes and saline bags are managed by Prodipan. 3% goes to city corporation bin and own burning pits. It shows that the people are in great health risk as the reuse of the used syringes can spread various infectious and vector borne diseases.

Lack of Trained Manpower

Trained manpower is essential for the proper management of waste. The stuffs involved in waste management should have knowledge and skill required for the proper management of hazardous waste. In Khulna 79% do not have any trained stuff for clinical waste management. Only 21%hospitals have trained manpower for waste management, who ware trained by Prodipan (Mukta, 2008).

PARTICIPATORY APPROACH TO CLINICAL WASTE MANAGEMENT SYSTEM IN KHULNA CITY

In Bangladesh the authorities responsible to manage this hazardous waste cannot perform their job efficiently for lot of limitations. Generally the hospital wastes are being managed with the domestic waste. It is disposed in the open community bin along with the normal waste. It is commonly scavenged by the boys/girls without any precaution, which might cause health hazard and infectious disease for the poor. Doctors, nurses and cleaners in the health institutions can also be affected from hazardous waste. Prodipan an NGO took a noble initiative to start a clinical waste management service in Khulna city, situated in the southern part of Bangladesh. Prodipan felt it when it was developing a community based solid waste management in the city. Prodipan initiate to run this approach with the participation different stakeholders from administration to local community. This approach was initiated with different stakeholders related with the service, Khulna City Corporation, Bangladesh Medical Association, Clinic/Pathology Owners Association and all the owners of clinic and pathologies. With the participatory appraisal, project organized a number of meetings, round table discussion and workshops to motivate the authority to bring them under CWMS. At one stage the owners were convinced and put the recommendations to initiate the service. But again when question came of financial contribution, the majority owners of clinic and pathologies said no to the service. Various initiatives took place to convince them. Finally City Mayor took the initiative to call every body in a meeting and urged them to participate in the service for the betterment of the city dwellers. The different stakeholders who are involved with this approach in Khulna city are: public Organizations (KCC), private Organizations (NGOs), and government Hospitals, private clinics, pathologies and manpower. The effectual involvement of public and private organizations helps this appraisal to be more effective and consecutive for betterment of Khulna city.

Public Organization Involved in Clinical Waste Management

Khulna City Corporation (KCC) is the public body for the management of wastes in Khulna city. KCC does not have any special arrangement for the collection and disposal of clinical wastes as they are not obliged to do according to their ordinance.

Collection, Transportation and Disposal

KCC collects the clinical wastes in the same vehicle with other wastes from the public dustbins twice a day. KCC has 19 trucks and about 200 wheel carts for the collection of wastes. After collection, the clinical wastes are dumped together with other wastes. Though KCC has 18 trucks but at a time highest 16 trucks go for waste collection. The trucks collect wastes only from primary dustbins. The wheel carts are used to bring wastes from the secondary dustbins to the primary dustbins (Mukta, 2008).

Dumping Site

KCC dumps its waste in the dumping ground near Rajbandh, about eight kilometers south of Khulna city. KCC also dumps their waste for land filling purpose at different locations of the city. It increases the risk of health hazard of the local community. The following flow chart shows the disposal method of waste by KCC.

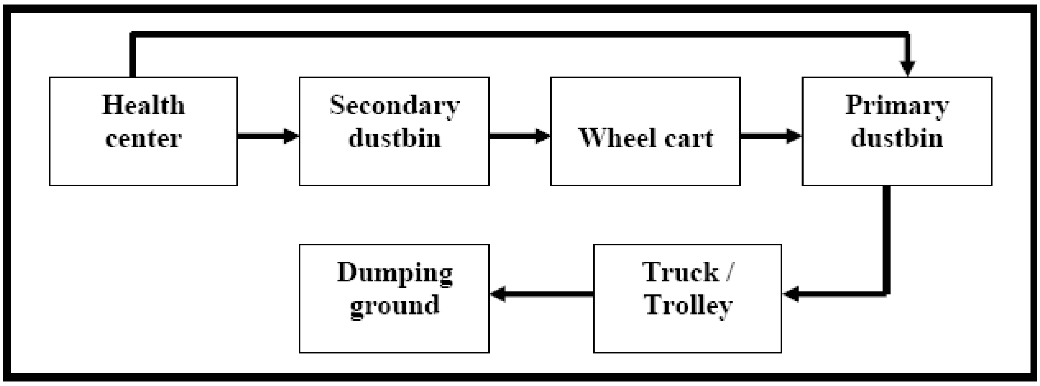

Figure 2 Diaposal Method by KCC

Technical Capability

As the governing body of Khulna city, KCC has some distinctive strength in its side. KCC has a strong institutional setup to run any project efficiently. It has more acceptances to the people than any private organization; which is very important for successful running of any project. As a public organization, KCC has the legal arrangements for waste management that also enables them to collect service charges for such services.

Weakness of KCC

KCC collects the clinical waste together with other solid waste which is extremely harmful for the people of the local community as well as for the environment. Lack of manpower specially trained manpower is a vital problem for KCC. The conservancy department of KCC identifies the lack of resources as the main reason for not having any arrangement to handle the clinical wastes separately. No research is conducted by KCC; neither there is any such research facility to identify the extent of different problems and to provide guidelines to mitigate that.

PRIVATE ORGANIZATION INVOLVED IN CLINICAL WASTE MANAGEMENT

Prodipan an NGO took a noble initiative to start a clinical waste management service in Khulna city. Prodipan felt it when it was developing a community based solid waste management in the city. They started their project with 20 health centers which has now risen up to 68. Only 35% hospital or clinic or diagnostic centre of Khulna are served by Pradipan and other 65% hospital or clinic or diagnostic centers are not served by Pradipan (Mukta, 2008).

Collection and Transportation

To segregate waste at the source of generation, Prodipan provides each hospital with at least a set of four covered drums to dispose four types of waste separately. The four drums are marked with four different colors for easy identification. The number of set of drums may vary with the size of the hospital. But actually it has been found that many hospitals have been provided with less than four drums. An auto van of 1.5 ton capacity is used for transportation of clinical waste from the health centers.

Final Disposal Method

Safe disposal is the most important thing in the management of clinical wastes. The methods adopted by Prodipan for safe disposal of the waste is as follows-

Prodipan has developed a simple burning chamber to burn the gauge, bandages, human organs etc. The reminders are disposed of by open dumping. Needle and all other sharp type materials are disposed in a concrete pit to check them from spreading germs. The syringes and saline bags are sliced in small pieces and then dumped in another concrete pit.

Table 1 Disposal Method of Clinical Waste Adopted by Prodipan

Serial no.	Waste type	Disposal method
1	Gauge, bandage, human organ etc	Burned after washing
2	Needle and all other sharp type material	Disposed in a concrete pit
3	Syringe, vial, ample, saline bags etc.	Crashed in a shredder machine and disposed in a concrete pit
4	Kitchen waste	Open dumping, composting

(Source: Prodipan, 2007)

Dumping Site

Khulna City Corporation has allocated a piece of land in their final disposal sight (Rajbandh) to dispose the clinical waste properly. There is concrete blocked box to dispose the needle and sharps. There is also a locally made incinerator to burn the infectious waste.

Technical Capability

Prodipan supplied covered drums marked with four colors to dispose four types of waste in separate drums to ensure segregation of waste at the source. The auto van used for the collection of waste has been specially modified to carry the four types of waste separately. The van has four blocks to carry the four types of waste. Prodipan has made incinerator to burn the infectious waste by manual batch loading system. The ashes are removed regularly. Two concrete blocked boxes have been made at the disposal site. The smaller one is used to dispose the needles and sharps and another one to dispose saline bags, syringes and other reusable plastic materials after crashing in the shredder machine. Prodipan has skilled manpower particularly for clinical waste management.
Prodipan took certain steps to make the service effective.
A) **Training for the clinical staffs**: Prodipan have organized a number of training for the Clinical staff like, nurses, cleaners and management staff. It is very hard to make the service effective without having skilled staff. Clinic and pathology authority expressed their satisfaction about this programme.
B) **New enrollment in the service**: In the year of 2000 Prodipan started with 20 clinics and at this stage of the project Prodipan running with 68 clinics and pathologies.
C) **Approach to government hospital**: Government hospitals are generating a huge quantity of waste. They have a lot of formalities to enroll them with the service, like permission from concerned directorate and arranging fund to contribute for the service. So they were convinced to start the service with their hospitals. Even Prodipan provided training to the doctors, nurses and cleaners about how to maintain a healthy HWM.

Weakness of the Prodipan

The burning pit used by Prodipan produce comparatively low temperature. It may in some cases cause unfinished burning and in case of presence of any type of plastic material in the waste, it may harmful as it helps in producing dioxin gas which pollutes the ecological environment in the ozone layer and helps in spread of cancer in human body. Prodipan disposes the needles and all other sharp material in a concrete pit. This can be feasible at small scale; but in case of whole city, where yearly generation of sharp type waste is about 24 Metric tons, the waste volume reduction is necessary. Prodipan practices the same procedure for the syringes and saline bags. But as they are generated in a huge amount (52 Metric tons / year in Khulna city) and can neither be burned in normal burners nor disposed on the ground, they are need alternative way of disposal. The present clinical waste management system of Prodipan is not a cost effective one.

Success and Weakness of this Appraisal

A great success of this system is massive awareness among city authority and other concern stakeholders had arisen about clinical waste management system. The only reason behind this success was that it was a participatory appraisal. All the stakeholders became conscious about this appraisal because ownership among them was grown-up. This system became affordable because it consider economical capacity of all stakeholders and adopt low technology. But the concern of govt. authority is very poor than private organization. Government doesn't enforced peoples to be aware about the clinical waste till now. Large portions of total concern stakeholder are still not conscious. Higher technology cannot be adopted in this system because of the consideration for economical affordability of the stakeholders. A NGO or a private organization cannot maintain the whole system without the assistances of govt.

Learning from This Approach

- To make a program successful, it should be participatory
- There should be good coordination between city authority and the concerned stakeholders
- Service must be regular and qualitative to ensure the participation of the beneficiaries.
- They must contribute financially which will develop the ownership among them.
- In case of underdeveloped country, the program like hospital waste management should initiate with low technology
- The program should start with small area and subsequently replicate in the other area.
- It is very important to impose the strict law from the concerned authority to participate with the process.
- A massive awareness movement should continue.
- Different treatment options should initiate gradually.

CONCLUSIONS

About 107 metric tons of hazardous waste is yearly generated by hospitals, clinics and diagnostic centers of Khulna city. If not managed properly, the patients and personnel involved in hospitals, scavengers and the people around the hospitals will face a severe risk of silent epidemics of infectious diseases like viral hepatitis, typhoid, gangrene, AIDS etc. Therefore, proper attention is required for the segregation, collection, transportation and final disposal of waste.

Identification of the hazardous and infectious waste and their segregation from the general waste is necessary at the source of generation. The collection and transportation system should be safe. Hygienic and cost effective measures have to be taken for the final disposal and treatment of the hazardous waste. Incineration can be the most appropriate method for Khulna city considering its performance and cost effectiveness. Both private and public sector will have to take initiative to mitigate this emerging problem.

Primary segregation of hazardous waste is mandatory. Separation at the point of generation and safe handling should be practiced to combat occupational health hazards. Then it may be wise to allow private sector to set up a plant for safe disposal and collection of clinical wastes. GOB or DoE should monitor such activities. Contextually appropriate treatment facilities are urgently required for the disposal of clinical waste. There should be a general consensus among the owners of the private clinics and administrators of the government hospitals to follow some code of conduct regarding disposal of clinical waste.

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Field Study on the Composition and Management of Solid Wastes Generated at the Health Care Facilities in Khulna City

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ABSTRACT

This paper describes the management of hospital/clinical wastes at Khulna city, southwestern part of Bangladesh. In Khulna city some government hospital possessing onsite collection and disposal system, but due to less practice it becomes inoperative. An initiative was taken by a local NGO named Prodipan in cooperation of Khulna City Corporation (KCC) by collecting solid wastes generated in healthcare facilities. For health care centers without the assistance of Prodipan, still there is no stable process to store hospital wastes separately. In the existing management system run by Prodipan, hazardous hospital waste is treated through burning at low temperature by locally fabricated burning units without following required standards. For recycling, some selected items of hospital wastes are sorted, cleaned in a tank filled with chlorinated water, then shredded which raised the question of the level of disinfection and sterilization. This paper also discusses a possible management guideline which is economically feasible to protect environment and to ensure sustainability of the adopted system.

INTRODUCTION

Presently hospital/clinical wastes are one of the ascension problems in Bangladesh. Establishment of various healthcare facilities such as pathological laboratories, clinics and hospitals results the generation of hazardous wastes in a high rate along with Municipal Solid Waste (MSW) and make the waste management difficult. In Bangladesh solid waste management system remains at the primitive stage despite the huge demand from the concerned stakeholders to address this social and environmental issues properly. In the absence of safe and sustainable management of solid wastes, hazardous portion of wastes generated in the health care facilities, in general, have also been disposed off in the secondary points i.e. on-site storage in and around hospital premises. The waste is then collected and transported to the ultimate disposal sites of MSW. There are no specific measures or procedures prescribed in the existing Act and Rules of Bangladesh to address the issues of wastes generated in the country's healthcare facilities.

Waste is a change of form of a particular item from one shape to another. It is useful to the first user but with its transformation after use some of the items may be useful to subsequent users. If subsequent utilization is harmful, it should be removed with such precautionary measure keeping it out of reach for others. But, the trouble with throwaway society, like the least developed countries, is that there is no such place as "away". It is obvious that the thrown away is liable to come back as a consequence of such fashion. Hospital waste is responsible for serious health hazards. Hospital waste means any waste generated in the diagnosis, treatment or immunization of human beings or animals, in research pertaining in the biological test. Though the persons involved in scavenging and housekeeping are handling this aspect, the existing status of biomedical waste management cannot be said satisfactory because they are poorly educated and operating without proper and adequate guidance and supervision.

Crude systems have been practiced for the treatment and recycling of wastes generated in the health care facilities This system includes incineration which is the most effective technology in sterilizing waste because it burns the waste at high temperature to achieve complete destruction of all types of bacteria, viruses, fungi and other infectious agents despite the possibility of emission of hazardous gases due to lack appropriate counter measures. The resulting residue is a small amount of completely sterilized inorganic ash, which can be disposed of at a sanitary landfill. An initiative at small scale level was first taken by Prodipan, a local NGO in Khulna city in 2000 in co-operation of Khulna City Corporation. The activities regarding the management of clinical wastes remain in 47 clinics/hospitals of the city, which is a small part of total healthcare facilities.

In the existing management system in Khulna city, the total hospital/clinical wastes are categorized into four categories: Non-hazardous (General wastes), hazardous wastes, sharp and recyclable wastes. Practically, two practiced are observed: (i) wastes are deposited together in the on-site storage and subsequently collected by city authority, transferred and disposed in the ultimate disposal sites (open dumping) with main stream of MSW; (ii) wastes are handled separately: general wastes are handled similar to MSW, hazardous wastes are burned, sharp wastes are stored in a sealed concrete chamber, and reusable wastes are cleaned to use in recycle industry. The wastes are separated in the source and deposited in four collection bins marked by the color: Black, Red, Yellow and Gray. Re-useable wastes are cleaned properly by soaking them into water for 48 hours with some medicine, later shredded them and stored for recycling, needle & sharp wastes are encapsulated in a 7 ft. deep concrete chamber. Remaining surgical wastes are kept for 24 hours for air-drying and then burned them in a locally made burning unit and the residues are then dumped in a nearby pit. However, the present study depicts that the system adopted earlier does not continue properly due to lack of sustainability, absence of monitoring and other inherent factors.

PRESENT SITUATION OF SOLID WASTE MANAGEMENT IN KHULNA CITY

Khulna, the third largest city in Bangladesh is situated in a flat terrain with industrial activity in and around the city, which acts as a gateway to the nearby sea port of Mongla (Fig. 1a). The city (Fig.1b), spreading over an area 70 sq.km & divided into 31 city wards, has a total population of 1.2 million with a growth rate of 5% per annum. The city core, which is about one-quarter of the total city area, is densely populated with mostly multistoried residential and commercial buildings. The rest of the city is a mixture of urban and sub-urban areas.

The average total per capita waste generation rate of Khulna City Corporation (KCC) is estimated as 0.22 kg/capita/day, and major portion (60% to 80%) of this is organic wastes (KCC & SDC 2000). Due to its organic characteristics, it needs frequent collection and disposal and may leads to environmental nuisance. KCC is responsible for the operation and maintenance of municipal services, including solid waste management. It is made up of eight functional departments and the conservancy department is responsible for solid waste management, street sweeping, public latrines and urinals, cleaning of drains, etc. The solid waste management service organizes waste collection from approximately 1,200 City Corporation masonry bins, located on roadsides throughout the city. Households are expected to dispose of their waste in the masonry bins. The waste is then transported to its final disposal site (about 8 km from the city center) by City Corporation trucks.

(a)

(b)

Figure 1 (a) Location of Khulna in Bangladesh map and (b) Location map of Khulna City Corporation

Heaps of waste remains uncollected in many parts of the city. KCC trucks only pick up waste from the roadside bins, around waste bin and some selected road sides open spaces while waste frequently disposed in open drains, free land and other spaces remain uncollected. It is estimated that of the 300tons of waste generated daily, majority of which is bio-waste and between a third and a half remains uncollected (CDIA 2009). A typical scenario of secondary disposal site of MSW in Khulna city is shown in Figure 2. It is estimated that under 30% of KCC households has access to waste disposal facilities in 2000. However, presently the figure is estimated as 50-60% due to involvement of NGOs, CBOs and Private Sectors in the MSW management. Details scenarios of MSW management can be obtained in CDIA (2009) as reported recently and also in WasteSafe (2005), Alamgir & Ahsan (2007a and 2007b).

Fig 2 Typical scenario of Secondary Disposal Sites at Khulna City

HOSPITAL WASTE IN KHULNA CITY

Clinical waste is a solid waste generated from healthcare facilities such as hospitals, clinics and laboratories. It includes materials generated from diagnosis of patient, treatment or immunization of human beings or animals. All hospital wastes are not hazardous. It is mainly the infectious wastes that pose health hazards to those involved with their handling and disposal. Nearly all reported cases of disease transmission from hospital wastes are the result of injuries by contaminated sharps. Some other wastes requires special attention because of aesthetic reasons e.g. body parts. Due to lack of motivation and the absence of effective legislation to protect the environment and to handle the wastes, the whole system is becoming a threat for city dwellers, planners and other concern agencies (Alamgir et al. 2003 and Alamgir et al. 2008).

Contaminated sharps e.g. used syringes and needles, surgical blades, broken ampoules and lancets, laboratory stocks and cultures of infectious agents, human tissues and organs e.g. placenta, amputated limbs and animal carcasses, infectious material from patients under strict isolation, cytotoxic drugs in bulk or significant residual volume in container (e.g. unused or partially used drugs in ampoules or syringes), dressings or other wastes dribbling with blood, caked with blood or containing free flowing blood etc are the main types of hospital wastes that requires special treatment. The associated diseases with clinical wastes are mainly Diphtheria, Pharyngeal, Crimean hemorrhagic fever, smallpox, Chickenpox, Hepatitis, AIDS, Encephalitis, Pneumonic plague, etc. are the main diseases associated with the improper handling and disposal of hazardous clinical wastes.
In Khulna city, all the hospitals, clinics and pathological centers generate all most similar waste in nature; however, amount depends on the infrastructural facilities of hospitals or clinics to handle the number of patients and the type of diseases. Considering the safety of the community, the wastes can be categorized in the following four types as shown in Table 1:

Table 1 Types of hospital waste

Types of wastes	Contents
Decomposable Wastes	Vegetable and food wastes, papers, medicine strips, plastics, cardboard, packaging materials, sweepings etc.
General hospital wastes	Gauge, cotton, tissue, human fetuses, blood or body fluids, excretion, drugs etc.
Non-sharp or Reusable wastes	Syringe, saline bag etc.
Sharp wastes	Used surgical blades, needles, broken ampoules and lancets, broken glasses, scalpels etc.

At first Prodipan, a local NGO takes the initiative for safe disposal of clinical wastes in Khulna city in 2000 (Ali 2000). Presently 47 hospitals, clinics and pathological laboratories are under the umbrella of waste management system of Prodipan. There is no reliable reported data about the total amount of clinical wastes generated in Khulna city. However, based on the project activities areas of Prodipan, the wastes production per day by these 47 hospitals, clinics and pathology laboratories remain almost in the similar composition and quantity as those reported by Alamgir et al. 2003. in Table 2003. From the table it can be seen that the total generated clinical wastes is 360kg per day, out of which, decomposable Wastes is 310kg (86.11%), general hospital wastes is 42kg (11.67%), non-sharp or reusable wastes is 6kg (1.67%) and sharp wastes is only 2kg (0.55%).

Table 2 Average waste generation rate of the hospitals, clinics and pathological centers (after Alamgir et al. 2003)

No. of Hospitals/ Clinics/Pathology Lab	Types & Weight (kg) of Wastes Generated per Day			
	Decomposable Wastes	General hospital wastes	Non-sharp or Reusable Wastes	Sharp Wastes
44	310	42	6	2

QUANTITY OF GENERATED HOSPITAL WASTE

Proper estimation about the generation of hospital waste is required to develop a cost effective and sustainable waste management system The total generation of hospital waste in North America, Latin America, Western Europe, Eastern Europe, Middle East, East Asia (high-income countries) and East Asia (middle-income countries) are 7.0-10.0, 3.0, 3.0-6.0, 1.4-2.0, 1.3-3.0, 2.5-4.0 and 1.8-2.2kg/bed/day, respectively (Pruss et al. 1999). In the present study it is observed that the average generation rate of total waste is 1.02kg/bed/day, 0.942kg/bed/day, 0.064kg/bed/day in the selected hospitals, clinics and diagnostic centers of Khulna city as shown in Figure 3. The mean hazardous waste is 0.175kg/bed/day, which is only about 15% of the total generated waste, and it comprises 12.6% general hazardous wastes, 1.7% non-sharp or reusable wastes and 0.7% sharp wastes. Other percentages of wastes categorized as domestics and infectious are shown in Figure 4.

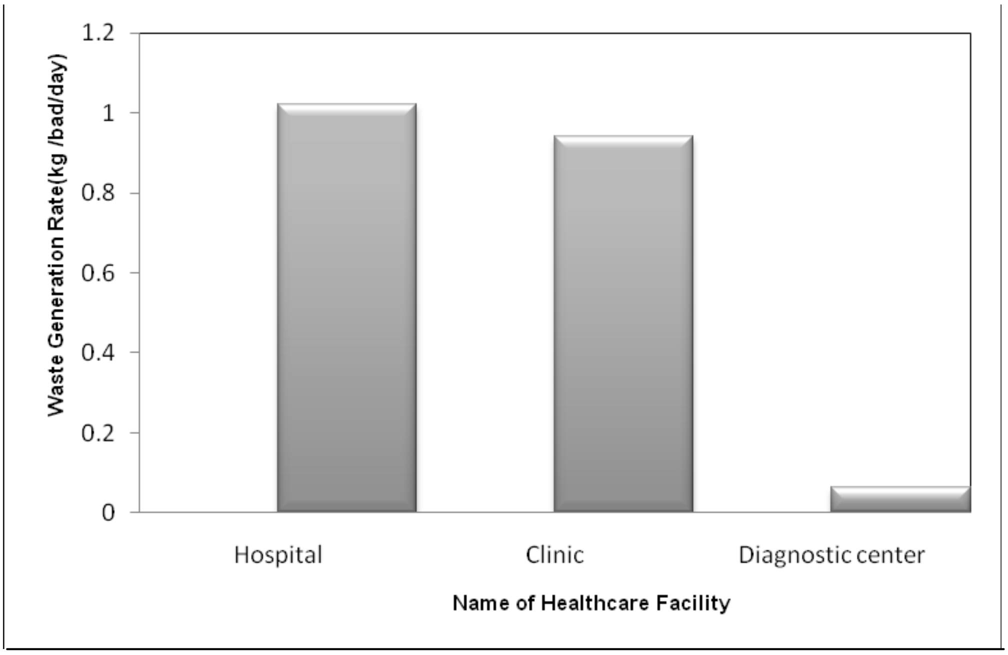

Figure 3 Hospital waste generation in different healthcare facilities

On the other hand hazardous waste generation rate of different countries are found as 25% in U.S.A, 28% in Italy, 14% in Denmark, 7% in Sweden and 5% in Netherlands.

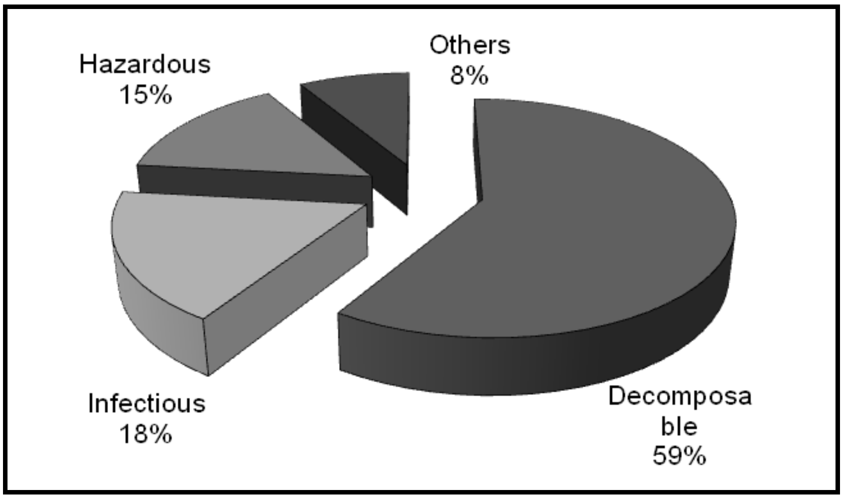

Figure 4 Composition of hospital waste in hospitals,clinics & diagnostic Centers

A conservative study (Rahman 2003) in one of major cities of Bangladesh, Sylhet reported that total generated MSW is 288 tons/day, in which only 6 tons are hospital waste. In the same city, from a recent field study (Sarkar et al. 2006) it is reveal that the percentage of non-hazardous general and reusable wastes are 60% and 17%, respectively, while hazardous clinical and sharp wastes are 15% and 8%, respectively. In Rajshahi city, a recent research report (BRAC 2006) shows that the percentages of hospital wastes in the categories of general, pathologic, plastic, soft and sharp are 79, 6, 8, 5 and 2%, respectively. From field study, the estimated hospital waste generation in the different areas of Bangladesh is illustrated in Table 3 for 2001(after MoHFW 2004) dividing the country into six major regions i.e. administrative divisions.

Table 3 Estimated hospital wastes in Bangladesh for the year of 2001 (after MoHFW 2004).

Six Divisional Regions of Bangladesh	Non-hazardous (General) (kg/day)	Hazardous (kg/day)			Total Hospital Waste (kg/day)
		Sharps	Other Infectious	Total hazardous waste	
Dhaka	8379	413	3009	3422	11801
Chittagong	3514	173	1262	1435	4949
Khulna	2752	136	989	1124	3876
Rajshahi	4696	231	1687	1918	6614
Barisal	1290	64	463	527	1817
Sylhet	1052	52	378	430	1482
Total	21,682	**1,069**	**7,787**	**8,856**	**30,538**

HOSPITAL WASTE MANAGEMENT IN KHULNA CITY

Unhygienic disposal of hospital waste in Khulna City poses a serious health hazard to the city dwellers in general and the scavengers in particular. In all the tiers of solid wastes management in hospitals/clinics lack of minimum requirements of hygienic approach in handling, storage, transport, treatment, and disposal as a result public health and the environment are in risk. It was realized that to overcome the adverse environmental impacts in the healthcare sectors, public awareness through mass media, proper hygiene education to the scavengers, mandatory staff education in waste segregation, and legislation to regulate hospital waste management systems need to introduce which eventually will change the traditional habits of different group of people involved in this sector.

Prodipan, a Local NGO, initiated a clinical wastes management system in 47 clinics, hospitals and pathological laboratories. Emphasis was given to separate the various types of clinical wastes at the generation points with the participation of patients, their attendances, doctors, nurses and other staffs involved in this process.

Figure 5 Waste collections by Prodipan

Motivation on regular basis was provided to the patients and their attendance to develop the awareness since the users of these two categories are changing frequently. Prodipan provides plastic container of four colors as shown in Figure 6 in each clinics for the separation of clinical wastes. The selected colors are (i) Black for Decomposable Wastes, (ii) Gray for general hospital wastes, (iii) Yellow for non-sharp or reusable wastes and (iv) Red for sharp wastes.

Figure 6 Different colors of the container to deposit the four categories of clinical wastes at the generation point.

Field investigation shows that the location of various types of containers is not convenient for the users. It is also found that almost 76.71% waste is separated in place and stored in the respective containers and remnant is mixed all together. Some healthcare centers do not follow proper color code but they separate the waste by their own arrangement.

Figure 7 Waste deposited into container not using color code

Among 74.97% of the healthcare centers uses cover plate on the respective container. Required numbers of containers are also not provided in some places. It is convenient for the users and also for management authority if all the four types of container can put in the same places and jointed together. Also some of the sharp waste are treated in the generation point is known as on site shredding. The concerned users preserve the wastes categorically in different containers marked as different colors and hence the waste collectors collect it daily and dropped in the proper chamber of Pick-up Van and finally carried them to the ultimate solid wastes disposal site of KCC at Rajbandh, Khulna for performing other parts of management. The overall process of clinical/hospital wastes management in Khulna city by Prodipan is presented in a flow chart in the Figure 8.

The collected re-useable wastes, a pictorial view is shown in Figure 9, such as saline bag, syringe, etc. are cleaned properly after being soaked for 48 hours in tank (1.22x1.22x0.92m) of beaching powder mixed water, then shreds in a shredding device fabricated locally. After that the re-usable wastes are stored for recycling. The materials have good demand and price in the local recycle industry to produce various plastic products

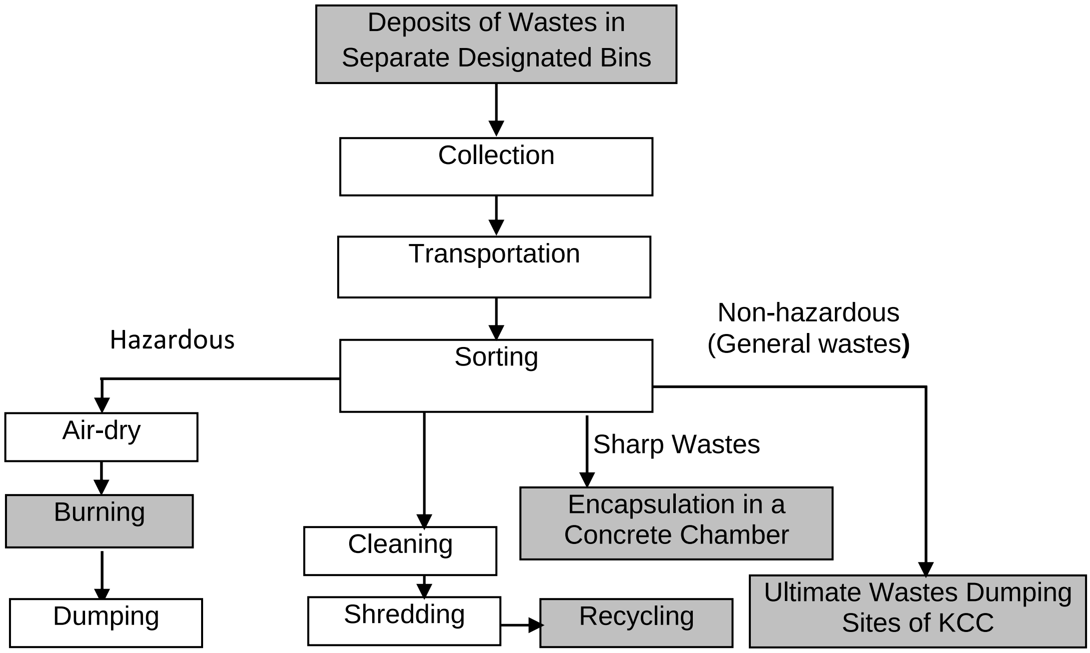

Figure 8 Typical flow chart of hospital waste management by NGO in Bangladesh.

Figure 9 Recyclable hospital wastes.

The Sharp wastes such as needles and blades are deposited in the pet bottles of 1.5 to 2 liter capacity at the generation points. These bottles with other sharp elements are then put in a sealed concrete chamber having the size of 2.00x2.75x2.15m as shown in Figure 10. From the beginning of this management system, these items are stored in the same chamber with any treatment or modification. Actually, Prodipan does not have any specialized knowledge to handle this item other than this crude way. The general hospital wastes are dumped after burning. If the wastes contain more moisture, it is air-dried in a shaded chamber of 10x2x1m as shown in Figure 12 for about 24 hours and then put in the burning unit (Fig.11), started in 2000 by Prodipan and located at Rajbandh, the wastes dumping sites of KCC. Kerosene fuel is spreading over the wastes to accelerate burning. The burning continued for about 2 hours. After cooling down naturally (nearly 18 hours), the ashes are dumped in a nearby pit. There is no system to monitor the quality of the emission of gases into the air and ashes produced due to the burning of the general hospital wastes. The details are given in Alamgir et al. (2003 and 2008).

The kitchen wastes are directly disposed to the KCC's ultimate dumping site of MSW located at Rajbandh (Fig.13). Rajbandh, spreading over 22 acres low-lying land, is an ultimate disposal site (UDS) of MSW collected by KCC since 1977, located at the south side of Khulna-Satkhira Highways and about 7km west of Khulna city center. However, in Khulna city, there is no engineered landfill like other cities of Bangladesh (WasteSafe 2005). All the clinics/hospitals/pathology laboratories under this waste management facility need to pay a monthly fee to get the required services from Prodipan. The service charge ranges from Taka 700 to 150 (US$ 12 to 2.50) per month based on the size and activities of the hospitals/clinics/diagnostic centers (Prodipan 2009).

Despite the initiatives taken by Prodipan in Khulna city for hospital management in 2000, the present field study reveals that the hospital waste management running by Prodipan in the Khulna City's clinics, hospitals and pathological laboratories are limited to only waste storage, collection and finally disposed in the UDS without conducting any treatment as it did earlier. Due to lack of coordination and proper management, financial constraints, ignoring the commitment and agreement with KCC, the main functional elements of the adopted system such as storage of sharp items, burning of general hospital wastes, cleaning and shredding of recyclable parts, have not been conducting. All the collected wastes just dumped along with the MSW, as shown in Figure 14.

Figure 10 Concrete Chamber to store Sharp

Figure 11 Burning unit wastes.

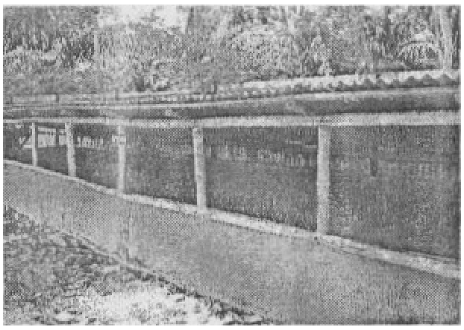

Figure 12 Air-drying unit.

Figure 13 KCC's wastes dumping site

Figure 14 Dumping of hospital wastes at UDS of KCC

NEED TO CHANGE PRESENT PRACTICE AND SCENARIO

As the present practice of hospital wastes management creates unhygienic environments in the urban areas and poses threat to human health and nature, Bangladesh needs comprehensive institutional initiatives since the initiatives taken by the NGO lost its initial momentum. To ensure effectiveness and sustainability in this sector particular attention should be given to: (i) A practical program for waste minimization, segregation and hazardous waste identification, (ii) Appropriate containers, handling and security techniques for hazardous waste; (iii) The pros and cons of collection and transport by special vehicles, and (iv) Cost-effective disposal operations, such as central incinerators or special landfill cells, as stated by Alamgir et al. 2008. The hospital waste management must be incorporated with the policy of the set-up of a healthcare facility and should consider it as an integral part of the management like other activities of hospital such as diagnosis, medication, food and cleanness. As the hospital wastes is an institutional waste, its management is not so complex like MSW, and by introducing training to the associated people, the target can be achieved. Considering the relevant socio-economic settings, technological capabilities and status of health care facilities of Bangladesh, the mechanism as shown in Fig.14 proposed by Alamgir et al. 2008 can be formulated and hence implemented in phases.

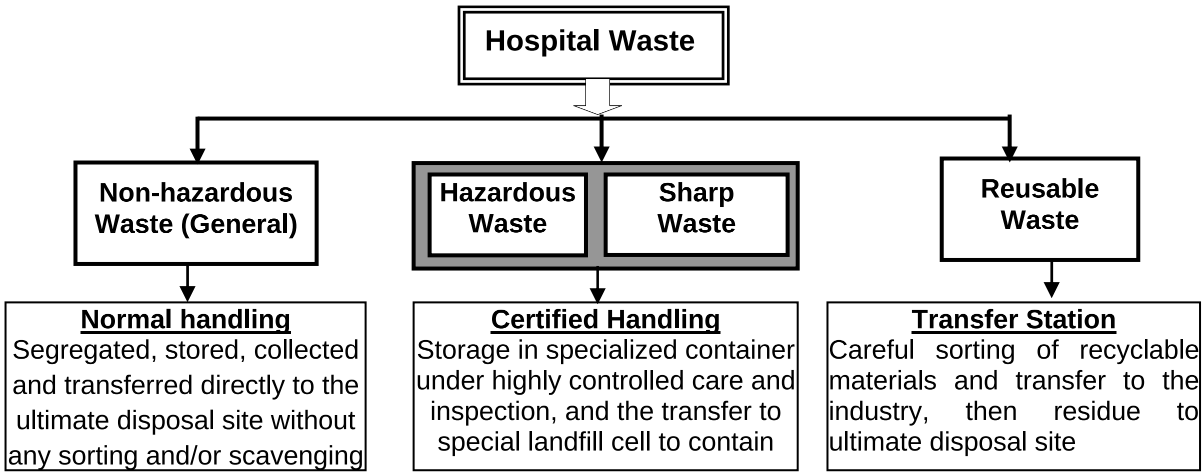

Figure 14 Flowchart to develop hospital waste management in Bangladesh (after Alamgir et al. 2008).

CONCLUSIONS

The study reveals that the hospital waste management in the Khulna city's healthcare facilities introduced by Prodipan has lost its momentum and the target, and running with several constraints ignoring the introduced important tiers of the system. Special initiative should be taken to introduce a sustainable system based on the present needs, technical capabilities, socio-economic settings and status of healthcare sectors to ensure the health, hygiene of city dwellers and to protect the natural beauty of the city. Waste segregation at source should be encouraged to reduce the cost after collection till the final processing and to recover the reusable of non-healthcare risk waste. Finally, it is realized that the system should be introduced in phase following very strict implementation of existing rules and regulation on hospital wastes. Successful implementation of regulation will encourage all the stakeholders.

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Management of Drainage Systems in Kolkata: A Note on Problems and Possibilities

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ABSTRACT

Kolkata has suffered chronically from drainage congestion and water logging during monsoon period which produces health hazards, damages to buildings and environment. The city proper has a combined sewer disposal system. The drainage is disposed through channels and canals partly via wetland ecosystem for natural sewage treatment and partly to river Kulti, which carries the discharge to Bay of Bengal. The added areas lack proper central sewerage collection system. Though many works have been done by the Central and State Government Organizations, the results have not been totally satisfactory. Huge population increment and tremendous urbanization in the city has produced huge sewerage load, surface run-off and lack of water recharge to the underground water table, and drainage management could not cope up with the demand. Recently, increasing awareness about environment, pollution, health hazard and sustainability has generated some actions taken up for better drainage solution in an integrated manner.

INTRODUCTION

Kolkata (historically ‘Calcutta’), once capital city of British India, is a linear city grown along the eastern bank of river Hugli (Ganges) during the last 250 years. It is the capital city of the State West Bengal in India. The Kolkata Municipal Corporation (KMC) area of the present day consists of 141 wards comprising an area of 185 sq km. 41 wards (101-141) have been added to the city proper (with 1-100 wards) during the last twenty years on the face of tremendous population increment and rapid urbanization (NATMO, KMC, 1996 2004). According to the last Census Report of 2001, the population of the municipal area was 4580544 and population density was 24760 per sq km (Census of India 2001). Population growth and spontaneous development after globalization and economic growth have not been supported with planning and construction of required adequate urban infrastructure. So, huge drainage and sewer load on the city’s existing system along with poor maintenance of existing drainage infrastructure has resulted inundation of most parts of the city during monsoon with all its ill effects on people and urban properties.

CLIMATE, SOIL, TOPOGRAPHY AND GEOMORPHOLOGY

Kolkata has a tropical monsoon climate with excess of humidity with annual maximum and minimum temperatures in summer and winter are generally 39^0C and 9^0C. Kolkata has an annual average rainfall around 1500mm with irregular distribution. More than 80% of the annual rainfall occurs in about 90 days from 15^{th} June to 15^{th} September during the monsoon season (Gupta 1991). The high rainfall intensity during monsoon period produces very large run-off. On 19^{th} July 2006, rainfall in some parts of the city was recorded as 180mm in 12 hours (@ 15mm per hour) (Mayor of KMC 2006).

Many areas of Kolkata have a thick fine silty clay layer with little permeability in the ground top soil. This retards quick absorption of rainwater into the ground resulting in high recharge lag time. Other areas have top soil with sandy river-belt deposit, which has greater absorption quality of rainwater into the ground.

The natural slope of the ground of the city is from west (river bank of Hugli) to east (fringe area with wetlands). Topographical ground configuration has land undulations in various areas of Kolkata (though apparently having a flat basin). Within the Kolkata Municipal Corporation area, there exist numerous water bodies (3500), wetlands, water channels and canals (11) (KMC 2006). The surrounding rivers and streams have tidal nature (flushing basin pockets during high tides).

DRAINAGE SYSTEMS IN KOLKATA

Drainage System in City and Fringe Areas

The KMC area generates roughly 600 million litres of sewage and wastewater everyday and more than 2,500 metric tons of garbage (KMC 2006). The city proper has a combined sewer disposal system laid in west to east direction following natural slope of the city. The drainage is carried by underground sewers to pumping stations, which dispose the load to channels and canals. The channels and canals dispose drainage partly to eastern wetland system and the rest to river Kulti, which flowing over rural areas and swamps in the Gangetic Delta, carries the discharge to Bay of Bengal (Figure 1). Huge quantity garbage is deposited at Dhapa Dumping Ground at eastern fringe.

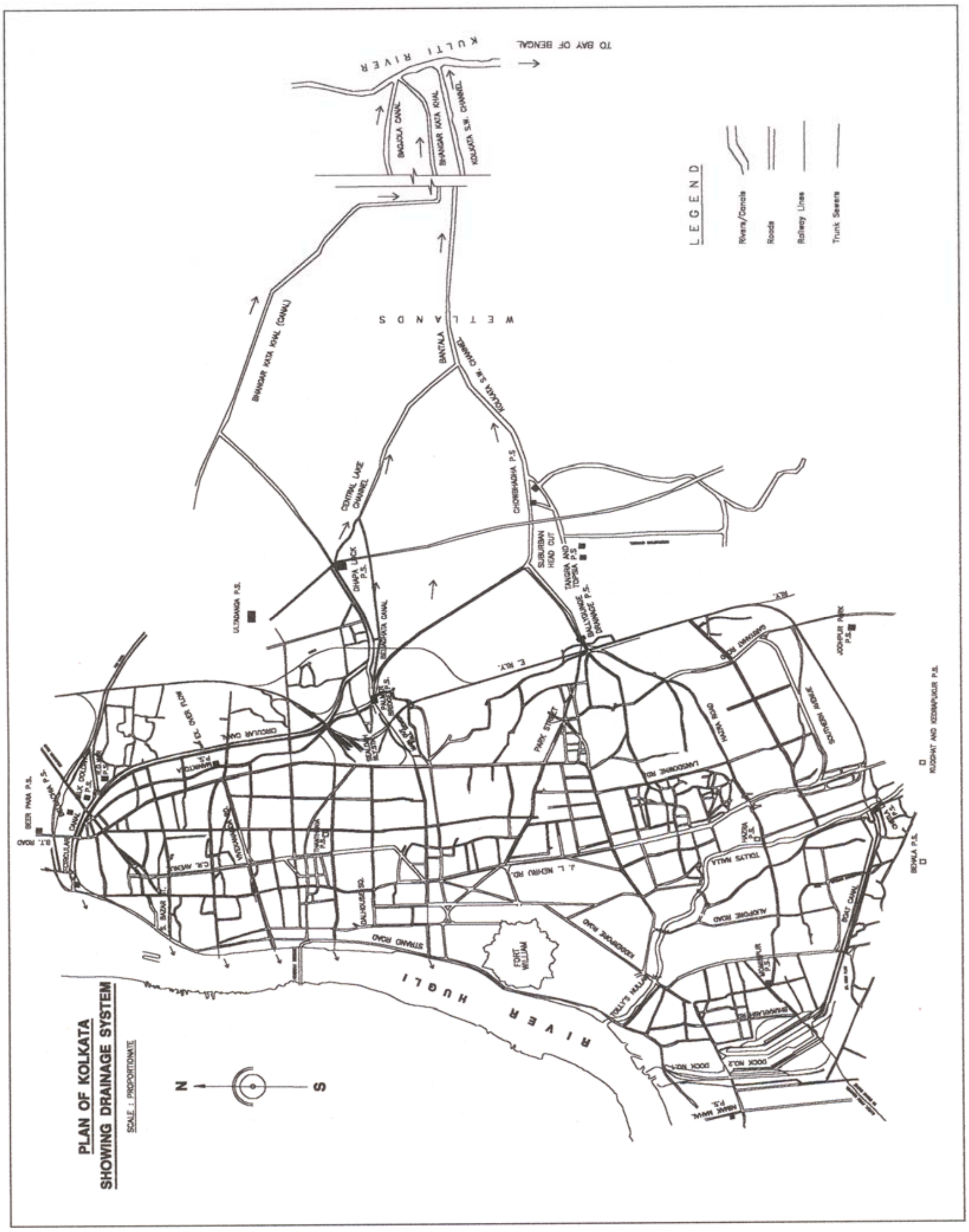

Figure 1 Map of Kolkata showing drainage system

The fringe areas do not have centralized sewer collection system. There, sanitary sewage is stored in individual septic tanks and the storm water (with sullage) is separately drained through municipal conduits or surface drains falling to nearby channels and canals. (Chakravarti, Chowdhury 2004).

East Kolkata Wetland System

The east Kolkata wetland ecosystem, included in the 'Ramsar List' in 2002, is spread over 12,500 hectares (with 5850 hectares of water body). It has 254 sewage-fed fisheries (being inter-distributing swamps with embankments and having depth varying between 0.5-1.5m). Approximately 250 million litres of sewage is flown into it everyday. Here, the organic compounds of the sewage and wastewater are biodegraded by plankton population in the shallow ponds with photosynthesis by solar radiation, and planktons are consumed by fish. This way, the sewage is treated naturally and the nutrients are converted and stored in fish for human consumption. Annually about 11,000 metric tonnes of edible fish and daily 150 metric tonnes of vegetable are produced from the wetland system. This stands as a unique example of treatment of one-third part of sewage and drainage of the city naturally and integration of drainage management with ecosystem and environmental flow.

Works Done by KMDA and under GAP

Kolkata Metropolitan Development Authority (KMDA) has undertaken several works like silt removal, construction of relief storm-drains and additional sewers, construction and augmentation of pumping stations, etc., during decades. Under the Central Government funded 'Ganges Action Plan (GAP)' which started in 1980s, three lifting stations and three sewage treatment plants have been constructed and operational in south of Kolkata.

RATE OF URBANIZATION

Tremendous rate of urbanization has taken place in Kolkata and in its surrounding fringe areas during 1996 till date, constructing high-rise buildings, demolishing historic and old existing buildings and fabrics; reclaiming land from agricultural lands, water bodies and wetlands; constructing upon open spaces; destructing urban agriculture and trees; and intensifying an adverse environmental impact locally.

During April 2005 to March 2006, total number of Building Proposals sanctioned by the Kolkata Municipal Corporation is 3000, out of which, buildings proposed above 14.5m (Ground + IV floors) height are 68 numbers and up to 14.5m height are 2932 numbers. Total floor area sanctioned for construction is 10,580,147 sqm (Rakshit, 2006). This is simply to understand the magnitude of development in Kolkata. The east Kolkata area has been subjected to construction of large commercial, institutional and other buildings and housing developments, and a recent township called "Rajarhat – New Town".

PROBLEMS

Whatever measures taken by all authorities concerned, the overall result even after completion of many projects remain quite alarming during monsoon with showers lasting for a few hours. The main problem that is suffered by people is urban flooding (Figure 2) during monsoon period in almost all parts of Kolkata in varying intensity with consequent damages. The problems related to inundation are many from damages to buildings and properties to ill health condition, disease and death of people; death by accident, drowning and electrical short circuit; stop of life's works, education, business and related loss; and gross environmental pollution and degradation.

(1) It has been observed by the Indian Institute of Tropical Meteorology in Pune and the Indian Meteorological Department (Government of India) that character of monsoon has been changing during some years. Heavy shower has become frequent occurrence during monsoon in Kolkata and some parts of the State while some western parts and the adjoining western region of the State suffer from lack of adequate rainfall. From early 1900s to 2000s, West Bengal now receives 10 cm more rainfall than earlier recording (Jayan & Mudur 2007). This perhaps has a link with quantity of local air pollution and global warming influencing climate change. It has been declared by the Kolkata Municipal Corporation that according to the drainage management capacity of the municipal system, no water stagnation will happen in any part in Kolkata if the rainfall is within 6mm per hour (KMC 2004). During monsoon period, many times the rainfall per hour exceeds the mark of even 15mm and it becomes beyond the draining capacity of the KMC. Nature's fury added with huge population and urban development and incompetent management of drainage system altogether pose a critical problem on property and life of people under inundation during monsoon in the city.

(2) In Kolkata, population is ever increasing, population influx from surrounding region of the State, other neighbour States and from Bangladesh (illegally) is quite high. Road in terms of area occupies only 6% of Kolkata's municipal area, which itself is a constraint for providing good civic service systems. Parks and open spaces are also very inadequate. After long decades of economic gloom, now the city enjoys economic boom of certain merit through various investments in large and small industries, retail and business. The city is in the process of metamorphosis in somewhat spontaneous and uncontrolled way. Imposition of strict control over development may adversely affect the much desired economic development within the city and region. Meanwhile, upgrade and capacity increment of drainage system could not have been done at per the pace of unprecedented urbanization with population explosion during the last two decades. Capital investment in development of real estate, housing, commercial buildings by private (promoters and developers) and by public-private partnership companies are much higher than investment in maintenance and upgrade of existing and development of new infrastructure by Government. This results in failure of civic service systems, be it drainage or supply of electricity in the city.

Figure 2 A part of Kolkata under inundation in 2006

(3) Full benefit from the works executed for drainage capacity improvement has not been realized due to lack of proper periodic maintenance of the completed works. Moreover, faulty planning and/or execution of drainage improvement works create more disastrous results. Some of the old and major underground brick sewer lines of the city are dilapidated and require immediate repair and restoration (Ghosh, ABP 2007).

(4) It has become the common practice in road-repairing work by the municipality that the existing top layer of the road is not taken out; rather a new macadam layer is laid on the existing layer thus increasing the level of the road after repair work. By this, especially at the historic part of the city where the buildings are older than a century, the ground levels of the buildings are rendered lower than the top-up road. This causes inundation of the premises and area. Many architects and engineers have pointed out this fact and stressed for rectification of the method of road-repairing, but the municipality does not rectify its method.

(5) In the city, many people throw garbage in plastic packets in the surface drains, road gutters, conduits, channels and canals. Road side shops and market places and slums add congestion of drains by garbage and plastic regularly. Plastic element in drainage system creates choking of drainage system resulting inundation (KMC 2006).

(6) The outfall channels and canals which carry sewage and drainage discharge have been silted up and polluted. The State Irrigation Department responsible for dredging of canals has not done substantial work in this account. The trunk-drains have also been silted up in the normal process but there are only limited programmes of silt removal (Chowdhury 2006). The river Kulti which finally carries the load to the Bay of Bengal through Sunderbans Delta also needs dredging.

(7) Drainage load of Kolkata city and surrounding region is flown through river Kulti down south to Bay of Bengal via Sunderbans. Hence, excessive human settlement and subsequent unscientific land reclamation at Sunderbans Delta would result in great problem of drainage management for Kolkata and the environmental degradation of the city's canals and the city itself.

(8) Dhapa Dumping Ground is shrinking rapidly, and the issue of environmental degradation by open-air garbage dumping is raised. During heavy shower, the garbage dumped locally and

temporarily across the city before being deported at Dhapa enters into the drainage system and chokes the conduits, as well as floating in the logged water spreads pollution and health hazard.

(9) A comparative study of satellite images with the administrative map of the eastern wetlands area by the State Environment Department reveals that wetlands have shrunk from 6100 hectares in 1992 to 5850 hectares in 2004. 250 hectares of water bodies have been filled up illegally. Also revealed that of the existing 5850 hectares of water bodies in the wetland, only 4400 hectares are 'active wetlands' and the rest is degraded and silted (Kamboj 2004).

(10) Many water bodies across the city have been filled up illegally for construction of residential buildings, and by local garbage deposition, thus diminishing the run-off and sullage storage capacity of the basins and impairing local climate, ecology and environment.

(11) In the eastern fringe areas, large numbers of low-rise-high-density dwellings and high-rise buildings built on previously rural/agricultural lands in unscientific ways of plot divisions and with narrow road spaces have blocked natural drainage path and created difficulty for providing proper sewage and drainage facilities by the municipality (Chakravarti 2004).

(12) Construction of highways and major roads in the eastern region, like Eastern Metropolitan Bypass has formed physical barriers and impedes natural drainage of the city which is according to the topographical slope from west (river bank) to east (wetlands).

(13) Though apparently having a flat basin with gradual slope towards east, many parts of the city have topographical depressions like saucers which enhance holding water for a long time during rainfall and inundation.

(14) Present work for the south-eastern extension of the Metro Railway over the Tolly's Nullah (an offshoot canal of river Hugli) has rendered the canal into a defunct and dead one adding environmental hazard.

(15) Urban development projects are under different departments of the Central, State and Local Governments and various joint sector and private organizations among which, there is little coordination for which undesired results happen (Ghosh 2004).

(16) A related environmental problem is that the groundwater level in the city is receding alarmingly. In a report submitted to the Calcutta High Court by Scientists of the Central Groundwater Board recently, it has been stated that groundwater (aquifer) level in the city has been depleted by 7m to 11m (ABP 2007). The reason for this is construction of a large number of high-rise buildings in the city and indiscriminate boring of deep tube wells for extraction of groundwater. The quantity of extraction of groundwater everyday in Kolkata municipal area has been estimated to be as around 868.9 million liter. The Government has not been able to increase the supply of filtered water from the river. Only a little quantity of rainwater reaches up to the aquifer. The groundwater depletion has been resulting in the city's subsidence and contamination of Arsenic with groundwater creating severe health problem to hundreds of thousands of people.

RECENT MEASURES TAKEN

It has become urgent and important to take up an integrated approach of management of drainage under broader physical, scientific, technological, ecological and environmental parameters for attaining environmental sustainability of the city. On the one hand, the city's capacity to drain out excessive quantity of rainwater during monsoon is not adequate; on the other hand, because of depletion of aquifer, a huge quantity of water needs to be recharged in aquifer. To address both the critical issues, an integrated and adaptive environmental management planning has been introduced out of dire needs, though rather spontaneously by the learned professionals like architects, engineers, planners, environmentalists and partly by the Government. The drainage solution is in minimizing municipal sewer and drainage load first by some means, and then increasing the capacity of infrastructure. The effort is also to provide drainage facility at maximum areas of the city and it's added and fringe areas towards rendering the city an environmentally sustainable one. Increasing awareness about pollution, ecological and environmental protection and sustainability, among various sectors of the community and administrative organizations has helped taking some measures for management of drainage load in an integrated way.

Intervention by State Pollution Control Board

The West Bengal Pollution Control Board (WBPCB) empowered to enforce the Water (Prevention & Control of Pollution) Act, 1974 has directed (in 2004) all Municipal Corporations and Local Authorities to ensure while granting permission for construction of any housing complex located within their jurisdiction having around 100 flats or more, or covering a super-built up area of around 6000sqm or more, that the wastewater from the housing complex is treated through its own 'treatment system' before discharging into the road sewer main of the Municipality or so (KMC, Chowdhury 2004).

In-House Sewage Treatment

It has become mandatory by the directive of the KMC that all large housing, commercial and other development projects in and around Kolkata have to treat wastewater (except storm water from roofs of the buildings) in the in-house Sewage Treatment Plants (STP), and the treated water can either be utilized by the inhabitants or be discharged into the municipal sewer main where it exists or to the nearby canal or pond designated for it (Bose 2006, 2007).

Rain Water Harvesting

The storm water from roofs of the buildings is collected separately into a storage tank with provision for filtration, treatment and recharging it into the aquifer or storage. Rainwater harvesting helps reducing drainage problem, and provides water for use (Gupta, 2004). Hence, rainwater harvesting and treatment of wastewater have become part of the architectural and construction management business, providing better environment and sustainability, and economic generation to such consultants, labourers and other people (Bose 2006, 2007).

Open Area with Vegetative Cover

In any large architectural project, a large portion of the open area (mandatory open space being 60% of the plot area) is directed to be treated with green cover (grass lawn and trees) as children's playground and recreational area, which helps in minimizing quantity of run-off to some extent and provide for some rainwater recharging into the ground. More often, some old trees are being kept by architects in their positions and integrated into the new design of the built forms as components of the environment (KMC 2004).

Conservation and Retention of Water Bodies & Recovery of Wetland

The Government enforces the West Bengal Inland Fisheries Act, 1993 (Amended) to restrict filling up of any water body. The Municipality is keeping vigilance and taking legal action against any offender and reclaiming the water body at the offender's cost. The State Environment Department has declared the 'East Kolkata Wetland (Conservation & Management) Ordinance 2005' to define the wetland area. The State Department of Land & Land Ceiling has also kept proper vigilance on any attempt of urbanization in the area (Bose 2006).

De-Silting and Cleaning of Sewer Lines, Outfalls and Canals

Work is being done in this regard. 14 vehicles with Jetting cum suction pump machine to suck and dredge silts deposited in the sewer lines have been bought from abroad during 2002-2005 and engaged in operation. Previously and till date in some areas where width of road is narrow, human beings use to remove silts manually. The State Government acknowledges the need to dredge and conserve canals. A number of canal restoration and rehabilitation projects have been started by the State Irrigation Department and the KMC (Bose 2007).

Solid Waste Management

The Kolkata Environmental Improvement Project (KEIP) has proposed for construction of a new Sanitary Landfill site spread across 114 hectares at Dhapa. The proposal has been cleared by the East Kolkata Wetland Management Authority and will be constructed within 2008. As sustainability value addition, it will have – (a) composting and recycling units, (b) waste to power conversion unit, (c) planned pisciculture and (d) a green belt (KEIP 2006).

Slum Improvement Programme

The KEIP's slum improvement programme has included works like (i) widening, realignment and lining of drains, (ii) construction of sewer/drain lines and (iii) provision of solid waste containers, along with other works to upgrade environmental condition of slums in the city.

KMDA's Recent Works

The Government has taken up a Trans Municipal Project with financial assistance from The Central Government under the "National Urban Renewal Mission" to be implemented by the KMDA with an objective of improvement of the drainage and sewerage system of the city's northern fringes across five municipalities (KMDA, 2006). Moreover, the KMDA has been doing several works for improvement of drainage in and around Kolkata.

Kolkata Environmental Improvement Project (KEIP)

This is a multi-agency endeavour to arrest environmental degradation in fringe areas where drainage & sewerage networks are inadequate. Its work has included – (i) efficient interception and collection of sewage by providing secondary sewers, (ii) build trunk sewers in addition to existing trunk lines, (iii) develop separate storm water drainage systems including pumping stations where necessary, (iv) laying new underground conduits in narrow roads and connect properties to the new networks, (v) construct/rehabilitate pumping stations, and (vi) upgrade treatment plants and construct new ones where necessary (KEIP 2006).

Gross Physical Planning and Fund Investment by Government and Municipality

A total of Rs.2520crore (around US$550 million) is being spent over a period from 2005 to 2009 by the Government and Municipality through the Jawaharlal Nehru National Urban Renewal Mission (funded partly by US Aid, partly by Central Government), Kolkata Environmental Improvement Project (funded partly by Asian Development Bank), and Project Nikashi (Drainage). The major works taken up under these projects are – dredging and re-excavation of canals, revamp of drainage and sewer system and network, drainage development, new pumping stations, repair and restoration of old pumping stations, automation in pumping stations, procurement of sewage-cleaning machines, etc.

Role of NGOs and Other Organizations

Recently, various organizations have been advocating for and working on decentralized sewage treatment systems in fringe areas of Kolkata where central sewer collection systems are absent. Through anaerobic treatment system, how wastewater can be treated to produce water for irrigation, agriculture and pisciculture are demonstrated to public and various authorities. It is appreciating that the private organizations, builders and developers are coming forward to take up this environment friendly solution. The KEIP has engaged NGOs to understand through them the need of the beneficiaries in compatibility with the ecological requirements and involve beneficiaries in all its development activities.

CONCLUSIONS

The problem of drainage system failure and subsequent inundation of many parts of the city is a regular phenomenon during monsoon since many decades. Mitigation of this problem not only needs proper environmental planning in an adaptive and integrated way, but also sincere participation and effort of all sections of the community and administration. To find fund support for investment in the drainage system development and management is not very difficult in present time. The difficulty is in proper planning and management of the works within multiple constraints and in a plural society where mitigation of poverty in a large section of population having been utmost important to attain sustainability of the city. Another important work is to inform and educate people about environmental pollution and the role of people in the process of mitigation of pollution for environmental sustainability. The students of architecture, civil and environmental engineering need to be educated the new thinking and the modern technological solutions in drainage systems and be taken part in community discussions. Proper emphasis is to be given on education, research, capacity building and participatory programmes of stakeholders and public for broadened awareness, proper cooperation and practical pro-sustainable activity in this regard to achieve the community's common goal.

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Conversion of Poultry Feather Waste to Feather Meal: Potential Waste Diversion in Cebu of Philippines

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ABSTRACT

Poultry dressing plants in Cebu Province, Philippines generate tons of feathers but plant operators mix these into the municipal solid waste stream. The enactment of the Philippine Ecological Solid Waste Management Act of 2000 (Republic Act 9003) stipulates reduction of impacts of waste on health, safety, and environment. This exploratory study converting poultry feathers into feather meal in Cebu relates to waste diversion strategies in order to manage municipal waste properly. This study used focus group discussion (FGD), rapid appraisal survey of major dressing plants, government agencies, academia and the end users of feeds. Two dressing plants as respondents process 9,000-25,000 broiler heads per day. The Bureau of Agricultural Statistics (BAS) reported that chickens dressed in Cebu plants in 2006-2007 reached around 16 to 19 million. The respondent-plants have 34,000 consolidated heads per day with at least 12.5 million chickens dressed annually, leaving some 6.8 million chickens dressed in other plants. Feathers account for 9-11 % of the total weight of the broiler; with average weight of one kilogram per chicken, the two plants generate 3.86 tons of feathers per day. Meanwhile, the fishery sector allots 70% of its total budget for feeds. Their concern is lowering down this cost and ensuring the protein, fiber, fats, carbohydrates and amino acids contents in the feeds. Product viability and knowledge base are also largely unexplored. Safe, easily digestible and competitive price – end users will patronize the product. Thus, waste diversion can be achieved from dressing plants effectively.

INTRODUCTION

The Philippines enacted its Ecological Solid Waste Management Act of 2000 (Republic Act 9003) in 2001 to address the growing problem of solid wastes. After eight years, the challenge to manage wastes has become increasingly complicated from reduction to proper disposal at the local government level. Different kinds of solid wastes are generated by various sources of households, commercial, institutional and industrial establishments. Many local governments try to segregate solid wastes, but these eventually end up mixed in disposal areas. In Cebu Province, enormous amount of poultry feather waste comes from 16 to 19 million chickens dressed in the year 2006-2007. Almost four tons of feathers per day could be generated from two dressing plants. Dressing plants are supplied by chicken growers/raisers located in various parts of the province. This study explores the diversion of poultry feathers wastes from any disposal facility in the province.

One option is to transform certain solid waste materials to become another useful material. For instance, styrofoams are melted to become blocks used for “pathwalks” in urban parks and gardens. Plastics are now being fed in a cement kiln as fuel, a process called “co-processing”. Supported by Holcim Cement Plant and the German Technical Cooperation solid waste management project, this is also slowly gaining legitimacy in the local government of Iloilo City, Philippines (Paul 2009).

Cebu Province has been in the forefront of economic development in the last two decades. With an area of 5,088 km^2, it has a population of 2,646,000 in 2007. Comprising the cities of Cebu, Danao, Lapu-lapu, Mandaue, and Toledo and 48 towns, Cebu is located in Central Visayas Region, bounded on the north by the Visayan Sea, on the east by the Camotes Sea; west by the Tanon Strait, and on the southeast by the Bohol Strait. Mandaue City, a highly urban area with an area of 33 km^2 and a population 180,285, hosts the major dressing plants which served as respondents. The province is a

narrow strip of land about 200 km long from north to south and 41 km at its widest. The climate is relatively moderate and there is no distinct wet or dry season. Cebu is the largest and most progressive major urban center outside Metro Manila.
While some feather wastes are generally used in making dusters to clean dust on appliances at home, most feather wastes are.disposed together with other municipal wastes. Creating an opportunity as a way of reducing solid waste at the dressing plant level, we explore the possibility of transforming feather waste into feather meal. Based on the survey and interview of key informants, the paper concluded that further studies can be undertaken based on the initial results of the study. This exploratory study is a first step that can be followed up by the business sector and the government as well to test on the viability of the study in terms of economic and financial market terms.

METHODOLOGY

Rapid appraisal survey forms were distributed to dressing plant operators, and a focus group discussion (FGD) with key government officials and informants was done. Interviews with relevant national agencies like Department of Agriculture (DA)-National Meat Inspection Services, Feeds Laboratory Office, Cebu Breeding Station, Environmental Management Bureau of the Department of Environment and Natural Resources, the academia and the potential end users of feeds from the fishery sector or growers of prawn and fish products have been conducted in different parts of the province: (1) in Bogo City, Cebu for the fishery sector (prawn and fish growers); (2) in College of Fisheries - Cebu State College of Science and Technology (CSCST) in Carmen, Cebu for the academia; and (3) in Mandaue City, Cebu for the dressing plants.

Chicken feather waste is the focus of the study because some chicken body parts are already recycled and bought by some local entrepreneurs. These are classified into two by-products: primary and secondary. Primary by-products are liver, heart, and gizzards, while the secondary by-products are feet, heads, and lungs. Management of feather wastes is confined to disposal because there is not much recycling activity and no sustained market for these, thus processing plants just mix these with their other solid wastes, which end up in disposal site.

FEATHER WASTE

Poultry feathers represent a large potential protein source for feed ingredients. Concentration of the poultry industry in certain areas and the consolidation of various dressing plants somehow simplify the collection of feathers for processing into feather meal (Jordan and Croom 1957). Hydrolyzed feather meal is the product resulting from the treatment under pressure of clean, undecomposed feathers from slaughtered poultry (DA Region 7, 2008). Hydrolyzed protein is a protein that has been broken down into its component amino acids. While there are many means of achieving this, one of the most common is prolonged boiling using an enzyme such as the pancreatic protease enzyme to stimulate the naturally-occurring hydrolytic process (Wikipedia, 2008). Feathers constitute around 9-11% by weight of a live bird and are rich in protein. This protein is not digestible. To make it digestible, it must be converted through a hydrolysis process. Hydrolyzation is accompanied by cooking the feathers with high pressure steam. Hydrolyzed feathers are produced with between 45-65%moisture content. This moisture must be reduced to 8% so that the product will have adequate shelf life as animal feed.

In Region 7, the Feeds Laboratory in the DA-Regional Field Unit compiled a reference standard that guides the specifications of the components of feather meal. Subsequently, moisture content should not be more than 10%, while protein should not be less than 79%. These are the conditions to meet after processing. The absence of salmonella should be ensured before processing.

GENERIC POULTRY DRESSING PLANT PROCESSING FLOW

The operations of a dressing plant include the following steps:

- Delivery trucks loaded with crates of live chickens and other products from poultry farms or local contract growers enter the plant/facility. Empty crates are washed and disinfected before leaving the facility.
- Live chickens and other poultry awaiting slaughter are kept inside the holding area to be sheltered from direct sunlight. They are given sufficient rest and water before slaughter.
- The chickens are stunned, using electricity, then bled and de-feathered. Feathers are placed in sacks or receptacles.

- Leaving the slaughtering area, the chickens enter the evisceration and post-mortem inspection area.
- The viscera in the chickens are then removed.
- Edible offal is further cleaned and the remains are discarded. Chickens are washed and chilled.
- Chickens are air-chilled or water-chilled to 1.1^{0}C or below.
- Chickens are then classified, weighed, packaged and labeled.
- Chickens are ice packed after weighing to maintain carcass temperature to below 4^{0}C before they are turned over to route truck or to the next process.

ENVIRONMENTAL CONCERNS

Poultry waste management and disposal appear to be a minor concern compared to hog waste pollution. A functioning market for poultry manure exists. The standard structures for poultry housing are such that bird droppings easily dry and are systematically collected by poultry manure traders. There is strong demand for poultry dung as organic fertilizer, particularly in the temperate high-value vegetable-producing provinces in northern Luzon (e.g., Benguet, Nueva Viscaya). But none of the other wastes like feathers are dealt with.

Environmental and human health dimensions in broiler production at the farm level pertain more to the odors emitted and flies attracted to the poultry farms close to residential areas and population centers. These concerns have led local governments to formulate zoning ordinances to regulate the establishment of new farms within certain distances from population centers and settlement areas. Health and environment concerns have also prompted integrators or producers to set new frameworks for contract growing. Contract growers near residential areas are being terminated, and new contracts are moving farther away from urban centers. Integrators require contract growers to be responsible for the putting up of waste and pollution control devices, in effect shifting the burden of internalizing environmental costs to the contract growers. This includes feather waste to be mixed up with other wastes. The integrators weigh the balance of costs and benefits of locating contracts farther from the headquarters.

In Mandaue City, Cebu the critical and important Butuanon River is the only tributary that drains out water from the west side of the city. Disposing of dead chicken carcasses to the river poses threat to humans since poor people scavenge there. Health and sanitation issues are minor yet critical in urbanized areas. In poultry plants, after de-feathering the chickens, feathers are collected and disposed together with other municipal wastes.

Depending on the monitoring of local government authorities, more serious pollution and environmental concerns do exist at the dressing plants level. Before their establishment, dressing plants have to secure Environmental Compliance Certificates (ECCs). Solid waste and wastewater treatment facilities are required. Effluent standards for these industrial undertakings are well established. This is the reason why the feathers are important waste materials that should be recycled because of its enormous amount generated by dressing plants.

Technology-driven rendering plants are the standard facilities but not all dressing plants have the capacity and scale to warrant the establishment of a rendering facility. The few rendering plants operated by some integrators are far from the dressing plants. Feathers have to be transported by trucks at the cost of the dressing plants. For instance, a toll dressing plant in Rizal province, Metro-Manila spends about PhP3,500 - 4,000 per truck per day for the transport of feathers to the province of Bulacan, north of Metro-Manila. Transport is only allowed at nighttime. There are odor problems in transit. The current cost of transport includes informal highway taxes collected by highway inspectors.

RESULTS AND ANALYSIS

The flow of the research starts from the gathering of primary information on the two dressing plants using FGD then the government sector, the academia, and the potential end user of feeds.

Dressing Plant Industry

There are three major dressing plants in Cebu. Based on FGD with representatives from the two main plants, 9,000-25,000 broiler heads are processed per day. All of the plants have buyers for the secondary by-products. These buyers or contractors pay the plants on a per bird basis to be able to get all the secondary by-products. Chicken barbecue stands along the streets are normally the target market for such by-products.

According to Bureau of Statistics (BAS), the number of chickens dressed in dressing plants in Cebu for the year 2007 is about 19 million and about 16 million chickens in 2006. Adding up the number of broiler heads processed in the two dressing plants would result in about 34,000 consolidated heads per day. This would amount to at least 12.5 million chickens dressed per year in Cebu. Using the 2007 figure, the balance of some 6.5 million chickens can be assumed to be dressed in other plants in Minglanilla, Compostela, Carcar and other plants within Mandaue City annually.

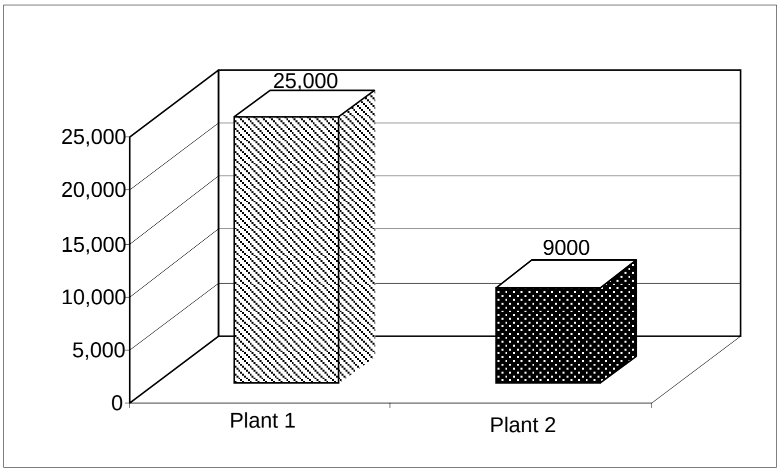

Figure 1 Average broiler heads processed per day

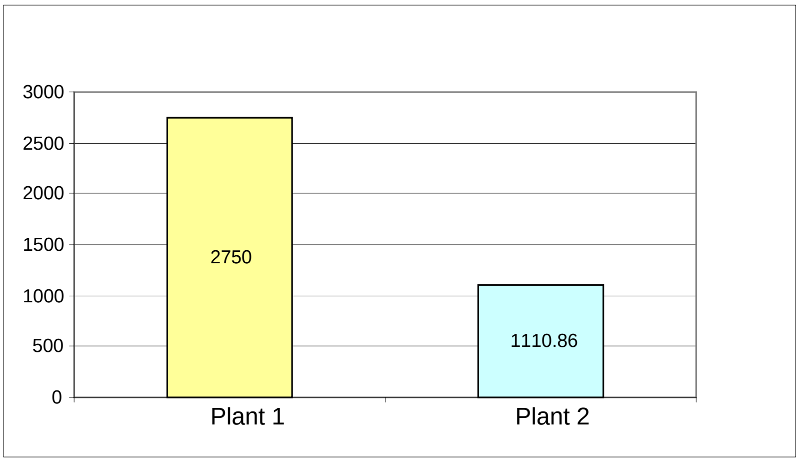

Figure 2 Estimated feather waste generation (kg/ day)

The estimated feather waste generation is computed to be in the range of 9-11 % of the total weight of the broiler according to plant operators. Industry assumption holds that average weight of one head/chicken is 1 kilogram. Using the 11 % as the proportion of feathers to the weight of the chicken, and factoring in feather moisture, the 25,000 heads per day of Plant 1 generate about 2,750 kilos/day of feathers or 2.75 tons per day. Plant 2, on the other hand, generates about 1111 kg/day or 1.1 tons/day. Hence, feathers generated in the two dressing plants amount to about 3,861 kg/day or about 3.86 tons/day.

The two plants responded positively on the possibility of recycling chicken feathers into feather meal. Its location should be far from residential area. They do know of a technology that converts chicken feathers into feather meal which is a rendering facility specifically in Pampanga and Davao only. There is no such facility existing in Cebu or in the Visayas. The two plants agreed that any sector (academe, government or private) could spearhead the research and development of this proposed recycling efforts.

Regarding the rendering facility, an FGD with a former top executive of San Miguel Foods Incorporated revealed that the cooking time to kill the bacteria is approximately six hours with 13 % moisture. In one hour minimum time, a rendering facility can cook 600 birds equivalent to one tonner cooker. So, 600 birds multiplied by 0.11 % feather content would mean 66 kilograms of feathers cooked. According to American standards, cooking is achieved with steam at temperatures of 240º to 290ºF (approximately 115º to 145ºC) for 40 to 90 minutes depending upon the type of system and materials (Meeker 2006). The basic rendering process that starts from the feathers and other raw materials as described by Meeker, covers sizing and heating up to certain temperature. Pressing to get protein and fats will lead to grinding and finally store it and delivery comes at the end.

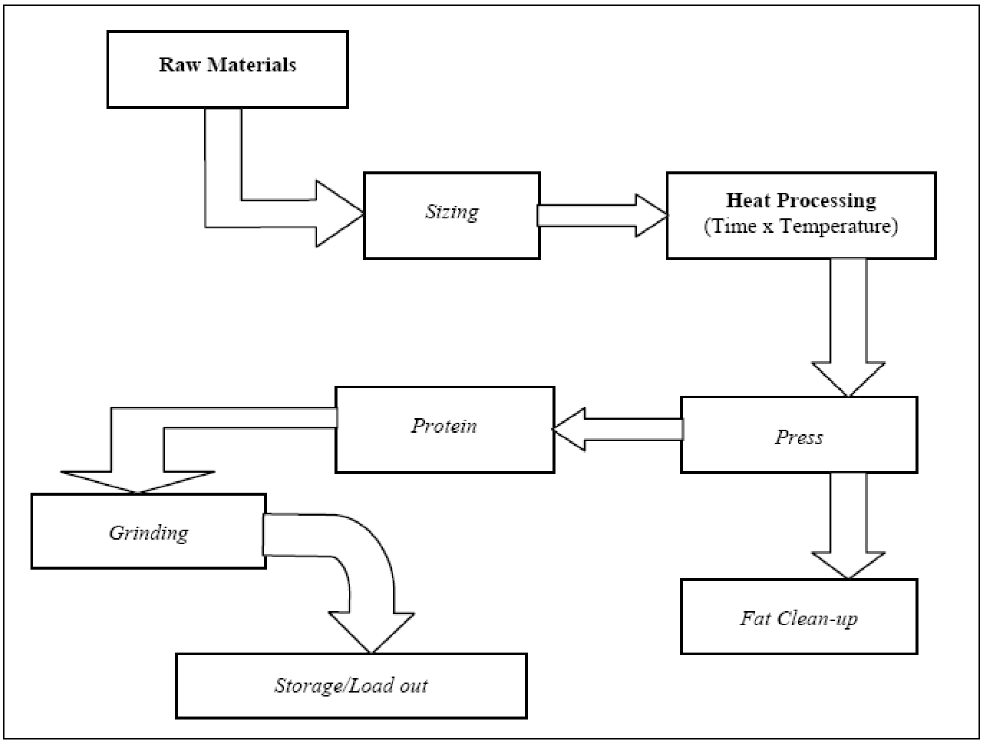

Figure 3 Basic Rendering Process (Source: Meeker, 2006)

Government and Academe Sector

The FGD involved relevant officers of DA-7, Cebu Breeding Station, NMIS, Feed Laboratory, Bogo City Planning and Development Office, DA-Bogo City LGU and College of Fisheries –CSCST Carmen, Cebu. They all agreed that it is possible to convert the feathers into feather meal in Cebu as a test case, but they were not aware of any government project promotion on this aspect nor any technology that processes such recycling method. However, they want the government or the academe to spearhead such investigation to ascertain if such recycling method is feasible. But interestingly, they have yet to know what kind of technology that processes these wastes. A high technology-based facility to process these wastes can only be found in Pampanga in Luzon and Davao in Mindanao. The estimated cost of the facility ranges from PhP 25 – 40 million.

Fishery Sector/End Users

Two respondents who come from the Northern part of Cebu (Bogo City) and operate fishponds for prawns and milkfish (bangus) are interviewed in fishery sector. Many fishponds abound in the province but the researcher randomly picked Bogo City where the large scale fishponds are located based on Environmental Impact Assessment (EIA) applications. The respondents classify their companies of medium size. But their fishpond size of 11 hectares could no longer be classified as medium. What makes them a significant group in this study is because they are captured end users of the potential product.

Grower 1 has feed requirements of about 500 kilos/week, 2000 kilos per month, 24,000 kilos annually or 24 tons/per year. Grower 2, with its *baname* species culture (shrimp type but imported from Southeast Asia), revealed they use 10,500 kg/ month; yearly it would reach 126,000 kilos of feeds for the seven blocks, modules or units. Similarly, in their overall operations budget, 70 % is allotted for feed requirements. The least price for the smallest package of feeds for Grower 1 was Ph 600/25 kilo/ sack while Grower 2's was Ph1000/25 kilo/ sack (1 USD=47 Philippine Peso). The basic nutrients or ingredients in feeds they consider in buying are protein, fiber content, fats, carbohydrate and amino acids. Correlating with the feeds analysis and feather contents, amino acids are produced because of the breakdowns of compounds as a result of hydrolyzation process. Thus, it could be a positive driving force for this recycling effort to prosper in the future.

Figure 4 A typical fishpond/prawn farm module in Bogo, Cebu

If in case there is already available fish meal product in the market made of chicken feathers, they would consider buying it to try although they need to test it further for safety reasons. The growers think that it will only be accepted in the market in the future if the proponents whether government or private sector will succeed in convincing the end users price and ingredient –wise.That is why the price should be competitive.

Normally, their company's general considerations and criteria in buying feeds are: 1) Safe product. They need to be sure if it is safe since they are in a risky business. 2) They need to check on the ingredients like protein and fiber contents so that it will be easily digested.

CONCLUSIONS

Based on the findings, after exploring the possibility, recycling for chicken feathers into feather meal can be done in Cebu for the following grounds:

- The number of poultry dressed in Cebu plants is adequate enough to warrant the conduct of the study. Thus, feather wastes can be utilized for such experimentation to further examine the contents to know the right ingredients and mix with chicken feathers as main ingredient.
- There is no saturation point yet in terms of its market viability. The knowledge base is largely unexplored. Although, a corresponding rigid economic market study should be undertaken based on the availability of feathers as resource materials for such product.
- The existence of feed analysis laboratory at DA-7 is also a positive factor in the experimentation procedures that will be needed in the future. Private laboratory/facilities attached with big producers can also be tapped to compare results and produce thorough analysis.
- Government's and academia's sentiments are in consensus of the potential of such project, although these sectors differ in their perspective in terms of in terms of pricing, and which institution should lead and pursue the efforts. But government can lead and private can take cue.
- Based on the interviews, end users in the private sector are upbeat and interested as long the product is safe, easily digestible and has competitive price. There are strong indications that feathers are rich in protein content which is one of the major nutrients needed by end users for their farms.
- Cebu has no facility yet to process feathers. Waste diversion can be achieved right at the dressing plants effectively if these are collected for the purpose. Thus, supporting the environment and health objectives of the RA 9003.

Although exploratory in nature, further studies and dedicated focus should be undertaken in the future in terms of financial viability of the project in order to ensure sustainability as well.

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Where Do the Used Tyres Go? A Case Study

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ABSTRACT

The proper disposal of used tyres in many cities is a big headache of the Solid Waste Management (SWM) authority in different countries. The situation might be different in Bangladesh. Old tyres are used in various ways for non-vehicular purposes. These tyres in due course may be return to the waste stream for subsequent treatment or environmentally safe disposal. Used tyres can beneficially replace some of the fossil fuels traditionally used in the brick making process. An attempt has been taken to look at the scenario of further utilization and disposal of used tyre in Khulna, the third largest city of Bangladesh. In this paper, the inherent utilization of old tyres are explained through intensive collection of data from the users and producers of old tyres products. The experimental results reveals that, (i) The tyres are used for different purposes in environmental sound process like production of dock fenders, washer, bucket, gasket, belt for rice mill shoe sole etc; (ii) There is a practice of using old tyres in brick kiln as a fuel by which energy is recovered, and (iii) Recycling and reusing of old or waste tyres are creating some job opportunities to the people of this city.

INTRODUCTION

The mountain of used tyres has grown dramatically during the last decades due to the increased number of vehicles. The proper disposal of used tyres in many cities of different country is a big headache of the SWM authority. The tyres can cause significant environmental pressure through the life cycle if their extensive natures of reuse or recycling options are not utilized. Old tyres are also used in their original form for non-vehicle purposes. Examples include the use of tyres as dock fenders, washer, bucket, gasket, belt for rice mill etc. These tyres will, in due course, be returned to the waste stream for subsequent treatment or environmentally safe disposal. Used tyres can beneficially replace some of the fossil fuels traditionally used in the brick making process. Four kilns in the UK have received full authorization to burn tyres with a combined capacity of over 100,000 tones. The high energy content of tyres initiated several applications of post-consumed tyres for energy recovery. For example, many worn out tyres are used as a supplemental fuel in cement kilns (Pieter 2001). Search of new alternative usages including as aggregate in flexible concrete and different disposal methods are going on (Olivaresa and Barluengab 2004). It would be nice to look at the scenario of the used tyre in Khulna, the third largest city of Bangladesh. It may imply the situation of whole Bangladesh. Usually the old tyres are used in different ways in Khulna city. In this paper, the inherent utilization of old tyres are explained through intensive collection of data from the users and producers of old tyres products.

Practices in Khulna

The used tyres have certain monitory value to a group of people of the society. It can be seen that the existence of tyres (as rubber) in any disposal point of mixed municipal solid waste (MSW) is unusual. Mixed MSW of Khulna City contains a very little amount of tyre as only 0.5 percent including all rubber by weight (WasteSafe 2005). This indicates that the people do not throw or dispose away the tyre directly. They try to utilize it in any possible way. The tyre selling shop in Khulna collect new tyres from dealers located in Dhaka. Among those Indian & Chinese companies are in top due to their lesser cost. Vehicle owners and different offices collect tyre from different tyre selling shops. After use of 15 to 18 months they either resole the tyre for reuse or sell it to the tyre repairing shops or garages. In case of government offices they store the old tyre for long time and then sell it through tender/bid process. Recycling Factory owner, secondary product maker, owner of garages and brickfields are usually bid to buy those old tyres. Then they either resole it or use for other purposes.

Tyre-Resoling

Used tyre is usually resold in tyre-resoling factory for further reuse. There are four tyre-resoling factory are identified in Khulna. Depending upon the physical condition, an old tyre can retread or resoled consecutively not more than two times. After each re-soling the tyre can be utilized for four to five months. The user, dealers of new tyres and the owner of resoling factory usually evaluate the tyre life by its service month. Considering three resoling the life time of a tyre can be increase from 15 to 25 months or 18 to 28 months depending on other factors mainly the mileage and road condition. Resoling information of a factory located in Khalishpur of Khulna city is presented in Table 1. Mostly eight types (T1 to T8) tyres for truck, bus, mini bus, and motor driven three-wheeler, etc. are available in Bangladesh as shown in Table 1. All types of tyre are resoled by the tyre resoling factory. Resoling is done by several steps. These steps are: (a) cutting into regular shapes; (b) rubber is pasted in layers using octane on the surface manually; (c) finally heating and molding is done to have a finished resoled tyre. An amount of new and specific rubber is needed for each type of tyre as mention in Table1. The cost of resoling is varied according to tyre type. Highest resoled tyre by the factory is type T4 tyre mainly used in minibus. The factory resoled 200 to 220 number T4 type tyres per month with cost ranged 1200 to 1400 taka/tyre. Total number of resoled tyre by the factory is found to be 535 to 615 per months. About 12 workers are employed in this factory. The total employed workers in this factory plus other identified three factories are 28.

Table1 Resoling information of a factory located at Khalishpur of Khulna city

Size of Tyre (Type)	Used Vehicle	Cost of resoling (Tk)	Require amount of rubber (kg)	Number of tyre resoled per months
1000x20 (T1)	Bus, Truck	2200-2300	12.5-13.5	10-15
900x20 (T2)	Do	2000-2200	11.0-12.5	65-70
825x20 (T3)	Do	1700-1900	10.0-11.5	50-60
750x16 (T4)	Mini Bus	1200-1400	5.0-6.5	200-220
700x16 (T5)	Mini Bus	1100-1300	4.5-5.5	30-35
700x15 (T6)	Micro Bus	1100-1300	4.5-5.5	30-35
650x16 (T7)	Micro Bus	1100-1200	4.5-5.0	25-30
400x8 (T8)	Three wheeler	250-300	1.0-1.5	125-150

New Product from Old Tyre

During recycling specially as resoling a huge amount of tyre dust is produced from cutting process. The tyre dust also has some sort of salvage value. This dust is used in local shoe sole factory as a raw material. The factory owner sells it at a cost of 5-6 taka/kg. When a tyre become unfit for further resoling, it also has some sort of use. Worn tyres are also collected by two shops in Khulna City. They collect all tyres except three wheeler tyre. The used or resoled vehicle tyres are utilized for different purposes. The tyres can be utilized in the same form or can be cut in different shape for specific usages. Specific use and price of some new products made from the used tyres such as cross belt, flat belt, gasket, coupling, mountain, washer, and bucket are listed in Table 2. The pile of old tires usually seen on the roadside shop in the country is shown in Figure 1a.

Table 2 Details of new products made from used tyres

Sl no.	Product name	Use of the product	Unit	Cost in taka.
1.	Cross Belt	Rice mill Shallow pump motor	3 pc	5.00
2.	Flat Belt	Rice mill	feet	6.00
2.	Gasket	For pipe joint	1pc	1.00
3.	Coupling	Gear box	1pc	6.00
4.	Mountain	Bus, truck, private car, motor cycle	1 set (4pc)	30.00
5.	Washer	Generator, pump	1 pc	15.00
6.	Bucket	Tube well	1 pc	15.00

The appearance of new products made from tyres is illustrated in Figure 1b. The products are sold at comparatively low price compared to new one.

(a) Pile of old tyre

(b) Varieties of new products made from old tyre

Figure 1 Old tyre and its new products

Miscellaneous Utilization Old Intact Tyre

There is a greater use of old tyre is in hand carts in the country. Usually two people work drive one hand cart to carry heavy goods through usual narrow roads. They are frequently seen near large bus and truck terminals, river ports, railway stations and wholesale dealer areas. Now-a-days previously used wooden wheels are replaced by the old vehicle wheel with old tyres and tubes. This kind of utilization created many job opportunities in the country.

Old Tyres are widely used in boats and barges in crowded ferry route in urban and suburban area of the country as shown in Figure 2a. The tyres are tied on the outside of outer extremities of water vessel to save them from different type of common shocks occur in normal navigation process specially during arrival in to the jetty. Usually a small boat needs 6 to 12 number T6 to T7 type Tyres. Tyre type T2 to T6 are used for larger barge or trawler with different numbers.

Large size burnt clay pitcher are widely used to store drinking water in roadside food shops. They use tyres to hold the pitcher safely in position as their bottom is spherical. The tyre provides a soft and durable base for this kind of earthen pitcher as shown in Figure 2b. Some times old tyres are kept in front of a garage as a symbol or signboard of tyre shop.

The used rickshaw or bicycle tyres are used as a bottom guard for hand made cane chairs, the local name is Mora. The bottom guard save the bottom part of the Mora from wear and tears during uses and consequently increase their life.

(a) Use in boats to resist impact from other vessel/object

(b) Earthen Pitcher Containing Water

c) Part of tyre stored for selling to brick field owner

d) On-site storage of tyre cut-piece at brick field

Figure 2 Miscellaneous use of old tyre

There is a greater scarcity of natural stones used as building material in Bangladesh. As an alternative a larger number of bricks made from clay are burnt in the brick kiln by burning fossil fuels traditionally. A large number of tyres have been beneficially replaced some of the fossil fuels used in the brick making process in Bangladesh. Abidance is available that four kilns in the UK have received full authorization to burn tyres with a combined capacity of over 100,000 tones. It is very difficult to collect data from brick factory regarding tyres burning in the brick field. They think that they are doing an illegal job. For incineration of mixed solid waste the temperature of burning should be above 800 ^{o}C (Davis and Cornwell 1998). The temperature for brick burning in brick kiln is usually above 1100 ^{o}C (Aziz 1981). Therefore it is safe to burn the tyres for brick burning in Bangladesh. It is expected from this research that there should be immediate permit for tyre burning in brick kiln in absence of any guideline. It will minimize a partial demand of the fuel for brick burning every year which is must as we need a huge number of brick for construction. It will also release the headache of the authority for its final disposal.

Search of new alternative usages including as aggregate in flexible concrete and different disposal methods is going on. A project on the strength behavior of tyre dust mixed concrete is going on in the Department of Civil Engineering, KUET. The initial result showed that the mixing of certain percentage of tyre dust highly increase the ductility with a tolerable reduction in compressive strength. This implies their further utilization in shock resisting members of the structure or foundations.

EMPLOYMENT GENERATION

Recycling of tyres in Khulna city is not only reducing environmental hazards but also creating job opportunity for low income group. Many people involve themselves in each phase of tyre recycling and thereby self employed. There are five tyre resoling factories providing job for around fifty workers. After getting experience from these factories, workers moves towards better factories for higher salary or open another factory in different area. Hence increase the job scope & reduce unemployment rate. It also creates work facilities to surrounding district like Pirojpur, Bagerhat, Satkhira etc. where there are no resoling factories. Some people from those areas have some form agreement with the factories existing in Khulna, for resoling at a reduced price. They collect order for resoling from those areas, resoled from Khulna at the contract rate and thereby continue their business without investment of huge capital.

There are a large number of garages in this city area. Two to three numbers of workers work in each garage. In addition, new product making shops also creates some sorts job field. Again some people involve themselves in a business of collecting tyre dust & cut piece and sell those to shoe sole factories & brick filed owner respectively. Thus tyre recycling process has an impact on poverty alleviation of the increasing population through income generation.

PROPOSED TYRE RECYCLING PATTERN

The tyres in due course are returned to the waste stream for subsequent treatment or environmentally safe disposal. As the old Tyres have a certain level of monitory value, the overall management of old tyre as a part of solid waste does not impose much pressure on the authority. A practical old tyre management diagram for cities and towns of Bangladesh based on the data collected in Khulna can be proposed as diagram shown in Figure 3.

It is observed that there exist continuous safe use & management practices of the used & torn tyre. New tyres enter into the market of Khulna through dealers, who collects those from Dhaka where importers imports from India, China etc. These tyres are then absorbed fully by different phases. These phases can be described in a flow chart shown below where dealers are in first phase. In second phase dealers distribute tyres to different tyre selling shops. Individual vehicle owner & different offices like Govt. & NGO's which uses tyres for their vehicle are in third phases. They buy tyre in retail price from tyre selling shops. These tyres are then used by them for a certain period. Afterwards these are either resoled or totally go to the brick field as a fuel.

Companies & offices store used tyres for a certain period and call for tender in order to clear their store which involve inventory control. Here exists a significant management practice. Company's call open tender for selling their used & worn tyre in a recurring period. Generally owner of resoling factories, tyre repairing shops and even of brick fields bid for the same. On the other hand, individual owner generally resoled their tyre for at least two-times and then sell it to the tyre repairing shops which are in fourth phase. Basically this phase is responsible for safe environmental disposal of worn tyres. These shops generally exist at different locations of city area, beside the main city roads; and help people by pumping air & repairing lick in tyre. Thereby they get well known to the drivers of individual vehicles from whom they buys worn & used tyres directly. And depending upon the condition, they sell tyres to either secondary product maker or resoling factories which are also in the same phase. Some times boat owner (to resist impact), men driven cart (locally called thela gari), etc also collect tyres from them.

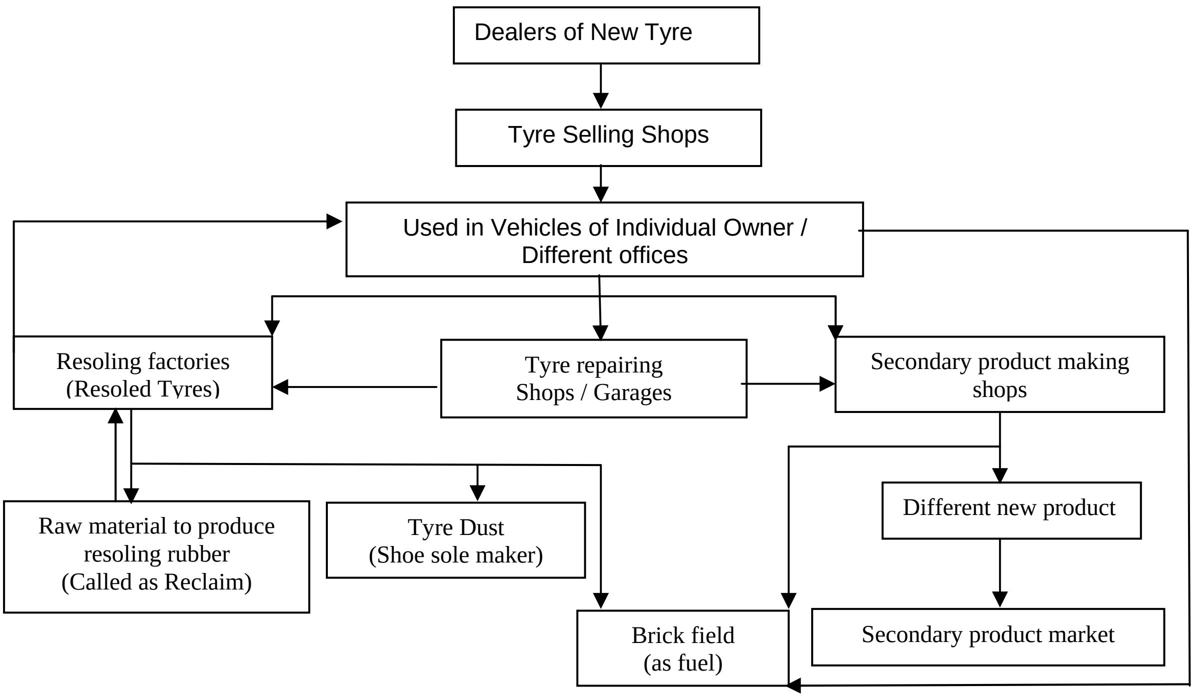

Figure 3 Tyre recycling pattern

Secondary product maker are doing excellent job. Searching of the background of these people gives amazing information. That is they actually have no technical knowledge & training but depending upon their practice and thereby gathering experience they make different new product from worn tyres as per demand. Sometimes it requires replacing different types of accessories of machines which can be built from tyre such as washer, gasket, bucket etc. If in case of emergency those parts are not available in the market in proper shape & size, people have no other alternative to go except these shops. For example, rice mill owners supply the size & shape of flat belt; and order them for the same which is very cheap rather than replacing that by a new one. Thus they are enormously helping to run factories, machines, pumps, vehicles etc. at a cheap cost. These shops generally collect worn tyres from garages (tyre repairing shops). They also bid the tender for worn tyres.

Tyre resoling factories are in the phase four. They usually collect old tyre which can be resoled. Here exist a good collaboration in between different garages and factory owners. These factory owner buys resole able worn tyres from garage owner and also gives incentive to influence them for catching the resoling order from individual vehicle owner. Hence maximum of the vehicles comes into their resoling stream. While producing resoled tyre, huge amount of tyre dust & cut piece are produced. They don’t throw these into the open environment rather they sell those. Tyre dust are used for making shoe sole which is a fantastic solution and can be considered as a fifth & final phase in the flow path. These dusts are also used to produce raw material to produce resoling rubber (Called as Reclaim).

Huge amount of cut piece are produced in resoling factories & secondary product makers shops. They store it consciously in a safe place and sell it to the brick filed owner after having sufficient amount. Brick field owner some times hire the secondary product makers for cutting the tyres which they directly buys as a full shape tyre. Use in brick field as fuel can be considered as final phase of the flow path.

CONCLUSIONS

The results depicts that

1. The tyres are used for different purposes in environmental sound process;
2. Old tyres are resoled to make it fit for reuse in motor vehicle;
3. A number of Tyre is disposed in environmental friendly way such as fuel for brick kiln.

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Waste Water Generation Scenario of Fish Processing Industries at Khulna City of Bangladesh

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ABSTRACT

Frozen fish food exports have been considered the second largest foreign exchange earners sector of Bangladesh to which numerous hatcheries, ponds and processing plants are associated. A significant numbers of fish processing industries are located in Khulna, the southern coastal region of the country. Along with their major contribution to the country's economy they also generate substantial wastes which are responsible for pollution that can affect the ecosystem. Analysis reports that Fish and shrimp processing effluent are very high in total suspended solid (TSS), moderately high in total Kjeldal nitrogen (TKN) and phosphate (PO_4^{3-}) and high in chemical oxygen demand (COD). Foreign importers impose some guidelines to these industries to maintain standard fish processing operation and then to sanitize the effluent emanated from the plant before they mix with the nature. In spite of understanding the bare necessity of this waste management, the local investors cannot cope with these regulations.

INTRODUCTION

Fish processing industries significantly are contributing to food security aspects in global scale. Global production of fish and shrimp has been in a steadily increasing trend over the last decade and this trend is expected to continue (FAO 2002). Of the estimated 131 million tons of fish produced in 2000 in the world nearly 74% (97 million tons) was used for direct human consumption. The remainder (about 26%) was utilized for various non-food products. In 2000, more than 60% of total world fisheries production underwent some form of processing (FAO 2002). The most important part of the fish products destined for direct human consumption was fresh fish (a share of 53.7%), followed by frozen fish (25.7%), canned fish (11.0%) and cured fish (9.6%). As a highly perishable commodity, fish has a significant requirement for processing. Shrimp production is the second largest export sector of Bangladesh after ready made garments with a share of about 5 percent in Bangladesh's total exports in the 1990s. In FY2003 shrimp exports amounted to US$ 297.04 million which was 4.54 percent of total exports. Two types of shrimps are cultivated in Bangladesh (i) *Golda, which* are sweet water shrimp can be cultivated in any region,(ii) *Bagda,* are the shrimp of brakish water which are cultured in the coastal district of Chittagonj, Khulna, Bagerhat and Shatkhira. The share of shrimp export in total export income from fish and fish products is almost 90 percent (2003). More than 2 million people are engaged in upstream and downstream activities related to shrimp industry in the country - in harvesting, culture, processing, exporting and other ancillary activities (Khatun 2004).

Numerous fish processing plants are situated in Khulna, south west region of Bangladesh which stands along the bank or a short distance away from Rupsha River. According to BFFEA (2004) there are 128 shrimp processing factories located in Khulna, Bagerhat, Satkhira and Chittagong spelled out of which 61 has license from the government to export, 44 has the permission to export to the EU (BFFEA 2004).Observing the growing demand and profit of shrimp industries, entrepreneurs are establishing new shrimp processing industries at that location. Therefore, currently in this particular region these shrimp processing industries along with some cement industries are the main focal point of economic activities.

For quality assurance of frozen fishes and prawns of Bangladesh for export, the HACCP (Hazard Analysis Critical Control Points) system is very much needed, from the point of catch up to consumption, i.e., during the journey from farm to processing plants and storage via some middle-men or agents. Precaution should be taken at every phase of the processing of raw materials. Quality maintenance might reach at a level that satisfies the customer, and also is economical to the producer or seller (Connell 1971). In the year 1997, EU (European Union) Commission imposed a temporary ban on prawns exported from Bangladesh for unhygienic condition of the product. However, after the introduction of HACCP system in 1998, the bacterial load of Bagda (Penaeus monodon) decreased more than three times than the previous year (Bhuiyan 2004). Fresh fish increased in volume (live weight equivalent) from an estimated 28 million tons in 1990 to 52 million tons in 2000 with a corresponding increase in the volume of processed fish (frozen, cured and canned) from 43 million tons in 1990 to about 45 million tons in 2000. Freezing represents the main method of processing fish for human consumption, and had a 55% share in 2000. In developed countries, the proportion of fish that is frozen has been constantly increasing, and frozen fish has become the most common form of product, with a share of 40% of fish production. Considerable studies have been done on the characterization of the processed products as well as the different possible modes of utilization of fish (Garc_ıa-Arias et al. 1994; Espe et al. 2001; Stepnowski et al. 2004) and shrimp (Jeong et al. 1991; Shahidi and Synowiecki 1991; Benjakul and Sophanodora 1993; Lee and Um 1995; Chung et al. 1996; Shahidi et al. 1999; Mok and Song 2000; Mok et al. 2000) processing by-products. However, the wastewater generated from fish and shrimp processing plants, the waste loads as well as the role of the wastes in environment have not been receiving enough attention since long.

CHARACTERIZATION OF THE SHRIMP AND FISH PROCESSING WASTEWATER

It is particularly important not only for the protection of the ecosystem but also for the sustainability of the fishery itself. The present paper attempts to synthesize and discuss the characteristics of shrimp and fish processing wastes and the probable impacts on coastal habitat and fishery sustainability.

MATERIALS AND METHODS

Study Sites

Samples as effluent were taken in July 2009 from the outlet of three shrimp processing industries along the bank or a short distance away from Rupsha river (Figure 1). Fish processing plants were visited and collected all sorts of activities involved during the completion of the whole processing.

Sampling and Analysis

Surface water samples were taken from each sites by using 1litter polyethylene bottles and transported to laboratory in a cooler box. Storage, preservation and analytical methods for particular parameter were used as standard method (APHA 1992).

RESULTS AND DISCUSSIONS

Fish Processing Plant Investigation

Most of the seafood processing industries in Khulna deal with the processing of the shrimp (local name both *Bagda* and *Galda* shrimp). As these industries are export oriented, so their process operation is supposed to comply with the international standards specified by Codex Alimentarius Commission provisions and has to meet buyer specifications as well as the regulatory requirements of the importing country (Khatun 2004). For the assurance of the quality of exported frozen fish, the HACCP (Hazard Analysis Critical Control Points) system has been adopted in 1998 (Bhuiyan 2004) which has been widely recommended by the buyers. Some of those industries did not comply with these guidelines due to large investment though they are now in the way of updating their process operation.

The main inputs in processing plants are fresh or iced fish and shrimp, water and ice. The chemicals which have been used are general salts (NaCl), STTP (Sodium Tripolyphosphate, $Na_5P_3O_{10}$), bleaching

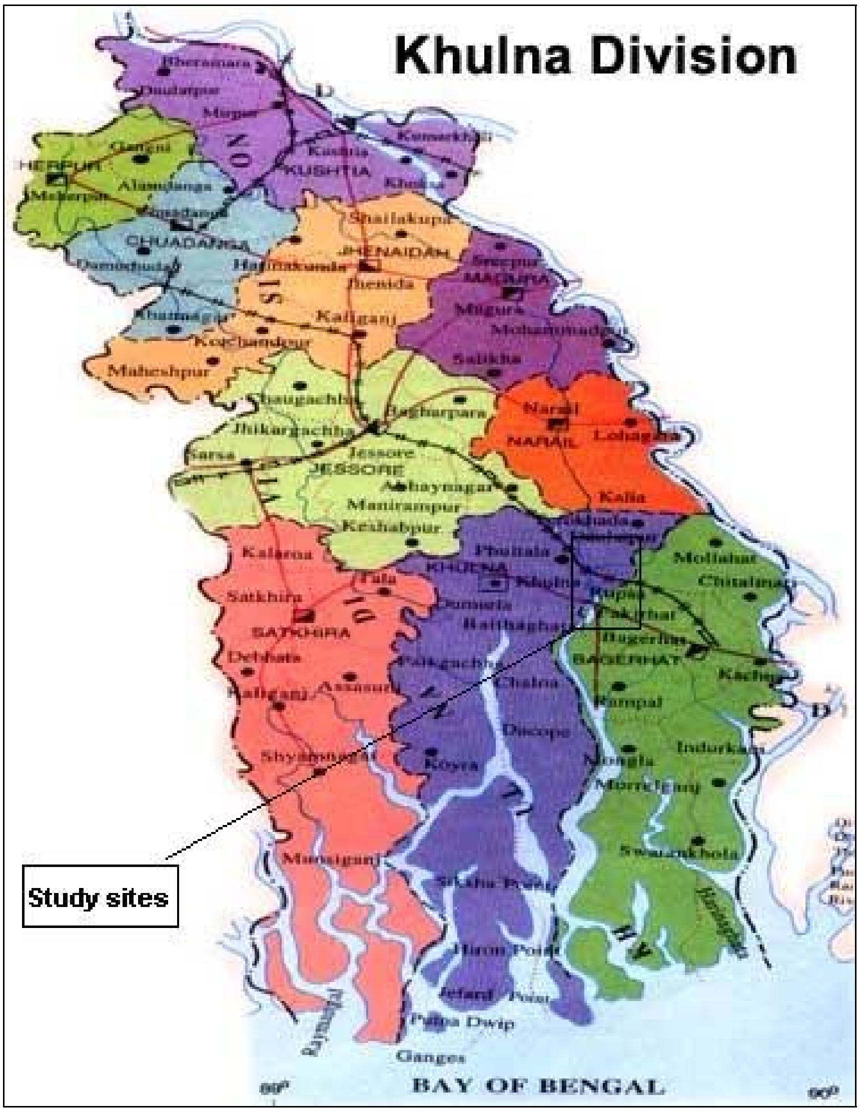

Figure 1 Study area

Powder (Calcium hypochlorite, $Ca(ClO)_2$). Soap are used both in hard and liquid form for washing and cleanliness purposes.

STTP are legally permitted additive which are widely used in the processing industries. The main benefit to use STTP in shrimp processing industries is to improve the retention of water by the protein in fish which increase the weight of shrimp. This purpose can be served with other salt but with unwanted flavor effects. Besides, its use before freezing reduces thaw drip. Bleaching powder is universally used disinfectant against microorganism that has approximately 30% residual chlorine. This chemical is added in water at the entrance, floor and waste treatment cell of shrimp processing plant to maintain the hygiene and to destroy microorganism.

The generated waste can be categorized as solid and liquid. The solid waste includes the head, shell, fin and tail of the shrimp. This solid waste accounts for approximately 50% of the volume of raw materials. Generally these are removed during processing and disposed separately from the plant (Figure 2). The operation of beheading or normal processing is done according to the requirement of buyers. Shrimps' heads consist of brain which is sold in the local market immediately after beheading as food item to the poor people. Recently, some industries have been established in that locality whose job is to sun-dry the shrimps' heads. This process produces the stinking smell that aggravates the air pollution condition.

Figure 2 Disposal of Shrimps' head from the processing plant.

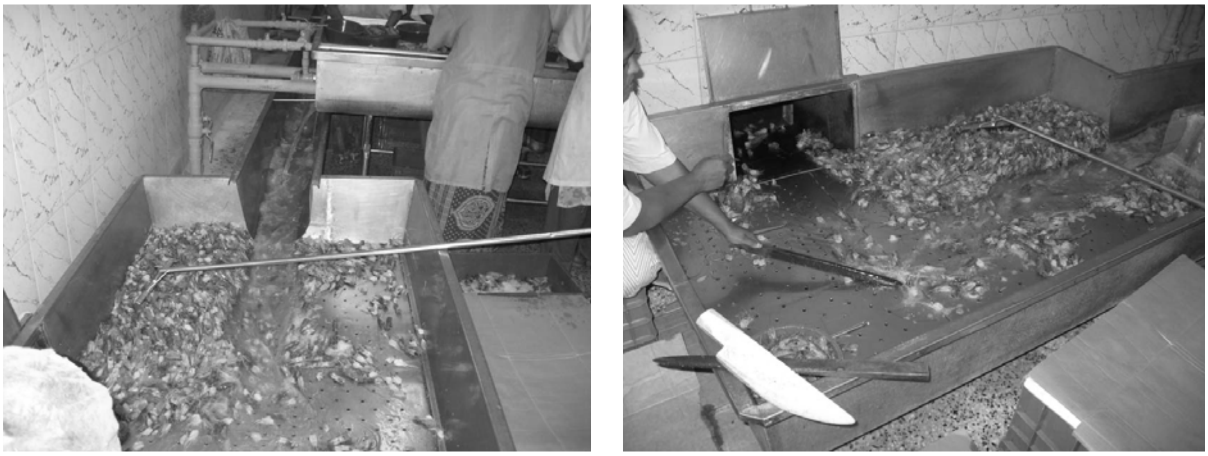

Figure 3 Washing out of the solid and liquid waste of shrimp inside the plant

Figure 4 Bleaching powder application and scum development at the waste water treatment cell

The wastewater from frozen seafood processing plants contains large amounts of organic matter, small particles of flesh, soluble proteins, and carbohydrates. Each and every phase of the washing process produces waste water (Figure 3). Besides, the water used for foot cleaning purpose at the entrance of the industry also passes through the effluent line mixing with proper doses of bleaching powder.

Almost all the surveyed industries have wastewater management zone which generally consist of three chambers. All the chlorinated water produced in the plant along with raw effluents with suspended and floating substance accumulates in the first cell and get screened. Scum is formed at regular intervals in this chamber which is collected and buried in soil with bleaching powder (Figure 4). In the second chamber, additional bleaching powder is added to increase the concentration of the residual chlorine that destroys the rest of the microorganisms in the effluent. At the last chamber further screening is arranged and supernatant liquid discharged into the nearby marshy land, canal or directly into the Rupsha river.

The whole process is diagrammed into the following flow chart where the total method of processing operation, waste generation, their disposal and activities of treatment plant has been shown in Figure 5.

Characterization of Fish Processing Plant Effluent

The results obtained for the waste water samples collected from five sampling sites are presented in Table 1. The pH values in water samples were within the tolerance limit (pH: 6.5 to 8.5) except in sampling site-II which was 6.3. Salinity range of the effluent water was from 4.5 to 6 which is not a problem because processing plants situated along the Rupsa river containing saline water over the year.. So these effluent waters can not influence the salinity of this river when these are dumped. Concentration of chlorides was also usually normal as can be specified for salinity. TSS and COD values of the effluents were beyond the tolerance limit specified by Department of Bangladesh (DoE 1991). The range for TSS and COD in effluent samples was 900 to 2700 mg/L and 200 to 420 mg/L respectively (Figure 6). The TKN and TP are also high than the standard but comparatively low than the global scale (Carawan et al. 1986; Park et al. 2001). The environment quality standard for COD and TSS are 200mg/L and 150 mg/L respectively. In this study shows that TSS is extreamly high than the standard. The phosphate value is also high than the Standard (5 mg/L) due to the use of phosphate containing compounds as additive. Total kjeldal nitrogen is also high. This is due to the dissolved organic content of shrimp body as solid waste.

Table 1 Characteristics of raw waste water collected from different fish processing industries in Khulna

Processing Plant	pH	Salinity in ppt	TSS in mg/L	COD in mg/L	Cl^- in mg/L	Residual Cl in mg/L	TKN in mg/L	PO_4^{3-} in mg/L
Site-I	7.4	5	2200	200	2769	<5	128	22
Site-II	6.3	4.5	900	370	3120	<5	79	29
Site-III	6.8	6	1800	290	2290	<5	82	34
Site-IV	6.8	4.5	2100	310	2840	<5	59	31
Site-V	7.1	6	2700	420	2895	<3	210	41

The most important chemical used in the fish processing plant is Calcium hypochlorite, $Ca(ClO)_2$ known as bleaching powder. This chemical is used for the washing purpose in order to disinfect the microbial activities. Due to large amount use of bleaching powder residual chlorine as reactive chlorine should be present in waste water which is extremely harmful for aquatic organism. But In this study residual chlorine could not be found in waste water. Probably form of chlorine can be changed and hence the much research would be necessary in order to find the form of chlorine in water as well as in sediment.

Although the volume and characteristics of shrimp and fish processing effluents often exhibit extreme variability, waste production in seafood processing industries are usually high in volume (Carawan 1991; Park et al. 2001) Waste water as effluent from processing plant are primarily organic in nature and therefore subject to bacterial decay. As a result, the oxygen concentration in the water is reduced with an increase in BOD. This can starve aquatic life of the oxygen it needs and anaerobic decomposition of organic matters lead to the breakdown of proteins and other nitrogenous compounds, releasing hydrogen sulphide, ammonia and methane, all of which are potentially hazardous to the ecosystem and toxic to marine organisms in low concentrations. Nutrients resulting from decaying organic matter enhance plant growth and excessive plant growth together with oxygen depletion can lead to alterations in ecosystem structure and these are both features of eutrophication. Partially decomposed processing effluents entering coastal waters contain a variety of harmful substances and pathogens and a variety of other organic and inorganic wastes. Around the point of discharge, there is a short-term increase in nutrients and, hence, prey items for the fish and, on occasions an increase in habitat complexity, which may cause an initial population rise in fish species.

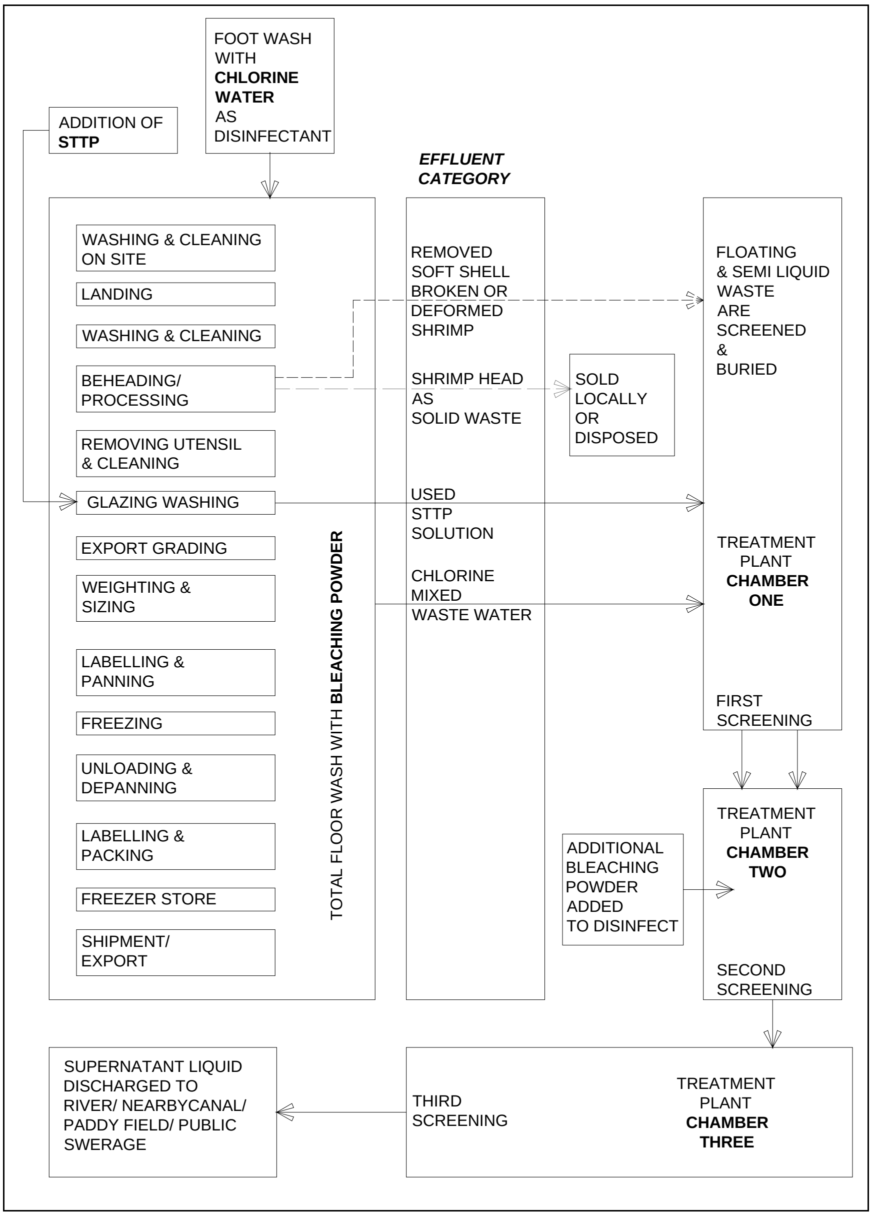

Figure 5 Typical process flow chart showing waste generation and removal of a processing plant

Yet, as nutrient levels increase so does the chance of algal bloom development, toxin production and a corresponding decrease in dissolved oxygen. Long-term effects include phytoplankton biomass increases and large scale decreases in species diversity with benthic and fish communities (Bonsdorff et al., 1997). Fish species feeding in water contaminated by algal toxins will absorb these toxins and are subject to mass mortality.

Eutrophication has been shown to cause major changes in species composition, structure and function of marine communities over large areas. The general response of phytoplankton communities to eutrophication involves an increase in biomass and productivity (Riegman 1995). A general shift from diatoms to dinoflagellates, and also down shift in size in phytoplankton towards a dominance of small size nanoplankton generally observed (Kimor 1992). A similar response is observed in zooplankton communities, with herbivorous copepods being replaced by small-size and gelatinous zooplankton (Zaitsev 1992).

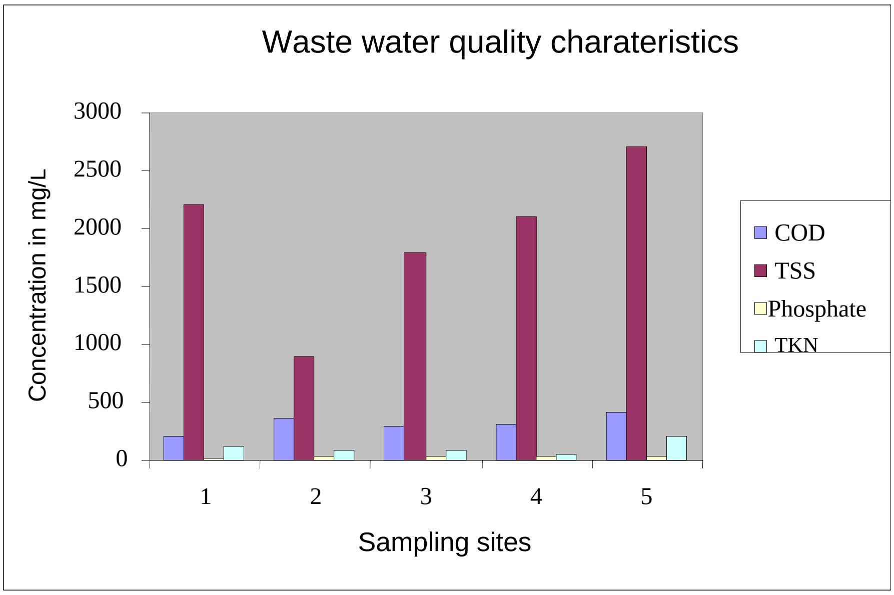

Figure 6 Waste water quality parameters of different fish processing plants

Eutrophication also promotes proliferation of macroalgae and filamentous algae. This often becomes a nuisance, and may affect benthic fauna, nursery and feeding of fish, amenity, recreational uses and tourism (Riegman 1995). Eutrophication-induced hypoxia alters the structure, diversity as well as trophic structure and food web of benthic and fish communities (Riegman 1995). Other potential problems caused by the mass release of processing wastes and associated debris are the loss of amenities affecting the recreational use of water. The spatial and temporal scale of the impacts of seafood processing wastes may vary depending on the amount and nature of the waste output. However, local impacts are particularly obvious because wastes from processing industries are generally produced throughout a year giving no chance for the environment to recover. Impacts are more likely to be detrimental when the same ecosystem receives wastes from cluster of processing industries.

Any literature is hardly available regarding the magnitude of regional and global loads of effluents produced by the fish processing industries and related impacts on ecosystem. Given the absence of any reliable estimate of the global production of fish processing wastes and the waste characteristics, an attempt was made to analyze the approximate waste quality in order to characterize as it is suitable for environment.

CONCLUSIONS

Production of fish and shrimp processing wastes and their discharge into the coastal and nearshore environment has not been quantified in details. Little is known about the probable role of fish and shrimp processing industries in polluting the coastal and marine environment. General impacts of processing wastes are believed to be the same as other sources of pollution that cause eutrophication of the environment. The hypothetical global values of the volume of water used by the seafood processing plants and the associated waste loading parameters reported in this paper show that the processing plants posses potential for polluting coastal and nearshore environments. It is also important the cost benefit analysis for pollution abatement program with the production fish processing. However, application of simple treatment options such as screening can substantially reduce the waste loads. For greater interest and sustainability of the fishery industry, processing plants should establish effective effluent treatments which are generally cost effective and monitoring facilities to reduce waste loads and pressure on the ecosystem.

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Engineering Properties and Permeability of Concrete in Presence of Rice Husk Ash

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ABSTRACT

This paper depicts the results of an experimental investigation on the engineering properties and permeability of concrete in presence of Rice Hush Ash (RHA). For every 1000 kgs of paddy milled, about 220 kgs of husk is produced and after burned in boilers about 55 kgs of RHA is generated and dumped as waste. This study investigates the effect of this waste in concrete. RHA was collected from an uncontrolled burning system. Cement was partially replaced by this RHA for concrete production. Cylindrical specimen of 200 mm × 100 mm were cast with different mixing proportions and water-cement ratios. The specimens were cured at 14, 28 and 90 days to find out the permeability and compressive strength of concrete. The experimental result reveals that the compressive strength of concrete increased in the range of 16% to 19% for 10% replacement of cement by RHA and for 20% replacement the result was not significant. In addition, it can be noted that the permeability of concrete was decreased up to 14% in presence of 20% replacement of RHA.

INTRODUCTION

Bangladesh is an agriculture based country and rice is the main crop accounting 76% of total agricultural cropped area and contributing 95% of cereal food for the nation (Ahiduzzaman 2007). Rice is the staple for the 150 million Bangladeshis who obtain more than 70% of their total calorie from rice. The per capita rice consumption in Bangladesh is higher than that in any other country where rice is the staple. There are main Three biomass by product comes from rice viz. rice straw, rice husk and rice bran. Rice straw and rice bran are used as feed for cattle, poultry, fish etc. and the rice husk is used as energy (Ahiduzzaman 2007).

Rice husk is an agricultural residue from the rice milling process. According to FAO (2008), the annual rice production in Bangladesh for 2007 was estimated by 43.504 million tons, the Husk constitute approximately 20% of it and the RHA approximately 5.5%. The chemical composition of Rice Husk is found to vary from sample to another due to the differences in the type of paddy, crop year, climate and geographical conditions (Chandrasekhar et. al. 2003). Considerable efforts are being taken worldwide to utilize local natural waste and by-product materials in making concrete, such as Rice Husk Ash (RHA) as supplementary cementing materials to improve concrete properties (durability, strength, etc.). The effect of using RHA as a partial replacement for cement has been investigated.

Concrete is a stone like materials produced from a carefully proportioned mixture of cement, aggregate and water. Depending on a structure's requirements, these components are mixed in specific ratios to achieve the desired quality and design specifications (Shetty 2003). Strength of concrete is commonly considered its most valuable property although in many practical cases other properties like permeability may in fact be making important. The compressive strength of concrete is very important, as it is used more often in compression than in any other way. It is rather difficult to give average values of the compressive strength of concrete, as it is dependent on so many factors. The available aggregates are so varied, and the methods of mixing and manipulation so different, that tests must be studied before any conclusions can be drawn. For extensive work, tests should be made with the materials available to determine the strength of concrete, under conditions as nearly as possible like those in the actual structure.

Permeability is defined as the coefficient representing “the rate at which water is transmitted through a saturated specimen of concrete under an externally maintained hydraulic gradient” (Suprenant 1991). Permeability is inversely linked to durability in that the lower the permeability, the higher the durability. Concrete is a porous material. Therefore, moisture movement can occur by flow, diffusion, or sorption. Generally the overall potential for moisture and ion ingress in concrete by there three modes is referred to as its permeability. The permeability regulates the speed of aggressive water penetration for inside of the concrete. The porosity of concrete is varies in accordance to the composition of the concrete, its factor water cement, its age and even though with its form of launching. The rate of chloride penetration into concrete is affected by the chloride binding capacity of the concrete. The objective of this study is to investigate the effect of Rice Husk Ash on the strength and permeability of concrete.

MATERIALS AND METHODS

Rice Husk Ash

The Rice Husk Ash used in this work was made in the laboratory by simply burning it over a steel sheet without controlling the burning temperature and time. After completion of burning the ash was grinded by grinding machine and finally collects the ash which was paned through 200No. BS sieve.

Aggregate

The Fine Aggregate (FA) used was river sand passing from 4.75 mm sieve with Fineness Modulus (FM) of 2.61 and absorption 0.76 %. The Coarse Aggregate (CA) was crushed stone with maximum size of 20 mm with specific gravity of 2.65 and water absorption 1.41 %. A grain size distribution curve of fine aggregate is shown in Figure 1 and that of coarse aggregate shown in Figure 2, and also the particle sizes are given in Tables 1 & 2.

Cement

The Cement (C) used in this work was Ordinary Portland Cement (OPC) with 3 days compressive strength 17.7 Mpa, 7 days compressive strength 21.2 Mpa, 28 days compressive strength 35.9 Mpa, Normal consistency 25.0%, Initial setting time 46 minutes and the final setting time 335 minutes.

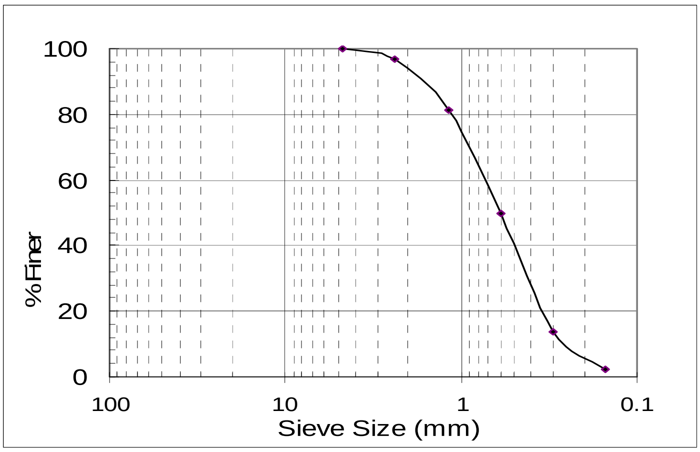

Figure 1 Grain size distribution curve of fine aggregate

Table 1 Particle size distribution of fine aggregate

Sieve size (mm)	Weight retained (gm)	Cumulative weight retained.(gm)	Cumulative % weight retained	% finer
4.76	0.50	0.50	0.10	99.90
2.36	15.10	15.60	3.12	96.88
1.818	78.00	93.60	18.72	81.28
0.600	157.00	250.60	50.12	49.88
0.300	180.50	431.10	86.22	13.78
0.015	57.00	488.10	97.62	2.38

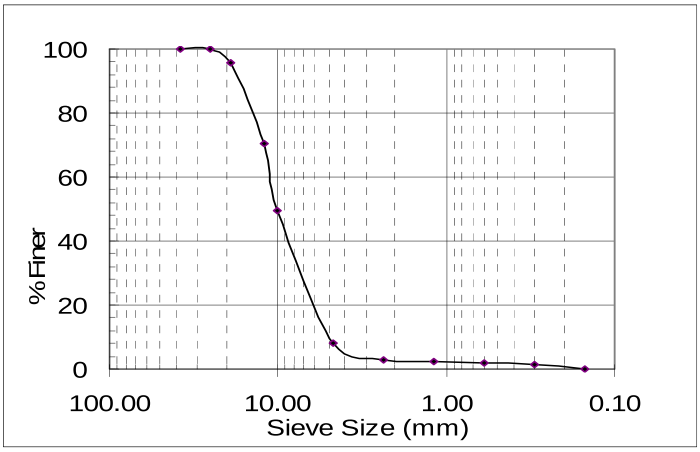

Figure 2 Grain size distribution curve of coarse aggregate

Table 2 Particle size distribution of coarse aggregate

Sieve size (mm)	Weight retained (gm)	Cumulative weight retained(gm)	Cumulative % weight retained	% finer
38	0.00	0.00	0.00	100.00
25	0.00	0.00	0.00	100.00
19	272.34	272.34	4.48	95.52
12	1515.49	1787.83	29.41	70.59
10	1278.17	3066.00	50.44	49.56
4.76	2530.94	5596.94	92.07	7.93
2.36	312.06	5909.00	97.20	2.80
1.818	31.00	5940.00	97.71	2.29
0.600	28.00	5968.00	98.17	1.83
0.300	32.00	6000.00	98.70	1.30
0.015	79.00	6079.00	100.00	0.00

Mixture Proportioning

The mixture proportioning was done according to the current British mix design method (Neville 2005). The target mean strength was 40 MPa for the OPC control mixture. The total mixing time was 5 minutes; the samples were then casted and left for 24 hrs before demoulding. They were then placed in the curing tank at 23 ± 2^{o}C until the day of testing. Mixing proportion of concrete samples are given in the Table 3.

Table 3 Concrete mixture proportioning

Sample	A1	A2	A3	B1	B2	B3	C1	C2	C3
Cement (kg)	462	315.5	369	336	302.5	269	242	218	194
RHA (kg)	0	46.5	92	0	33.5	67	0	24	48
FA (kg)	554	554	554	404	404	404	291	291	291
CA (Kg)	1016	1016	1016	740	740	740	533	533	533
Water (liter)	254	254	254	185	185	185	133	133	133
W/C ratio	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Permeability Testing Procedures

A schematic diagram of the device used in this study is shown in Figure 3. Instrument used for measuring the permeability of concrete is a voltage generator, potentiometer analyzer, milliampermeter, magnetic agitator and diffusion cell. The diffusion cell is a cylindrical PVC tank covered with a lid. The test tube is a cylindrical core of concrete (100-mm diameter and 100-mm height) in which a secondary drilling produces a central cavity of 40-mm diameter as presented in Figure 4. This tube is fixed firmly in the cell by the intermediary of a hollow PVC roll. The sample delimits two compartments sealed by two elastomer membranes. The external compartment contains 0.1M/L of NaCl. This solution is homogenized periodically by mechanical agitation. A cylindrical stainless steel electrode dips in this solution and is connected to the negative pole of the generator. The internal compartment contains 0.1 M/L NaOH uninterruptedly homogenized by magnetic agitation. A carbon electrode dips in this solution and is connected to the positive pole of the generator. The amount of chlorides that diffuses through the porous tube of concrete is followed with a great sensitivity using a chloride probe. The detailed fabrication of the testing procedure and device can be followed of AASHTO (1990), ASTM (1993) and also Streicher et. al. (1995)

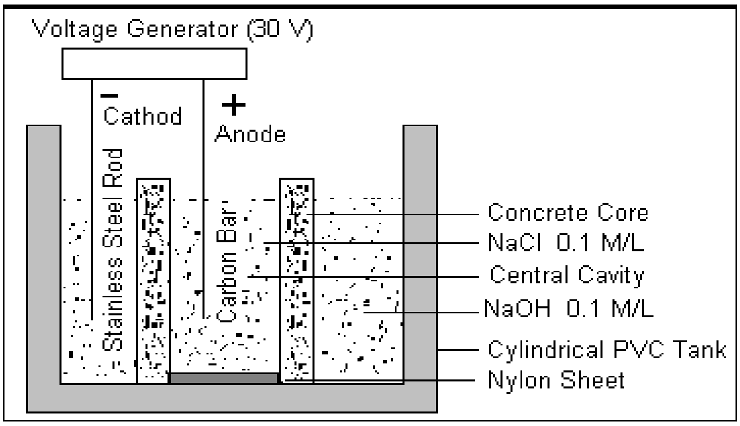

Figure 3 Chloride migration device

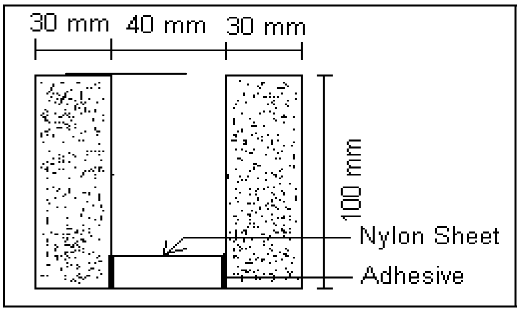

Figure 4 Concrete core

RESULTS AND DISCUSSIONS

Compressive Strength

The average of three results of compressive strength of concrete is shown in Table 4 and also presented in Figures 5 and 6. The age of concrete specimen used it find out this property at 14, 28 and 90 days and shown in Figures 5 and 6. It is observed from the result at early age, concrete without RHA shown better results and at later the results was reverse.

Table 4 Compressive strength of concrete at different age

Sample ID	Strength (Mpa)		
	14 days	28 days	90 days
A1	13.72	15.72	18.88
A2	12.72	15.46	21.82
A3	12.55	15.28	19.36
B1	16.15	18.83	20.48
B2	15.21	18.45	24.65
B3	14.99	18.25	23.07
C1	6.81	7.32	9.01
C2	6.8	7.40	10.67
C3	6.42	7.04	9.75

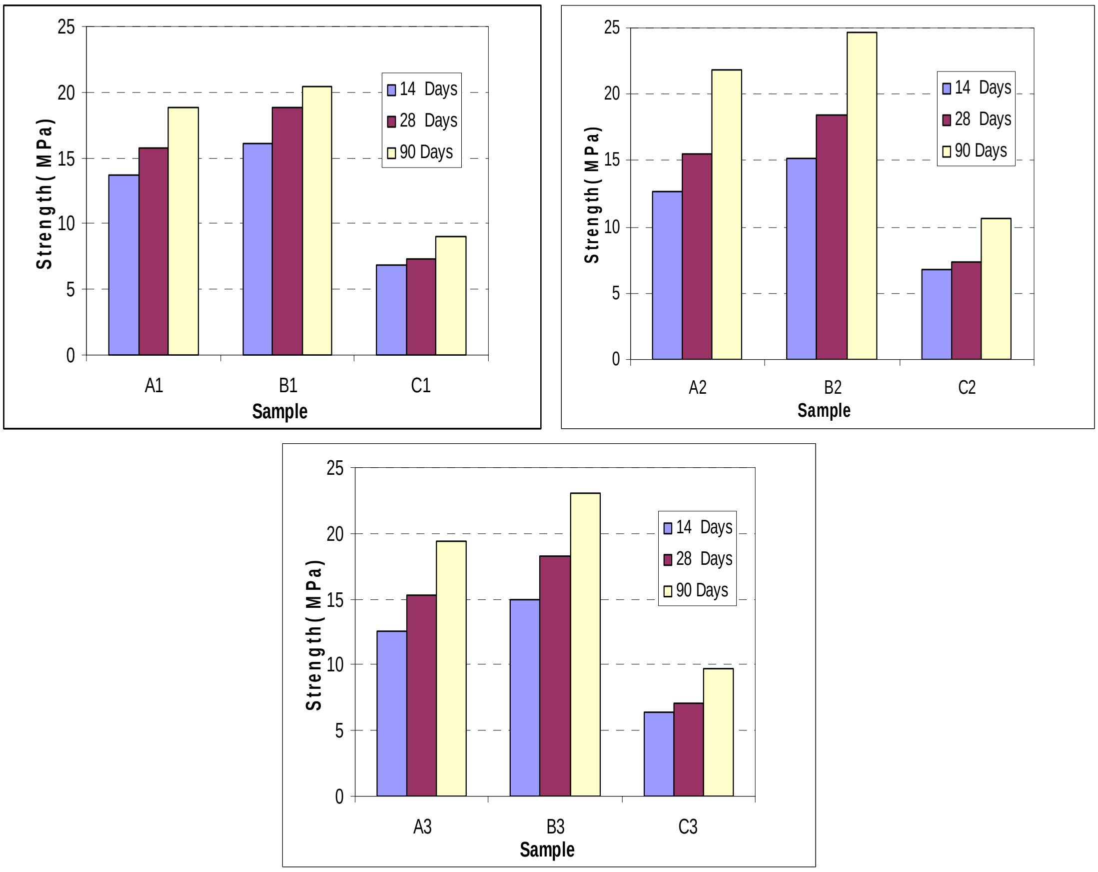

Figure 5 Variation of compressive strength of A, B and C sample

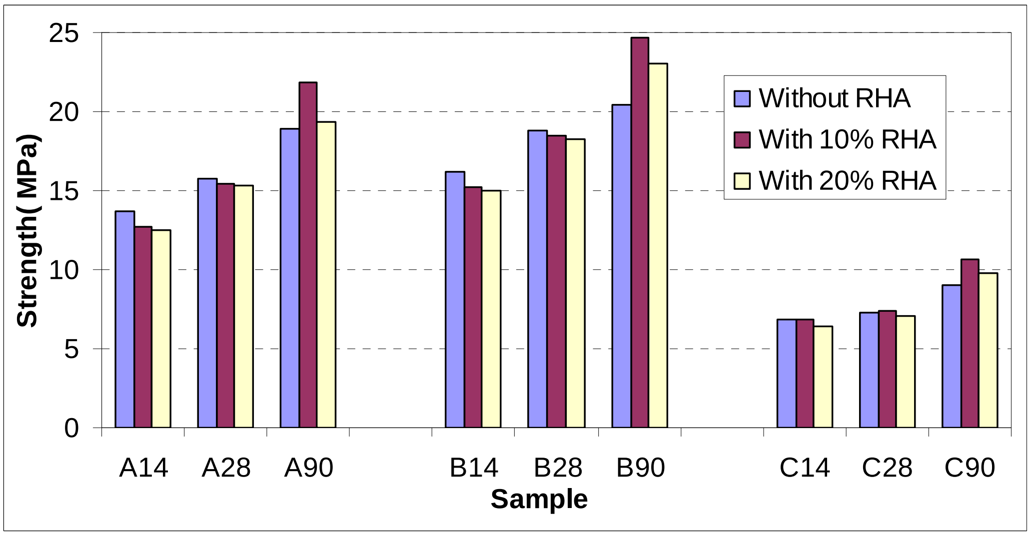

Figure 6 Variation of compressive strength of the sample

Permeability

Permeability is most frequently described by the chloride-ion permeability test, which measures the passage of electrical current through a concrete specimen exposed to a batch of sodium chloride. The permeability of concrete depends on the pore structure of concrete while electrical conductivity of concrete is determined by both pore structure and the chemistry of pore solution. The electric charge passes through the concrete sample is given in Table 5.

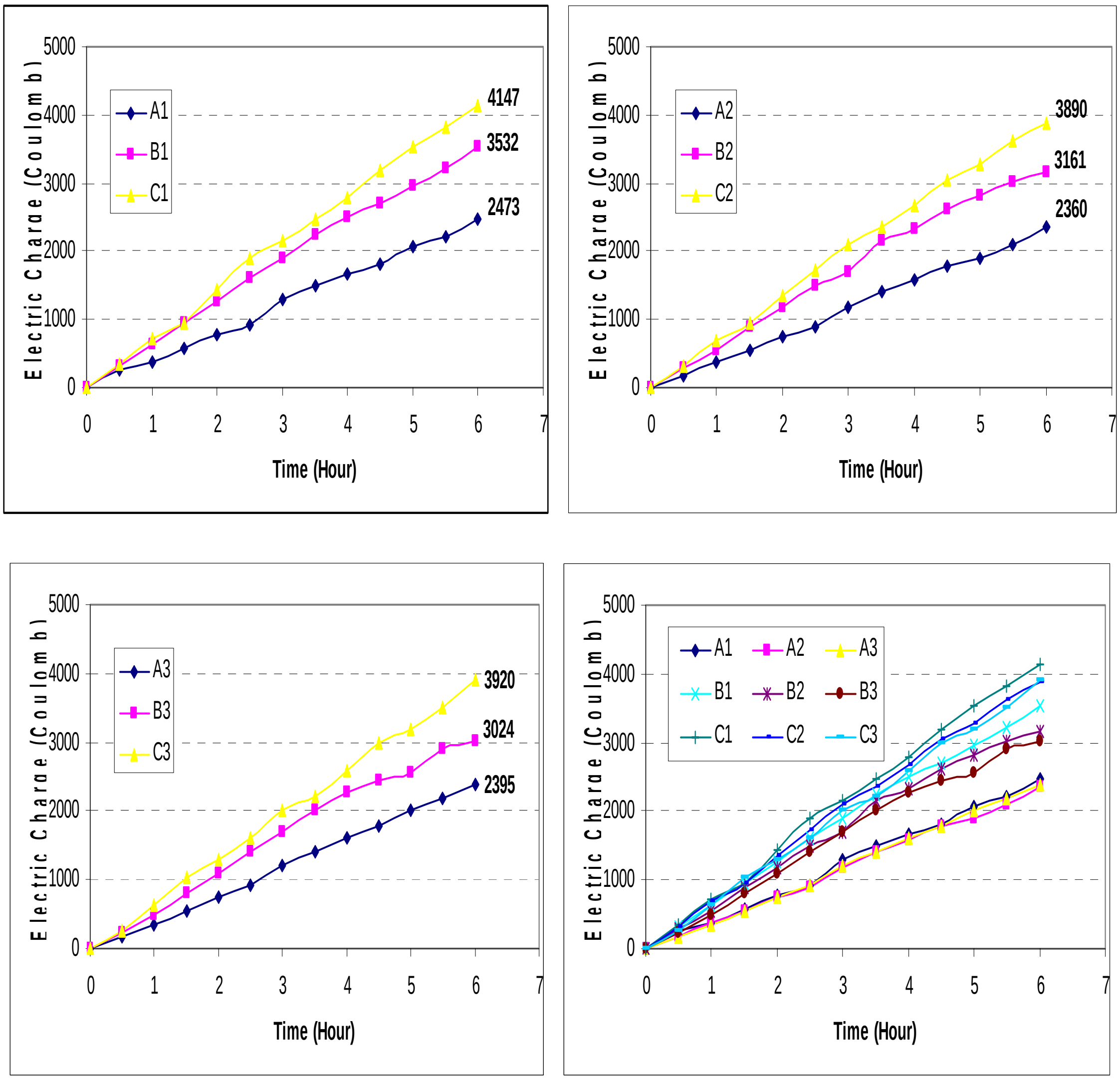

Figure 7 Electrical charges vs. time curve of A, B, C sample

Figure 7 shows that rich mix proportion that is high cement content shows lower electrical charge or chloride ion permeability. The permeability of concrete is decrease with addition of Rice Husk Ash is all mixing proportion.

Table 5 Electric charges passing through the concrete at 14 days curing

Sample ID	% of RHA	Electric charges (columb)
A1	0	2473
A2	10	2360
A3	20	2395
B1	0	3532
B2	10	3186
B3	20	3024
C1	0	4147
C2	10	3890
C3	20	3920

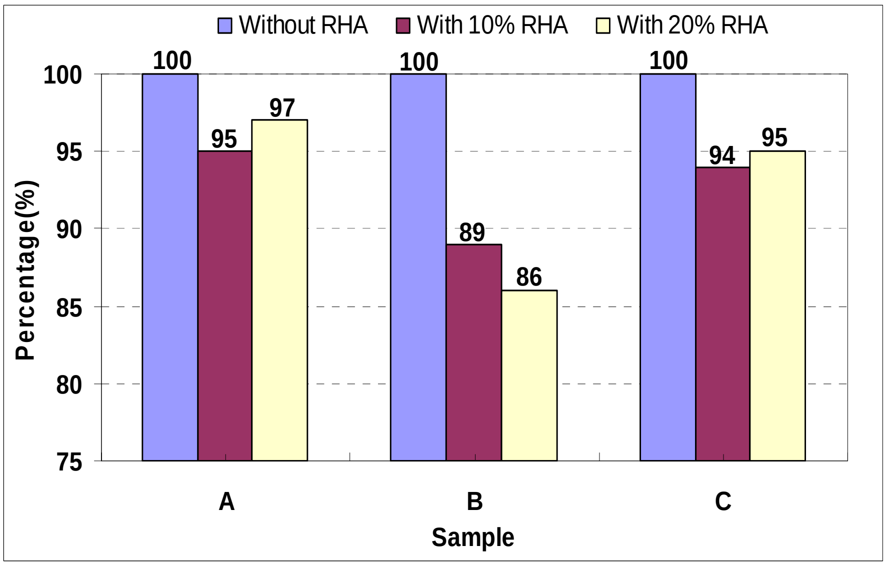

Figure 8 Percentage variation of permeability with respect to OPC

Figure 8 reveals that while RHA is added to the OPC, the permeability is decreases about 3 to14% depending upon mixing proportion.

CONCLUSIONS

The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is employed primarily to resist compressive stresses. Therefore, the concrete making properties of various ingredients of mix are usually measured in terms of the compressive strength. Permeability is a complex phenomenon and can not be totally prevented but can be minimized. From the study, it was observed that addition of RHA in the cement content decrease the permeability.

The major conclusions derived from this study are as follows:

1. Adding RHA to concrete, a decreasing in permeability was verified.
2. Reducing the permeability of 5 ~ 11 % for 10% replacement of RHA and 3 ~ 16 % for 20% replacement of RHA at 14 days curing, was observed when compared to the OPC sample.
3. Rich mix proportion Exhibit less chloride ion permeability.
4. Concrete strength was decreased at initial age in presence of RHA and increased at 90 days.
5. The compressive strength of concrete increased by 16% to 19% for 10% replacement of cement by RHA and for 20% replacement the result was not significant.

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Problems and Potentiality of Garment Waste Product: A Case Study of Dhaka in Bangladesh

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ABSTRACT

The garment industry is the major contributors for the country's most important manufacturing sector earning around $5 billion annually and accounting for about 66% of total exports. During, 1980s adjacent land and water was polluted as a result of indiscriminately throwing away of the waste raw materials or by products from garments locally known as "Jhoot". Every bit and pieces of waste raw materials starting from cut-pieces of clothes, zippers, buttons, thread, elastic fasteners, used plastic packets, broken cloth hangers, empty bobbins to rejected pants, shirts and t-shirts can be sold from the garment factories to waste traders to recycle them for producing cheap clothes. The study identifies the existing problems of garment waste product and the potentiality of collection and recycling facilities, policies and framework for business opportunities.

INTRODUCTION

Global trade in garment and textiles is worth $350 billion, making up more than six percent of total world trade, and many countries are almost totally dependent on the garment industry for export earnings and manufacturing jobs. In Bangladesh for example, garments and textiles are responsible for 95 percent of the country's industrial exports. The garment industry created 1.8 million jobs directly another 2 million jobs indirectly (Ethical Trading Initiative 2004). The economy of Bangladesh has been relying on agriculture as most of the people live in rural areas. After the birth of Bangladesh, jute and tea were the most export-oriented sectors. But with the constant threat of flooding, declining prices of jute fibre followed by a significant decrease in world demand resulted into insignificant contribution to the economy of Bangladesh (Spinanger 1986). Since 1980 the attention has turned to the role of manufacturing sector, especially in garment industry. The garment industry of Bangladesh has been the key export division and a major source of foreign exchange for the last 25 years.

The country generated about $5 billion worth of products exporting garment in the year 2002 (Mahmood 2002) and increased to $12 billion in the year 2007 (Razzaque et al. 2008). The country's garments industry grew by more than 15 per cent per annum on average during the last 15 years (Haider 2007). The textile and garment sector in Bangladesh fulfils a crucial role in the country's economy. In the 2006/07 fiscal year (July 2006-June 2007), it accounted for as much as 76% of the country's total exports. And in 2006 it provided jobs for 4.5 million people, accounted for 10.5% of the country's GDP, and contributed 40% of its manufacturing output. Exports have been growing at an impressive rate in recent years. In 2006/07 alone, they increased by 18.2% to reach US$9.6 billion, a record level for the fifth consecutive year (Textiles Intelligence 2008). In 1991 the number of workers in the ready-made garment industry of Bangladesh was 582,000 and it grew up to 1,404,000 in 1998.

Bangladesh has about 4000 garment industries and the garment industries are on the increase. Some important issues related to its development are given in the Table-1.

The industry provides employment to about 3 million workers of whom 80% are women (Begum 2001). The international market for garment exports is dominated by China (26.9% of world exports), followed by extra-EU export (8.2%), Turkey (4.3%), India (3%), Mexico (2.6%), Bangladesh (2.3%), Indonesia (1.9%) and the USA (1.8%). The international market for garment imports is dominated by the USA (27.9% of world imports), followed by the EU (extra-EU import 24.7%), Japan (7.8%), Russian Federation (2.7%) and Canada (2.1%). The dependence of garment imports, especially in major EU countries, is growing because of the increasing production costs and a rapid decrease of production capacity in Western Europe. In the case of Bangladesh, the EU imported 55% of the Bangladeshi RMG, followed by the USA (28%), Canada (4%) and Japan (2%) in 2006. (source: WTO 2006). For Bangladesh, the readymade garment export industry has been the proverbial goose that has been laying golden eggs for over fifteen years.

Table 1 Important issues related to the Bangladesh ready-made garment industry

Year(s)	Issue
1977-1980	Early period of growth
1982-1985	Boom days
1985	Imposition of quota restrictions
1990s	Knitwear sector developed significantly
1993-1995	Child labour issue and its solution
2003	Withdrawal of Canadian quota restriction
2005	Phase-out of export-quota system

Source: Compiled by the author from Quddus and Rashid (2000), Mainuddin (2000) and databases of the Bangladesh Garment Manufacturers and Exporters Association, and the Export Promotion Bureau, Bangladesh.

Currently, more than 95 percent of garment industries are locally owned with the exception of a few foreign industries located in export processing zones (Gonzales 2002). The garments industries are located with in or in the periphery of Dhaka city, Tongi, Gazipur, Savar and Narayanganj.

Most of them are located in Mirpur Section 10 where around 400 industries employ 10000 people mostly women. These garments industries are producing a huge amount of waste raw materials or by products locally known as “Jhoot”. Every bit and pieces of waste raw materials starting from cut-pieces of clothes, zippers, buttons, thread, elastic fasteners, used plastic packets, broken cloth hangers, empty bobbins to rejected pants, shirts and t-shirts can be sold from the garment factories to waste traders to recycle them for producing cheap clothes. The various stages of textile production starting from spinning, weaving and knitting, to dyeing and finishing require enormous energy and water. A significant amount of water can be saved by recycling garments as to grow the fiber for one cotton diaper requires 105.3 gallons of water, one T-shirt needs 256.6 gallons of water, one bath towel needs 401.4 gallons of water, a man's shirt requires 414.5 gallons of water, and 987 gallons of water are required for one pair of jeans (Cotton Facts 2005). The study identifies the existing problems of garment waste product and the potentiality of collection and recycling facilities, policies and framework for business opportunities.

STUDY AREA

Eighty garment industries have been randomly surveyed which are located in Gazipur, Tongi, Mirpur, Tejgaon and Rampura area of Dhaka city (Figure 1a and 1b). A questionnaire has been prepared and obtained feedback on the amount of garments waste generated, its types and composition, storage and recycling facilities, the price at which the different components such as cut-pieces of clothes, buttons, thread, used plastic packets, broken clothes hangers and empty bobbins are sold to the Jhoot traders.

Dhaka’s mattress industry is dependent on these shredded or cut pieces of clothes. Buttons, zippers, broken hangers and plastic bags are resold to mini garment accessory sellers. A schematic diagram from generation of Jhoot to recycling process is shown in the Figure 2. The average monthly income of garments industry and employees working with Jhoot traders are surveyed. Their working environment and types of vehicles used for transportation of Jhoot, existing problems with Jhoot business are identified through the case study.

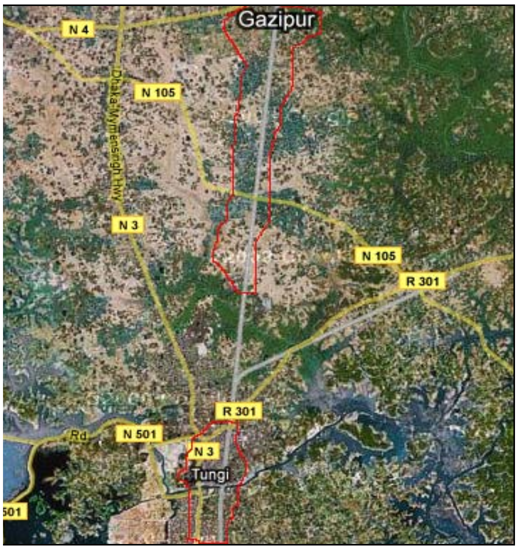

Figure 1 a. Case Study area within Dhaka city (Source: googlemap)

Figure 1 b. Case Study area Gazipur and Tongi (Source: googlemap)

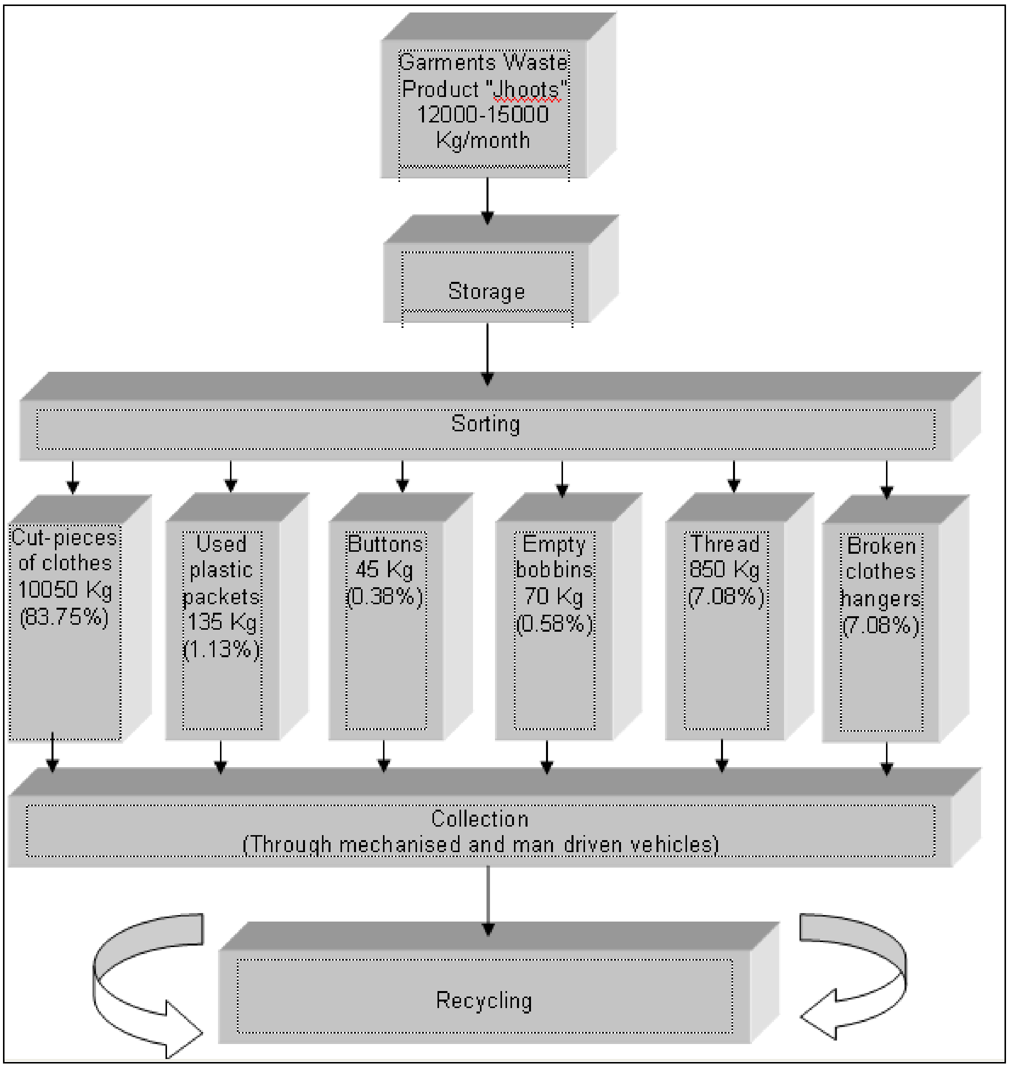

Figure 2 Schematic diagram showing generation of Jhoot to recycling process

The study area was chosen based on the concentration of garments industries, density of population, threat to physical environment and proximity to the water bodies or natural streams. It could be added that some of the garment industries located near the water bodies are highly susceptible to contamination as shown in the Figure 3 below.

Figure 3 Contamination of water by dumping of Jhoot.

RESULTS AND DISCUSSIONS

There is a tremendous potential as Jhoot industry creates employments for urban poor and a significant amount of garments waste are brought under the recycling programme. As the informal sector requires small investment, Jhoot businees attracts a good number of investors who are employing thousands of people in Bangladesh. The Jhoot business is flourishing rapidly as it involves good profits.

The survey identified that on an average 12000-15000 Kg of Jhoot is disposed in a month. Based on this generated Jhoot, the recycling annually prevents 576000 tons of postconsumer textile waste from entering the solid waste stream. Following types and composition of Jhoot has been observed based on the survey as shown in Table 2.

Table 2 Types and composition of Jhoot

Types	Kg/month	(%)
Cut-pieces of clothes	10050	83.75
Buttons	45	0.38
Thread	850	7.08
Used plastic packets	135	1.13
Broken clothes hangers	850	7.08
Empty bobbins	70	0.58
Total	12000	100

Almost 67% of garments industries have its own storage facilities in the form of warehouse and the rest 33% have Jhoot stored in the garment industry lobby and floor. Jhoot are separated based on its different composition and then sold as per the average rates given below (Table 3).

The garment industries earn an average of Tk. 1,15,000 on a monthly basis by selling Jhoot to the Jhoot traders or businessman. Each Jhoot traders employ 15 people on an average. Among the Jhoot employees 80% are women (Figure 4). The average earning of each employee varies from Tk. 1800-2000 per month. 83% of Jhoot traders use man driven van for collecting and carrying Jhoot from garments industry and rest 17% use mechanized vehicles or trucks (Figure 5).

Table 3 Price of Jhoot sold based on its different compositions

Types	Tk./Kg
Cut-pieces of clothes	18
Buttons	50
Thread	45
Used plastic packets	50
Broken clothes hangers	*NA
Empty bobbins	30
Total	**12000**

* Not Available;   1 US $ = Tk. 68.5

The Survey found there are no recycling facilities available nearby and the Jhoot traders are not aware of any Government policy or rules and regulations for disposing of Jhoot.

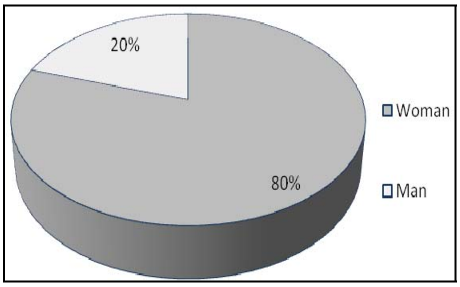

Figure 4 Distribution of Jhoots Employee

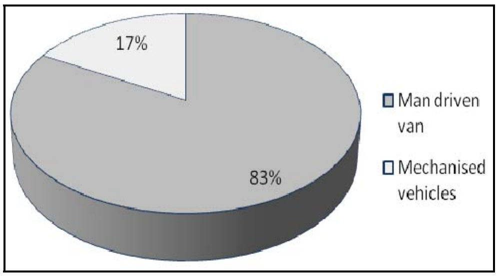

Figure 5 Types of vehicles used for Jhoots collection

It has been found that about 75% of the Jhoot workers had sound health before they started working with Jhoot. The reasons of health declines were unfavourable working environment resulting from exposure of rotten clothes and chemicals used during dying. One of the major hindrances in the development of Jhoot industry is that people have negative attitudes as the owners in Jhoot business have earned bad reputations resulting from disputes and crimes.

Strength

- Jhoot industry generates employment and a good number of women involved in Jhoot sorting.
- The waste products of garments industry are recycled and assist in promoting the 3Rs approach of waste management.
- Less energy is consumed while recycling clothes obtained from Jhoot as it does not require be re-dyeing or scouring.

Weakness

- Lack of fundamental infrastructures for example proper road access.
- Jhoot may be toxic for example jeans buttons are brass items and needs to be recycled with proper care.
- Lack of adequate equipments and safety measures for the Jhoot employees who works with bare hands.
- The employees who are recruited by the Jhoot traders are sometimes deprived and likely to work under unfavourable working conditions.

Opportunity

There is a great potentiality if Jhoot can be managed properly and monitored and regulated by the Government to identify the obstacles to its development and take necessary measures accordingly.

Threats

- Improper disposal of Jhoot may cause water and soil contamination. Water contamination by Jhoot may result into chemical borne diseases whereas soil contaminated by Jhoot is likely to have impact on food chain.

- Storage of Jhoot comprising cut-pieces of clothes and cottons poses a fire risk.
- Jhoot industry involves a high profit for Jhoot traders which often results into serious conflicts and disputes. A number of murders have been reported resulting from Jhoot business.

CONCLUSIONS

It is recommended that all textiles should be banned from dumping into the landfill site and needs to be collected separately from the rubbish. Textiles possess particular problems in landfill as synthetic products will not decompose, while woolen garments do decompose and produce methane, which contributes to global warming. Jhoot industries should be located along the periphery of the city and at least 100 m away from any water bodies in order to prevent it from contamination. Polluter Pay Principle (PPP) needs to be implemented for any inconsistency in setting up the Jhoot industry that may threaten both human health and physical environment. The Government should set up a development and monitoring cell to assist in flourishing the Jhoot industry and eliminate the problems or any conflicts that may arise in the Jhoot business. The promotion of recycling through use of Jhoot business needs to be encouraged by providing necessary road infrastructures and facilities.

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Environmentally Conscious Manufacturing in a Marble Slab Producing Unit-Case Study from India

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ABSTRACT

India is the twelfth-largest economy and the second largest exporter of minerals in the world. Rajasthan accounts for over 90% of total marble production of the country. Rajasthan has numerous slab manufacturing units and this is considered as 90% of the total marble slab production of India. In recent years the problem of generation of marble slurry and its unsystematic disposal is becoming a serious cause of environmental and ecological degradation. The paper describes attempts towards better manufacturing of the marble slabs and waste marble powder utilization. The effluent samples were taken from three places in the Effluent Treatment Plant (ETP) & were analyzed for several parameters. The influent had high pH, total solids, salinity, and turbidity values which were reduced considerably after treatment. The marble powder is dumped in low lying areas and creates major risk to human health and environment. In this study the powder has been reutilized to make statues, bricks, tiles and cups. The product development from waste marble was done in a small scale sculpture making unit in Mumbai.

INTRODUCTION

India is the twelfth-largest economy and the second largest exporter of minerals in the world. The top five marble producing countries in 2006-07 were, in descending order by tonnage, China, India, Italy, Iran, and Turkey. These countries accounted for about 69% of the world's production. Marble deposits are widespread in India, with deposits of economic importance being concentrated in the states of Rajasthan, Gujarat, Madhya Pradesh, Haryana, and Andhra Pradesh. The largest state of India, Rajasthan accounts for over 90% of total marble production of the country. Estimated reserves of the state are 1100 million tons, which are more than 91% of the total marble reserves of the country. Export from India is primarily that of green marble. Rajasthan has numerous slab manufacturing units and this is considered as 90% of the total marble slab production of India. Nearly 95% of marble deposits of the state of Rajasthan are found & exploited in the districts of Udaipur, Rajsamand, Chillor, Banswara, Durgapur, Sirohi and Ajmer. The marble industries generate significant revenue, export earnings and provide employment to a large number of rural people.

The present hard times faced by the industry in the state are in fact a result of imbalance of demand and supply of marble in the market. With the advent of modern technology in the past few decades, the production of marble has increased tremendously. The cost of production has come down and the speed and quality of production have improved a lot. Moreover, it has also resulted in increased production.

Due to the several million tons of marble produced annually, tonnes of slurry are generated every year. Mined marble blocs are cut in the laboratory by the "Gang Saw' units. During the process of slab making and tilling, saw powder is generated as waste. In order to avoid excess heating during the process, water is continuously fed into the Gang saw and the powder of the marble is converted to slurry. The marble slurry imposes serious threats to ecosystem, physical, chemical and biological components of environment.

In recent years the problem of generation of marble slurry and its unsystematic disposal is becoming a serious cause of environmental and ecological degradation. Today, marble slurry is one of the most hazardous waste in Rajasthan. The paper describes attempts towards better manufacturing of the marble slabs and waste marble powder utilization. The effluent samples were taken from three places in the Effluent Treatment Plant (ETP) & were analyzed for several parameters including heavy metals. The influent had high pH, total solids, salinity, and turbidity values which were reduced considerably after treatment. It was followed by image analysis & scanning electron microscopy techniques done on the marble powder. The product development from waste marble was done in a small scale sculpture making unit. The different products made were statues, tiles, bricks etc. The strength of bricks was several times more than ordinary bricks.

Marble and Marble Slurry

The metamorphosis of limestone (a sedimentary rock) results in the formation of marble (a metamorphic rock). The principal component of both limestone and marble is the mineral calcium carbonate. When the smaller calcium carbonate particles within limestone re-crystallize to form large calcium carbonate particles, the limestone has metamorphosed into marble. Chemically, the impurities may be in the form of silica (SiO_2), as free quartz or silicates, iron oxides as hematite (Fe_2O_3), limonite ($2\ Fe_2O_3\ 3\ H_2O$), manganese-oxide (MnO_2), alumna (Al_2O_3) in the form of aluminium silicates, and sulphur usually as pyrite (FeS_2).

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The present hard times faced by the industry in the state are in fact a result of imbalance of demand and supply of marble in the market. With the advent of modern technology in the past few decades, the production of marble has increased tremendously. The cost of production has come down and the speed and quality of production have improved a lot. Moreover, it has also resulted in increased production. There are around 4000 marble mines and about 1100 marble cutters in medium sector spread over the 16 districts of Rajasthan. Due to the several million tons of marble produced annually, tonnes of slurry are generated every year. Mined marble blocs are cut in the labs by the "Gang Saw' units. During the process of slab making and tilling, saw powder is generated as waste. In order to avoid excess heating during the process, water is continuously fed into the Gang saw and the powder of the marble is converted to slurry. The marble slurry imposes serious threats to ecosystem, physical, chemical and biological components of environment.

Marble slurry is generated as a by-product during cutting of marble. The waste is approximately in the range of 20% of the total marble handled. The amount of marble slurry generated in Rajasthan every year is very substantial being in the range of 5-6 million tones. The marble cutting industries are dumping the marble slurry in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of vast area of land especially after the slurry dries up. This also contaminates the underground water reserves. (Palla, Nema and Gupta 2007)

Table 1 A typical chemical analysis of marble slurry

Constituents and test carried out	Test Value %
Loss on ignition	43.46
Silica	1.69
Alumina	1.04
Iron Oxide	0.21
Lime	49.07
Magnesia	4.47
Soda	Less than .0
Potash	Less than .01

While marble blocks are cut by gang saws, water is used as a coolant. The blade thickness of the saws is about 5 mm and normally the blocks are cut in 20 mm thick sheets. Therefore, out of every 25 mm thickness of marble block, 5 mm are converted into powder while cutting. This powder flows along with the water as marble slurry. Thus, nearly 20% of the total weight of the marble processed into marble slurry. The marble slurry has nearly 35-45% water content. The total waste generation from mining to finished product is about 50% of mineral mined. Table 1 shows the chemical analysis of marble slurry.

Table 2 Physical properties of marble slurry

Property	Result
Bulk Density (gm/cc)	1.3-1.5
Specific Gravity	2.83-2.87
Particle size	Less than 363.5 Micron

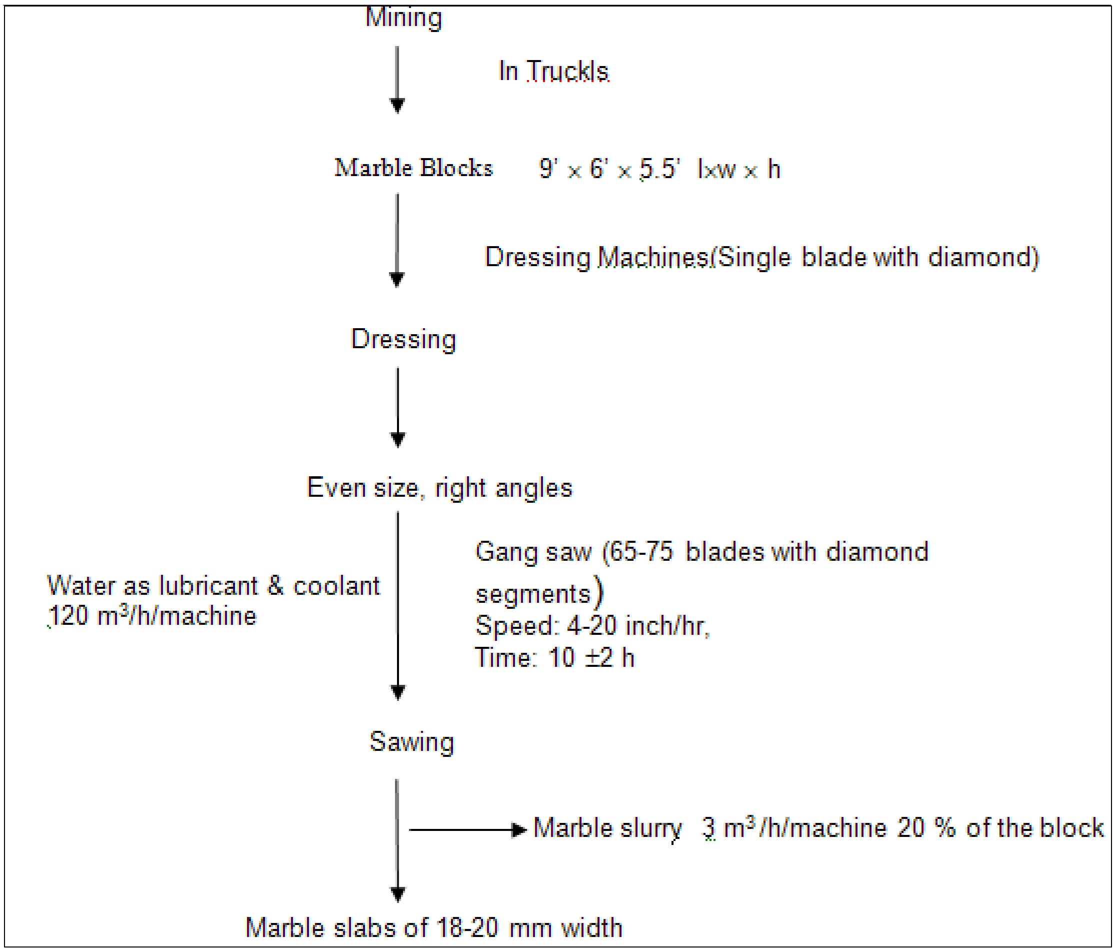

Figure 1 Process for generation of marble slurry

Kishangarh, near Jaipur (Rajasthan) is agglomerate of about 250 marble processing units where huge marble pieces are cut into slabs of 18mm thickness. Marble slabs of about 9 feet x 6 feet x 5 ½ feet (length x width x height) are brought from quarries and used as raw material. Many processors have their own mines. The marble slabs come in trucks. The colors are white, green, pink or even black. Some marbles have coloured lines in the slabs. Cranes help offload the marble slabs. There are dressing machines that dress or bring the slab to an even size. The dressing machines have single blade with diamond segment. These machines also give the blocks right angles. These blocks are further processed using Gang saw machines. These machines have 65 - 75 blades. Diamond segments are mounted on the blades. The blades are fixed on a frame that is moved with 125 -150 HP motors. The motor rotates the flywheel and through connecting rods, movement is given to the frame. Each stroke of the machine is about 600 mm. The block is lifted and put on the trolley and the trolley is fixed to the machine. The trolley moves up for sawing and down for rest period. The speed is increased for hard materials and reduced for soft materials. The cutting speed is 4 - 20 inch/ hr. Each block is cut into 18 mm width slabs. Water is used as a lubricant and is continuously required. Water requirement is 120 m^3/h/ machine. Cutting of one block takes about 10 h ± 2h on an average depending on the hardness of the material, e.g., soft blocks may take 6h only for a full sized block (9 x

6 x 5 ½ feet). The marble slurry waste that is generated during the above processing is about $3m^3$ /h/ machine. About 20% of the blocks are wasted as slurry during processing.

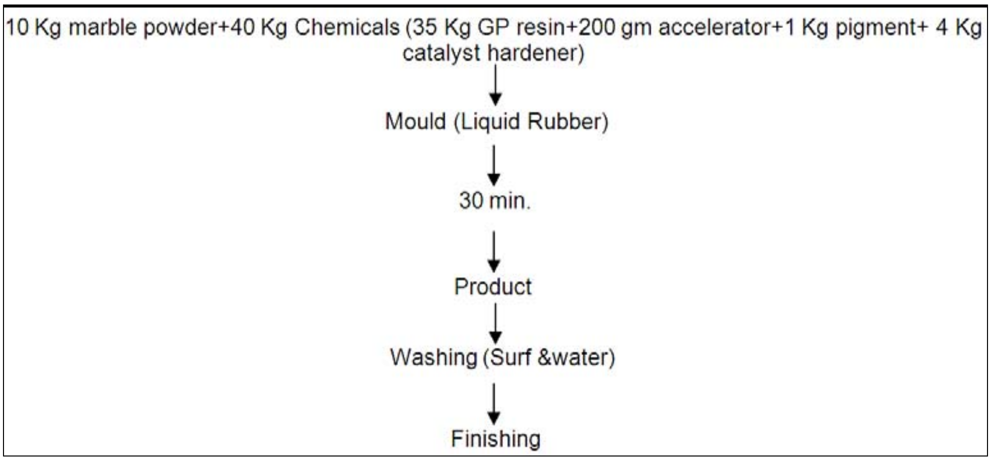

Figure 2 Procedure for product development

Design of an ETP

The ETP is installed outside India for marble slurry treatment. Steel Fabricated Water Sedimentation Tanks ensures crystal clear filtration and recycling of water which is mixed with marble slurry, hence, keeping the environment pollution free. Supply of clean water to machines enhances fast cutting of stone as well as more production and tool life. The process of filtration involves the collection of slurry mixed water from the machine in an underground tank. Here water is chemically treated by injecting chemical through state of art dozing pump for separation of water from slurry.

Table 2 Analysis of waste water samples taken from a marble processing industry in Kishangarh

Parameter	Inlet Influent before Polyelectrolyte	Effluent after Polyelectrolyte	Final Effluent
pH (value)	7.42	7.80	7.67
Total Hardness (mg/L)	1720	1840	1500
Calcium (mg/L)	252.31	142.97	243.90
Calcium Hardness (mg/L)	630	510	609
Total Solids (mg)	5055	214693	3959
Magnesium (mg/L)	265.96	324.52	217.40
Chlorides (mg/L)	198.55	184.37	156.01
Salinity (mg/L)	358.41	332.81	281.62
Alkalinity (mg/L)	280	220	280
Phosphate (mg/L)	BDL	BDL	BDL
Sulphate (mg/L)	180	186	450
Sodium (mg/L)	140	140	140
Potassium (mg/L)	35	45	32
Turbidity (N.T.U)	750	-	54
Ammonia (NH_4 - N^+) (mg/L)	precipitate	precipitate	precipitate
Cu (mg/kg)	0.66	0.46	-
Co (mg/kg)	BDL	BDL	BDL
Fe (mg/kg)	88.8	185.6	-
Cr (mg/kg)	2.58	3.74	-
Cd (mg/kg)	BDL	BDL	BDL
Mn (mg/kg)	9.8	17.4	-
Zn (mg/kg)	2.64	4.64	-
Si (mg/kg)	BDL	BDL	BDL
Ni (mg/kg)	BDL	BDL	BDL
Al (mg/kg)	BDL	BDL	BDL

Then chemically treated water is pumped through a battery of heavy duty slurry pump to conical tank. Here slurry settles down in the cone of tank and clear water over flows in another tank which supplies clear slurry free water to machine. The deposited slurry in conical tank in removed through a heavy duty sluice value at the bottom of tank directly in to truck tanker for disposing slurry at prescribed site in order to maintain pollution free environment. Table 2 shows the analysis of waste water samples taken from a marble processing industry in Kishangarh.

Treatment Process

The slurry is treated for removal of marble powder. It is taken to a pit or tank, where flocculent is added (about 20 g for 3 m^3 slurry) to facilitate faster settling. The slurry goes to a setting tank, where thick settled slurry is either taken to evaporation ponds or to a filter press to remove moisture. The cake from filter press still has 17-20 % moisture. It is dumped in an area/empty field marked for such dumping. Clear water overflows in tanks for reuse as lubricant in gang saws. Effluent samples were taken from three places in the ETP. The first sample was of ETP influent, the second was after treatment with the polymer and the third was from the final tank. The samples were analyzed for several parameters including heavy metals. Table 3 presents the results of the analysis.

Characterization of Marble Powder Waste

Waste marble powder samples were collected from various places and analyzed for various physical and chemical parameters. Table 3 shows the characterization of waste marble powders from three locations.

Table 3 Characterization of waste marble powders from three locations

Parameters	Kishangarh	Raj Samand	RPCB Sample
Moisture Content (%)	16.662	0.1156	0.05
Specific Gravity	1.17511	1.487	1.2546
Bulk Density (gm/cm^2)	1.1591111	1.46	1.4
pH (value)	7.2	7.0	9.68
Alkalinity (mg/gm)	0.4799	0.40046	0.52
Chlorides (mg/gm)	0.68111	0.709	0.1624
Salinity (mg/gm)	1.2591	-	-
Sulphate (mg/gm)	1.59	0.119	0.043
Phosphate (mg/gm)	BDL	BDL	BDL
Ammonia (mg/gm)	ppt.	-	-
Organic Matter (mg/gm)	4.952	4.816	-
Organic Matter (%)	0.495	0.482	-
Carbon (%)	0.287	0.028	-
Calcium (mg/gm)	2.852	-	-
Magnesium (mg/gm)	1.64	-	-
Sodium (mg/gm)	0.195	1.251	-
Potassium (mg/gm)	0.086	0.260	-
Copper(mg/gm)	0.0046	0.0066	-
Cobalt (mg/gm)	BDL	BDL	BDL
Iron (mg/gm)	1.856	0.88	-
Chromium (mg/gm)	0.0374	0.0258	-
Cadmium (mg/gm)	BDL	BDL	BDL
Manganese (mg/gm)	0.174	0.098	-
Zinc (mg/gm)	0.0464	0.0264	-
Silicon (mg/gm)	BDL	BDL	BDL
Nickel (mg/gm)	BDL	BDL	BDL
Aluminum (mg/gm)	BDL	BDL	BDL

RESULTS & DISCUSSIONS

Associated Environmental Problems

The marble slurry imposes serious threats to Eco - system, physical, chemical and biological components of environment. Problems encountered are:

- when dumped on land, it adversely affects the productivity of land due to decreased porosity, water absorption, water percolation etc. (Pareek 2007)
- slurry dumped areas can not support any vegetation and percolation etc.
- slurry dumped areas can not support any vegetation and remain degraded.
- When dried, the fine particles become air borne and cause severe air pollution. Apart from occupational health problems, it also affects machinery and instruments installed in industrial areas. (Mishra & Mathur 2006)
- dried marble powder from the mounds mixes with are, forms fugitive dust affecting visibility and becomes an eye sore.
- its dumping adversely affects soil productivity, by decreasing porosity, water absorption, water percolation etc.
- during rainy season, the slurry is carried away to rivers, drains, roads, and water bodies affecting quality of water, reducing storage capacities and damaging aquatic life.
- due to long term deposition on land the finer particles block flow regime of aquifers thus seriously affecting underground water availability.
- the heaps of slurry remains scattered all round the industrial estate are eye sore spoil aesthetics of entire region. Subsequently tourism and industrial potential of the state is adversely affected.

Uses of Marble Waste

Marble slurry can be utilized for several applications like:
In Building / Construction Industry: For making bricks / blocks, as roofing tiles / flooring tiles, as wall panels, as raw material for manufacturing artifacts (for decorative purpose), as substitute for fine aggregate, as backfill materials for retaining walls, as replacement of '*Khadanja*' (used as *Pedestrian Road* or *Courtyard Floor*), for miscellaneous uses e.g. flush toilets, tree cover guards, boundary walls. In Road Construction-for construction of road embankments, for construction of road pavements as pavement blocks (layering up to 25 % to 35%)**,** In Rubber and Plastic Industry as inert filler (Soni 2006)

Products Developed from Marble Slurry

The products were developed in a small scale sculpture making unit with 4-5 workers in Mahad, Mumbai. The small scale industry made statues using marble powder called Sanjeera powder obtained from Rajasthan through a dealer in Mumbai. The products developed using the marble powder obtained:

Building stone and foundation of the road, manufacture of soda ash by Solvay Process, Paints, plastics, sealants, pharmaceuticals, marble repairs and as adhesives, Ornamentals, Paintings, Tiles, Hard-wearing facades, outdoor waste-bins and wash-stands and Paints.

Products Developed by the Small Scale Industry in this Study

- tiles with 50 % marble dust and jute fibre bound with resin. Tiles have also been made with marble dust with cement bonding.
- door panels made out of marble slurry were also displayed. This product can also be used as a wood substitute
- tiles made with marble dust up to 90% bound with resins.
- their preliminary work has suggested that marble slurry can be used for road making exercises.
- building bricks have been developed using marble slurry.
- possibilities of using this waste for cement making are being explored in NCCBM.
- fired tiles incorporating marble slurry/dust have been developed. The technology is available with them.

Impact of Government Policies on the Industry

Removal of Excise duty: One of the major changes that the Government has introduced is the removal of the excise duty on marble (upto the annual sales of Rs.1 Crore). The removal of the excise duty will reduce the landed cost of marble to the end user and this will surely increase the demand of marble in the market.

New marble policy: The new policy for the marble mining will facilitate the search of new marble areas in the state. The new policy not only allows the grant of mining lease for marble in the state but also permits the prospecting work for the search of new areas of marble deposits. In toto (Goyal 2003).

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Increased Efficiency of Sewage Treatment Plants by Co-Digestion

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ABSTRACT

The rising prices of energy and disposal of sewage sludge encourages plant operators to consider energy production besides sewage cleaning as techniques for wastewater treatment. The energy production is attainable by using the biogas emitted from the anaerobic stabilisation. The optimisation of the anaerobic stabilisation process to produce high-energy biogas from the biogenic waste is discussed in this paper.

The analysis of the actual and the target state guides the improvement opportunities of the sewage treatment plants. Regulation, extension of a plant and co-digestion are possibilities to increase the biogas yield. The current situation in Germany, for example the sewage treatment plant Tiefurt, demonstrates the calculation base for disposal of bio-waste which is useable in digestion tower. The transfer of the results demands adapted waste accumulation from the research region and the knowledge of specific anaerobic technology.

INTRODUCTION

The wastewater treatment is one of the basic requirements to achieve a good quality of our surface and groundwater. The cleaning methods demand a high technical standard which requires high energy consumption. A useable potential to increase the efficiency offers compensation to electricity costs.

The research objective is the optimisation of sewage treatment plants regarding sludge regulation and the digestion tower capacity. The uses of disintegration of sewage sludge and process improvement have no significant bearing on the efficiency of wastewater treatment plants.

Moreover energy saving affords the anaerobic digestion of sewage sludge its own energy production. Using more co-substrates helps to produce more gas and consequently more electricity at only marginal additional cost. This is accompanied by the reduction of the water content and the organic matter in this biologic process in addition to the disposal cost of sewage sludge.

Generally sewage sludge digestion is applied in wet single-step processes such as continuously stirred tank reactor. The substrate is normally diluted with dry solid content of maximum 15 %. Anaerobic digestion (AD) is a very cost-effective process that has been practiced in wastewater treatment since the turn of the twentieth century. It is a biological process where micro organisms degrade organic substances in the absence of oxygen. The main products are methane and carbon dioxide. This biogas can be used for heat and electricity production by means of a block heat and power plant. Thus the sewage treatment has the possibility to reduce the energy costs. Furthermore, offers the digestion of sludge and biogenic waste the treatment similarly.

On the other hand the additions at co-substrates have positive implications in the de-watering of the sludge. This is mainly due to the higher fibre content of the added materials compared to the sewage sludge which reduces the amount of the needed de-watering polymers. Some costs are on the decrease.

The advantage over the separate treatment of sewage sludge and bio-waste is the utilisation of a complete infrastructure for a fermentation process and the gas usage in wastewater treatment plants. The challenge to deal with these two materials of high organic matter offers higher biogas production and relieved treatment logistic. The mixing of different organic matters allows some flexibility to compensate for seasonal mass fluctuations of wastes. Under loading and overloading of digester can be avoided and the digestion process can be maintained at a constant rate. The utilisation of organic matter depends on its availability and feasibility as well as the legal regulations. These limits require a close examination of the local conditions.

METHODOLOGY

A raised biogas yield can be expected by using the co-digestion of sewage sludge and organic matter. The utilisation of the regional available organic materials demands an appropriate sorting of the organic fraction. The waste can be of commerce, industry and households origin. Table 1 shows the allowed types of waste for co-digestion.

Suitable materials are, for instance, municipal bio-waste, old cooking fat, leftovers and draff. In relation to that the quantitative calculation is based on the estimated values from waste management studies. The utilisation of biogenic waste calls for the harmlessness of these substrates. Rules and standards classify the waste as adequate and suitable to a limited number of matters. The ecological viability of bio-waste is mainly discussed in the German study "Co-fermentation of biogenic waste in digesters of sewage treatment plants" (MUNLV 2001).

Table 1 Types of biogenic waste are suitable for co-digestion (Reipa et al. 2008; and Dwa-M 380,2008)

Description of waste	Source of waste
Separately collected bio-waste	Private households (bio-waste bins)
Contents of grease traps, flotation sludge	Slaughterhouses, meat processing, canteens, large-scale catering establishments, foodstuffs industry
Storage time-expired foodstuffs	Production and trade
Food scraps, kitchen waste	Canteens, large-scale catering establishments, restaurants
Starch sludge	Potato, rice and maize starch production
Dough/pastry wastes	Bread factories, pasta production
Fruit, grain and potato distillery wash	Alcohol distilleries
Market wastes	Central and weekly markets

The following consideration is based on suitable waste without itemisation. It must be pointed out that the input of co-substrates does not exceed the volume fraction of 50 % (Munlv 2001). Otherwise the commencement of the waste legislation results from this frontier is crossed. In this case is transferred a sewage treatment plant to a waste treatment plant with other regulations. The fundamental operational aim of a sewage treatment plant is the cleaning of wastewater. The utilization of co-substrates must not affect its intended purpose.

Knowledge of the daily throughput of sludge and the capacity of the digester is used to calculate the hydraulic retention time (HRT), which is a measure of how long liquid remains in the digester. The HRT is calculated according to equation 1, the ratio of the digester volume to the daily input of organic matter (flow rate)

$$HTR = V / Q[d]. \qquad (1)$$

In order to determine the free capacity of the digester, a minimum retention time of 20 to 25 (Schemelz 2003) days under mesophilic conditions is required. Most of the sewage are oversized and command a high HRT. Keeping in notice that the mass of biogenic waste which is inserts into digester is calculated. For this purpose waste management studies are considered as a basis. Table 2 summarises the main European key data of waste accumulation and the specific biogas yield. The continuative calculation demanded the utilised capacity of e.g. the restaurants and hospitals considering the meal per day of the inhabitants. Other influences are sorting attendance, the average level of the waste bins and other treatment possibilities.

Furthermore, it is essential to know; that Germany there is a growing demand for organic matter. Many waste management companies are specialised in treating types of waste, like separating bio-waste or cooking fat. They have their own treatment plants. These limiting factors for the utilisation of biogenic waste demonstrate the merits and limits of the AD in wastewater treatment plants.

Table 2 Approximate mass calculation of biogenic waste and the specific biogas yield

description of waste		mass calculation: calculation of wet basis	unit	biogas yield [m³/t w.b.]
bio-waste	separately collected bio-waste	50 – 150	kg /(p*a) [2]	80 – 120 [4]
grease	grease separator contents	7	l/(s*meal) 1 seat ≈ 2 meals [3]	11 – 450 [4]
		2,5	kg/(p*a)	
		1,5	m³ per grease sep.	
	cooking fat/oils	0,65 0,5 – 2,8	kg/(p*a) kg/(p*a)	650 [5]
leftovers (LO)	LO hospital	0,327	kg/(p*d) 301 patient days per bed [1]	220 [4, 6]
	LO foster home	0,412	kg/(d*resident) 90 % utilised capacity [1]	
	LO restaurants	2 – 2,5 10	kg/(seat*week) [1] kg/(p*a)	
	LO canteen	0,09	kg/meal [1]	
draff	spent grains	19	kg/hl [1]	105 – 130 [4, 7]
	brewery draff	165	kg/m³ [8]	

[1] Gallenkemper et al. 2001, [2]Schmelz, 2000, [3]Mall, 2008,[4]Fnr-s ,2006,[5]Boxer,2008, [6]Seilnacht,2008, [7]Knappe,2007, [8]Brustermann et al. 2006,

The calculation of by-products and waste from bakeries counts as 86,5 kg/(p*a) of bread, the average consumption per person in Germany. Five percent of this bread production may be treated in waster treatment plant. (Brustermann et al. 2006)

Based on the design basis, the current situation in Germany and the choice of wastewater treatment plant, demonstrate preferences of AD over sewage treatment plants.

Current State of Co-Digestion in Sewage Treatment Plants in Germany

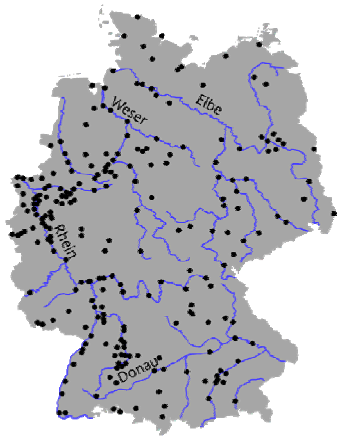
In the Federal Republic of Germany 82 Million inhabitants live on a 357 Million km² area. Table 3 shows the number of waste water treatment plants and their scale. The maximum capacity of all plants is higher than the population. This is due to the influence of the industry wastewater capacity. The connection rate of German population on sewage is near 100 %.

More than 1230 (municipal sewage treatment plants in the Federal Republic of Germany are equipped with a digester. These are sixty percent of sewage with more than 10.000 PE and one-level mesophilic digester (Reipa 2003). Most of these plants have free treatment capacity as the quantity of wastewater has changed. The reasons for this are overdimensioning, more household appliance which conserve water and decline in population. In the course of the wastewater decrease the capacity in the digester for co-digestion increased. Between 15 and 30 % of the digester capacity can be used for co-fermentation (Weiland 2000)

Many sewage treatment plants in Germany have a HRT of more than 30 days. In terms of anaerobic stabilisation 20 days would be sufficient. The reduction of the HRT time offers the use of co-substrates to increase the efficiency of the sewage treatment plants. Figure 1 clarifies the potential of organic matter which can be used. Hygienic harmlessness is a condition precedent to this matters disposal. Otherwise more pre-treatment processes are essential. The pre-treatment steps might include three basic processes size reduction of the substrate (chopping), removal of indigestible components (sieving, removal of metals, glass, sand and stones) and hygienisation(Braun et al.2003)

Table 3 Sewage treatment plants in Germany 31.12.2002 (Bmu 2002)

scale [total number of inhabitants and population equivalents (PE)]	number of sewage	extendible by a capacity of sewage [million PE]
> 100.000	237	73,6
> 10.000 – 100.000	1.860	59,0
2.000 – 10.000	2.587	12,4
> 50 - < 2.000	5.510	2,8
∑	10.194	147,8



Typical co-substrate addition rates in sewage sludge digesters are between 5 – 20 %. The addition of flotation sludge, fat trap-contents, food leftovers considerably raises the biogas productivity of these digesters by 40 – 200 %.(Braun et al. 2003)

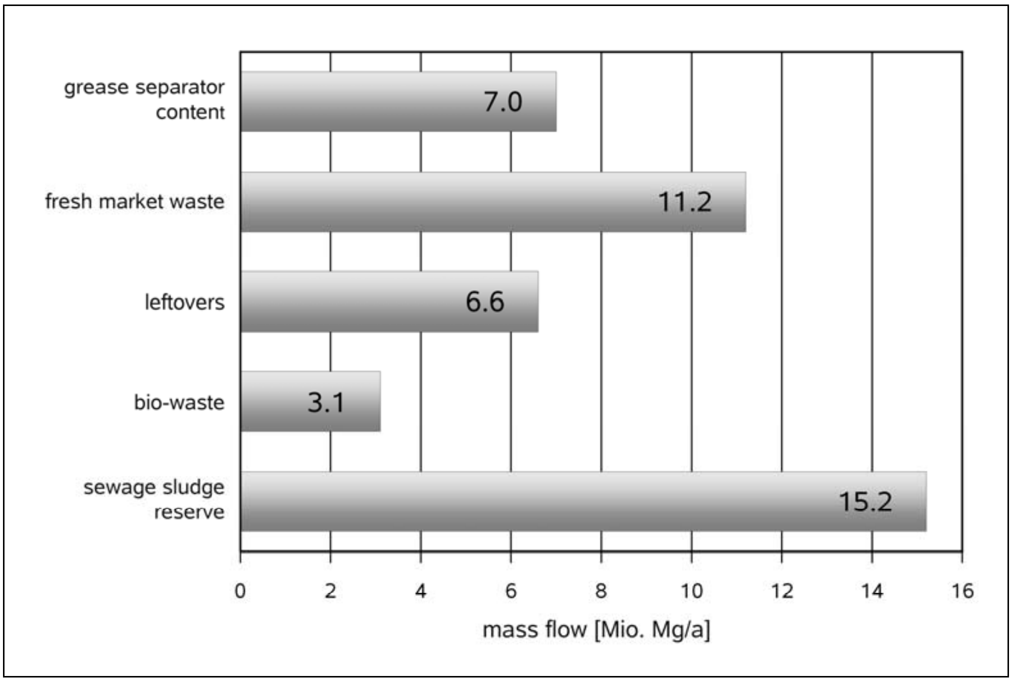


Figure 1 Potential of utilisation from organic matter in Germany(Schroder 2007)

Figure 1 shows a current situation overview of the co-digestion in Germany. In the following the case studies of the sewage treatment plant Tiefurt, which carries out co-digestion in wastewater treatment. Based on the waste management key data, the calculated waste accumulations point out the utilisation in AD.

CASE STUDY OF SEWAGE TREATMENT PLANT TIEFURT, GERMANY

This study examines the possibilities for co-digestion of sewage sludge, industrial organic matter and household's organics of wastewater treatment plant in Tiefurt near Weimar. Approximately 64.000 habitants live in Weimar. There are many service units, like hotels and restaurants, and industry located in the town. The industries with a high organic matter access which is digestible are the brewery, some bakeries and a fruit juice mill. The valuation of substrate applications has to consider the following aspects: expected biogas yield, sanitation requirements and mechanical conditioning, separation and collection.

The calculated HRT is 32 days. With a digester volume of 3.200 m³ a daily input of 100 m³ primary and secondary sludge is possible and can be reduced. The compensation of HRT except for 25 days affords the additional organic amount of 28m³/d. In this case it is possible to use the municipal bio-waste and organic matter from other sources. By using these co-substrates, a more biogas production is possible which leads to a higher energy production.

With the utilisation of co-substrates, a decrease of sewage performance is not allowed. Furthermore, additional components of pre-treatment are avoided within the course of the calculation, other treatment possibilities and potentials of collection and utilisation are discussed.

Figure 2 represents the comparison of theoretic and acquirable organic matter in Weimar. Some biogenic wastes are selected. The composting plants already deal with the separate collected bio-waste. Leftovers and grease separated contents are collected by different waste management companies. Therefore, the case study describes the available biogenic waste.

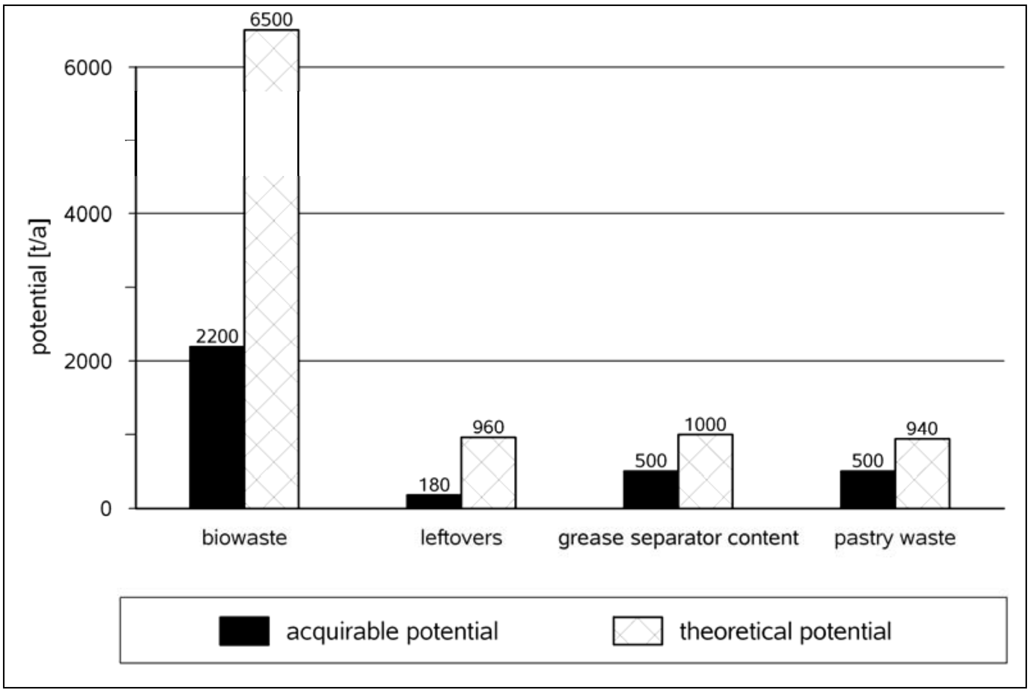


Figure 2 Comparison of theoretic and available organic matter in Weimar

The calculation takes some boundary conditions as a basis. Several of these are, e.g. should the fraction of organic matter in bio-waste bins with a proportion of 40 % and specific collection rates. The estimate of the leftovers of the service units demanded an average utilisation of 30 % for hotels and an accommodation rate of 573.000/a. Furthermore, daily tourists with a number of 3.000.000/a and the inhabitants of Weimar are deciding.

The final outcome for these boundary conditions and the bases of calculation from table 2 abstracts in table 4. The calculation of the biogas yield results is obtained using the specific wet basis, because the dry matter content is unknown. The methane content has an average of 65 % and the block heat and power plant is characterised by an electrical efficiency of 35 %.

Furthermore, the research of substrate feasibility is obligatory. The valuation of leftovers presents the critical aspect due to the content of pathogen germs. A pre-treatment is necessary for legal reasons. Other substrates, e.g. draff and pastry waste are mono-fraction and do not need special treatment like the inhomogeneous bio-waste with many impurities.

The biogas potential offers energy and heating recovery. A usual wastewater treatment plant can generate approximately 30 to 50% of electrical energy which is required and used in the treatment plant, in addition to nearly 100 % of the required heating energy [REIPA ET AL. 2008]. In Weimar, the gas quantity is enhanced by 100 % which leads to nearly 60 % electrical energy produced by the co-digestion of sewage sludge and biogenic waste. Furthermore, an increased efficiency is possibly using the heat for other processes, such as community heating

Table 4 Biogas potential and waste accumulation in Weimar [WEITZE 2008]

Source	Specific parameter				Biogas potential
	Substrate	Acquirable potential [t/a]	Biogas yield [m³/a]	Energy production [kWh/a]	
households	bio-waste	2.880	288.000	645.120	734.266 [m³/a] 1.644.756 [kWh/a_{el}]
	cooking fat	9,6	8.131	18.214	
service units	leftovers	180	32.400	72.576	
	grease separator contents	500	22.500	40.400	
	cooking fat	35	29.645	66.405	
industry	spent grains	318	38.160	85.478	
	pastry waste	540	270.000	604.800	
	pomace	5	1.325	2.986	
	apple pomace	65	9.555	21.403	
	fruit draff	570	8.550	19.152	
	grape marc	100	26.000	58.240	

CONCLUSIONS

A higher biogas yield can be expected using a technical optimisation and co-digestion. The preconditions are the availability and feasibility of the organic matter and the adequate digestion tower capacity. The current state in Germany demonstrates the possibility of co-digestion on waste water treatment plants.

Using the sewage of Tiefurt as an example for dimensioning is explained. The biogenic waste treatment of sewage is an effective way to increase energy production. The produced heat can be entirely required for co-digestion and the enhancement of energy production. This case study provides a basis to calculate the biogas yield of other treatment plants. For this purpose an adaption of key data of waste accumulation is required.

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