Proceedings of the

International Conference on Solid Waste Management

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,
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Volume 2

First published in November 2009

WasteSafe 2009 International Conference is organized by the Department of Civil Engineering, Khulna University of Engineering & Technology as an activity of WasteSafe II Project (EU-Asia Pro Eco II Programme of the European Commission Contrct: ASIE/2006/122-432) 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 is also aegis of Department of Environment, Ministry of Environment & Forests, Government of Bangladesh.

Published by

WasteSafe
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Khulna University of Engineering and Technology (KUET)
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Website: http://www.wastesafe.info

ISBN: 978-984-33-0761-3

250 Copies

Cover Design
K. M. M. Hasan and M. Alamgir

Page Layout
G. Sakar, M. K. Howlader, K.M.M. Hasan and M. Alamgir

Printed at Enrich printers, 41/5 Purana Paltan, Dhaka 1000, Bangladesh

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Organized by
Department of Civil Engineering
Khulna University of Engineering and Technology (KUET), Bangladesh

Co-financed by
EU-Asia Pro Eco II Programme of the European Commission

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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 is 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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ISBN: 978-984-33-0761-3, Vol. 2, pp.417-426

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Limited Resources-Evaluation Wanted; Procedure Supporting Preparation of Landfill Concepts

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ABSTRACT

Deposit of municipal solid waste is presently still most common used disposal form in many developing countries. In contrast, series of technical concepts for environmental friendly disposal were developed and implemented in Germany, known as multibarrier system. An evaluation algorithm should support the choice of suitable landfill concepts, especial for low and middle income countries. The development is based on the principle of the multibarrier idea and depends on the principle, that each barrier has a specific protective potential, but in contrast a specific economical and technical effort is necessary to achieve it. The multibarrier system is hierarchically subdivided in its essential components and elements. At the bottom level an evaluation takes place. The underlying raw data base on state of the scientific and technical knowledge. By using the assessment algorithm it will be possible to create stepped and appropriate landfill concepts. It will serve as a decision tool for decision makers and professionals within the activity field of landfilling.

INTRODUCTION

Open waste disposal sites within the city, numerous open dumps on the outskirts as well as missing waste treatment facilities characterise waste management situation in Bangladesh (Alamgir, 2005). At same time, the 1.5 million residents of Cambodian's capital Phnom Penh dispose ca. 90 % of their municipal solid waste untreated on a open dumping site at the outskirts. Deposit of municipal solid waste is until present time most common used disposal form. In low and middle income countries, more than 50 % of municipal solid waste is not disposed of in an environmental friendly way. This leads to significant environmental pollution. Emissions are mainly discharged over gas and leachate path. However, emissions are transboundary. (Hädrich 2007)

But economical conditions and options limit rapid improving of that situation in that countries. Therefore, waste management concepts according to German or European standards can not be implemented currently under these circumstances. Nevertheless people request is high for a clean and intact environment. That demands adapted approaches.

In contrast to the above mentioned situation, series of regulations and technical concepts for environmental friendly disposal have been developed and implemented in Germany, known as multibarrier system (Siedlungsabfall 1993). But not only institutions like the World Bank have recognised, that these regulations and concepts are technically and financially hard to realise in low and middle income countries. That has been led to the development of a couple of documents and guides for decision makers and professionals in waste management, see for instance UNEP (2005) and Bidlingmaier et al. (2006). Present work should be act as supplement in depth regarding technical landfilling.

An assessment algorithm has been created based on the fact, that waste is deposited on dumps and therefore uncontrolled in the environment in many countries. By means of the scheme it will be shown which protective potential is realisable by which economical and technical/ engineering effort. Derived from that, it should be possible to decide where available technical and financial resources are used most effectively. On the basis of a standardised rating matrix the scheme should support the choice of suitable alternative landfill concepts especial for low and middle income countries. Thereby, priority is given to an environmental friendly disposal and conservation of protected properties, primarily air, water and ground.

METHODOLOGY

Concept and boundary

The algorithm has been developed on the principle of the multibarrier idea as mentioned amongst others in German TA Siedlungsabfall, nowadays incorporated in the German Verordnung zur Vereinfachung des Deponierechts. This idea considers several extensive independent barriers of a landfill concept to prevent release and dissemination of pollutants in the environment. The waste pre-treatment, the choice of suitable locations, suitable landfilling techniques, emission treatment and maintenance as well as defined allocated values for waste are ranked to that barriers. (TA Siedlungsabfall, 1993)

Two aspects have been stood in front of the scheme development. It should be independent and/or uncoupled from any location to point out its generality. Furthermore it should be mainly a tool for low and middle income countries. Hence, modifications have been taken place regarding underlying terms in general regulation. The regulation served as foundation is in first instance the Verordnung zur Vereinfachung des Deponierechts. The assessment algorithm focuses on barriers and its associated components as well, which do not fulfil the proof of equality as required amongst others in the TA Siedlungsabfall and/or EU landfill directive. In that context, the scheme has to be seen as a catalogue including several different possibilities to each barrier. These possibilities have a specific protective potential as well as economical and technical effort not meeting the above mentioned proof of equality.

The considered components are located within the grey area of figure 1, whereas the focus is on components that are between the point of origin and the norm of the EU landfill directive and/or other comparable standards. The considered landfill concepts should be in frame of simple solutions up to solution after state of the art. As a result it will be possible to indicate a specific value margin. The uncontrolled waste dumping has been set as reference scenario, that means there are no emission barriers existing.

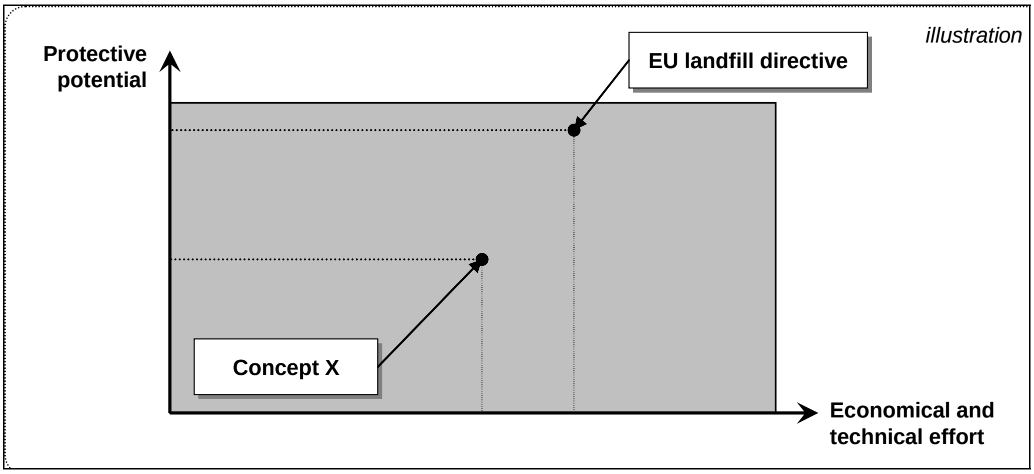

Figure 1 Classification of landfill concepts regarding EU standard

The scheme is concentrating on the parts pre-treatment (extensive mechanical-biological processes), landfill bottom liner, emplacement technique/landfill body, surface cover/liner, emission treatment (considering gas- and leachate path), as indicated in figure 2. Specifications describing the situation in respective application area can serve as input data, e. g. leachate amount. Output data are the contribution of the total emissions escaping the landfill. Immissions are beyond considered field. A rating of protected properties influenced by emissions does not take place within the system. That decision is left to the respective responsibilities in application area. The time horizon is set between 50 and 100 years, as mentioned and assumed in DIBt-Grundsätze (DIBt-principles 1995) amongst others.

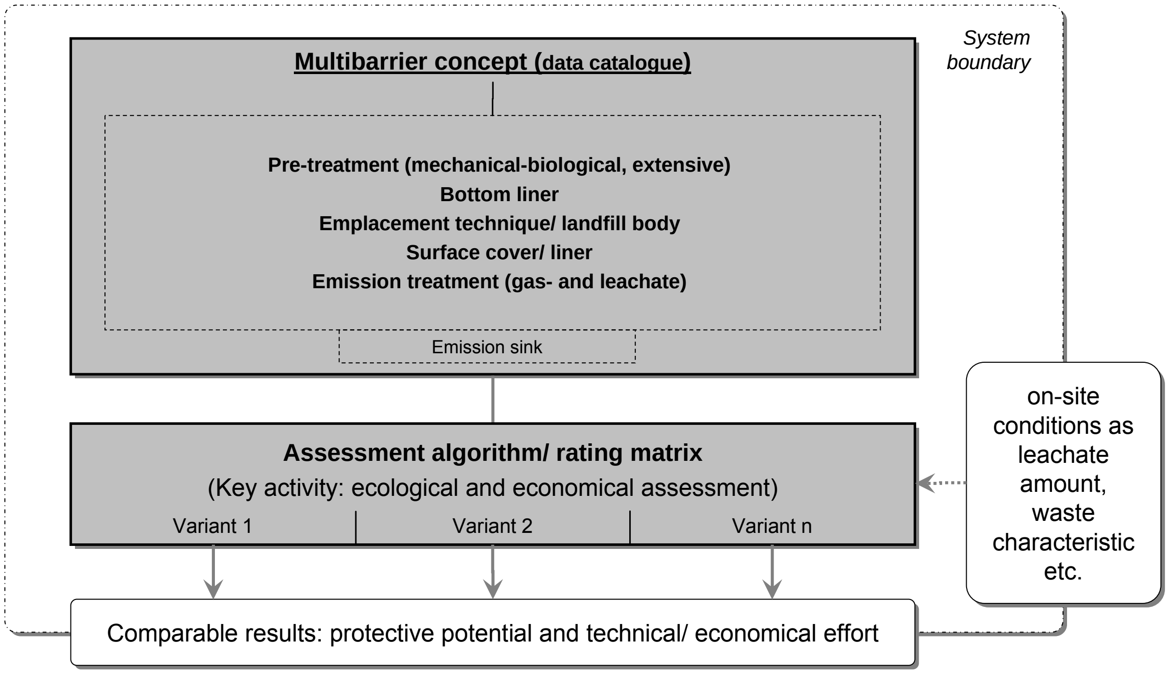

Figure 2 Schematic of system composition and boundary of assessment algorithm

Structure, Criteria and Parameters

Suitable and different modifiable value benefit analyses (Bogon et al. 1995) as well as cost-effectiveness analysis, as used similarly by Hutterer et al. (2000) and Schmid et al. (2001), form the methodical base of assessment procedure. The system of objectives serving as main work base to identify the protective potential is displayed in Table 1, see also Hutterer et al. (2000) and Nienhaus (2001). Thus, a good structuring and overview is given as well as a more objective processing.

Table 1 System of objectives as orientation basis for each barrier

Objectives		Intentions – reduction of:	Operationalised objectives – reduction of:
Protection of individual/ environment	Preserve air quality	local impacts	fires wind-blown dispersal and dust smell/ gases
		global impacts	landfill gas
	Preserve water (and soil) quality	leachate quantity	portion of leachate amount
		leachate quality	pollutant discharge (organic) pollutant discharge (inorganic)

Classification of relevant criteria and associated parameters to describe the protective potential has been carried out for each barrier, based on the operationalised objectives. That allows a clear separation and evaluation of barrier components and its variants, see Bogon et al. (1995). The main focus lays on the biological degradable organic carbon, because its leads to the main emissions of a landfill via gas and leachate path. Main part of the economical and technical effort geared on the cumulated energy demand, on part for use (KEA_N). Based on it the specific process chain divided in reasonable steps are displayed for each barrier reflecting necessary work steps and techniques. Thus an estimated energy demand for operation can be displayed and it shows the engineering complexity necessary to implement a specific barrier and/or landfill concept. The conceptual structure is illustrated in Figure 3.

Where applicable the individual barriers are divided into following hierarchical levels:

- the essential components of each barrier,
- its different variants and
- type of constructions, as seen in Figure 3.

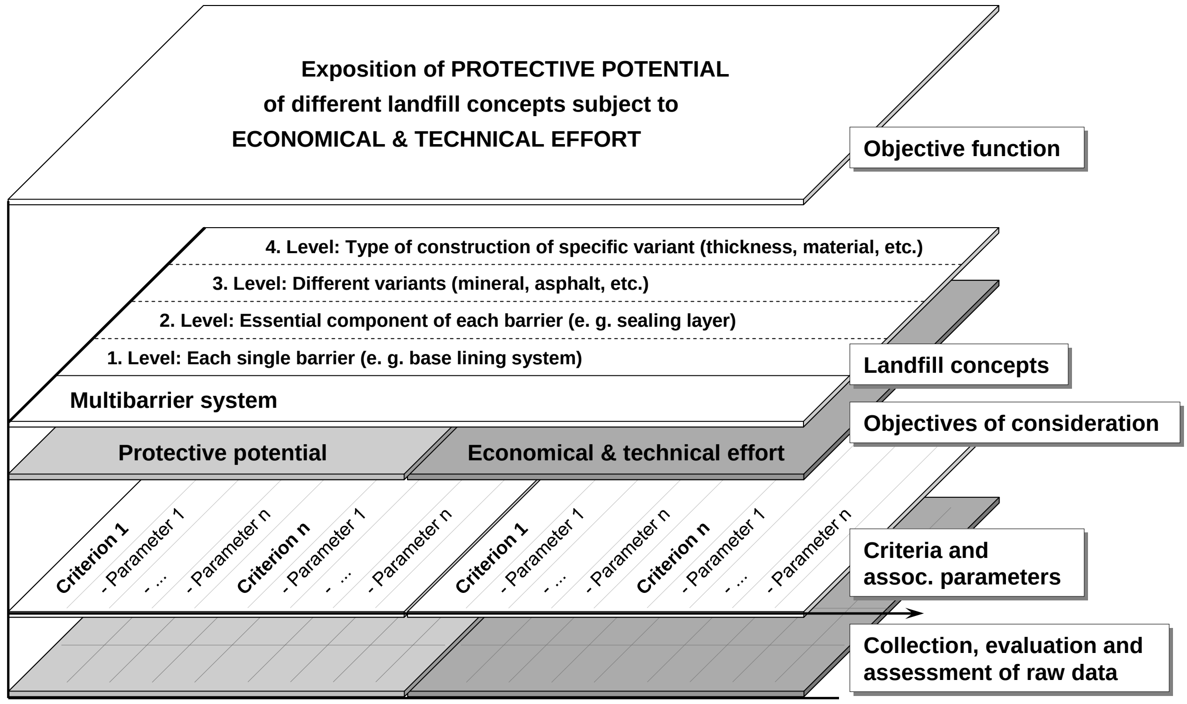

Figure 3 Conceptual structuring of assessment scheme

In the bottom level, single elements have been considered and proved with data and/or values according to criteria and associated parameters. These elements build the base for each combination and consequently for upper levels. Thus, the objective function has been differentiated in several independent processable subsystems and subsequent partial results can be combined to an overall result, see also Bogon et al. (1995).

Data aggregation

The protective potential - also definable as effectiveness - of considered barriers describes the emission contribution which is retained and not released in the environment. That is displayed as a normalised factor between 0 and 1 on an ordinal scale. The factor is determined by comparing released emissions of chosen barrier and reference scenario, see equation 1. The factor itself gives information about the potential of emission reduction, whereas the factor multiplied with an emission amount gives information of real amount of retained pollutants.

$$\text{EQUATION: protective potential (PP)} = \frac{\text{emission of reference scenario – released emission of barrier}}{\text{emission of reference scenario}} \qquad (1)$$

Each single barrier and/or its components are being analysed regarding its protective potential starting from bottom hierarchical level. Where necessary, data have to be aggregated from different components or parameters. Where applicable that data result from achievement of target yields (TY) of individual components or parameters and its weighting (W). Thereby the effectiveness (E) and/or part-effectiveness (PE) is the product from weighting (W) and target yield (TY). The target yields of upper levels are calculated by weighting and target yield of lower level, see equation 2 and 3 (Schmid 2001). In contrast to that, there is no weighting between two issues protective potential and economical/ technical effort. Here, former is leading objective of consideration. The underlying raw data rest upon state of the scientific and technical knowledge. Therewith, evaluation bases on measurable values, if procurable.

$$\text{EQUATION:} \qquad E / PE = \sum_{n=1;n=max} (W_n * TY_n) \qquad (2)$$

$$\text{EQUATION:} \qquad TY_{i-1,\,j} = \frac{\sum_{n=1;n=max} (W_{in} * TY_{in})}{\sum_{n=1;n=max} W_{in}} \qquad (3)$$

n: amount of criteria / parameter

i: hierarchical level

j: next hierarchical level

SELECTED EXAMPLES

On the basis of barriers pre-treatment, bottom liner and leachate treatment as well as emission path leachate the functionality of the scheme is illustrated. As reference scenario it is assumed that the municipal solid waste is dumped into the surrounding area without any barrier between it and the environment, viz. 100 % of emissions (in that example leachate) go into the environment. Emissions from biodegradable organic carbon are considered as main emissions. The leachate amount and concentration serve as basic data, measured or estimated. It is assumed also that 5 - 1 % of organic carbon escapes the landfill via the leachate path, the rest is emitting via the gas path, based on literature data.

The protective potential are described by leachate load reduction, whereas the load results from the leachate concentration and amount. Each barrier influences either the leachate amount or load or has an influence on both parameters. By means of available waste composition data a first range of emission amount of biodegradable organic carbon [$kgC_{bio.deg.}/Mg_{DM}$] can be estimated as orientation, based on the composition of municipal solid waste or residues waste to be disposed, the organic dry matter, carbon proportion and biodegradability of single fraction.

Mechanical-Biological Pre-treatment

The mechanical-biological pre-treatment (MBT) process can be divided into the essential components such as mechanical and biological treatment. The mechanical step can comprise sorting, shredding and/or crushing and homogenisation and if so moistening. The biological step can be an aerobic or anaerobic process. As pre-treatment option extensive aerobic processes are considered only, like passive aerated trapezoid windrow rotting or triangle window rotting process active aerated by turning.

Regarding the system of objectives the mechanical biological pre-treatment influences mostly the emissions paths landfill gas and leachate and therewith the operationalised objectives landfill gas and pollutant discharge (organic) next to the others. Therefore following assumptions are made based on several research projects and analyses: a reduction of 80–90 % of gas and 90 % of leachate emissions is set regarding biodegradable organic substance and/or carbon by a proper mechanical-biological pre-treatment of municipal solid waste. That means the protective potential is estimated with 0.9 regarding leachate and conservatively with 0.8 regarding gas path.

The process flow chart, an estimated use energy demand (KEA_N) and mass-specific space demand characterise the technical and economical effort. Based on the process flow chart, the necessary work steps are identifiable. The use energy demand is estimated with 60 – 90 MJ/Mg, based on literature data. That number is an orientation value for energy demand summarising diesel fuel and electric energy. It displays not primary energy. The mass-specific space demand can be estimated for passive aerated trapezoid windrow (“Kaminzugverfahren”) with 0.5–1.5 m²/Mg a and for active aerated triangle heaps with 0.4–1.0 m²/Mg a. The minor differences occur of different treatment duration, 12–18 months for first mentioned process and 3 – 6 months for second. The assessment of the barrier pre-treatment takes part at a whole and is not created from a lower level.

Bottom Liner

The fundamental construction inclusive all components of a bottom liner system are geared for instance to the requirements of the German Verordnung zur Vereinfachung des Deponierechts. In this regard, the documents include the highest requirements and set the direction for an upper limit of protective potential. The base lining system named in the documents has been subdivided as indicated in Table 2. The construction types consist of suitable elements for a base lining system and elements required amongst others in concerning regulations. The listed elements are basic elements and its combination leads to the overall structure of a base lining system, such as required in respective documents. The sealing layer can consist of natural or synthetic material only or be a combination of it.

According to the DIBt-Grundsätze (1995) the efficiency of a landfill bottom liner are characterised by the assessment criteria impermeability, mechanical stability, resistance and producibility. The assessment geared on the criteria of that principle; thereby the impermeability is used to describe the protective potential of bottom liner. Referring further to the DIBt-Grundsätze (1995) the advective and diffusive mass contaminant transport are the processes to characterise the impermeability of a bottom liner.

Table 2 Classification of barrier base lining system(based on German Verordnung zur Vereinfachung des Deponierechts, 2009)

Barrier	Essential component	Variant	Type of construction
Bottom liner	Artificial sealing layer	Natural materials	Natural mineral materials (clayey soil) Modified mineral materials
		Synthetic materials	Geomembrane Geosynthetic clay liner Asphalt sealing layer
	Artificial drainage layer	Natural materials	Mineral drainage layer
		Synthetic materials	Geosynthetic drainage layer

Mineral liners are influenced by both advection and diffusion, whereas intact geomembranes are characterised by diffusion only, because of its non-porous inner structure. But pin holes and holes caused by improper installation would lead to a local advection into subjacent layer, who has a high influence. (Rowe et al. 2004; Müller 2001)

Based on the general equations of advective and diffusive contaminant mass transport, through mineral sealing layer and geomembranes under stationary conditions the emission rate and flow rate respectively through a bottom liner is estimated considering chosen bottom liner material and its characteristic. Thereby the parameters shown in Table 3 have to be considered.

Table 3 Associated parameters regarding bottom liner assessment considering advective and diffusive contaminant transport

Parameters		Unit
General	Leachate amount	[l/m² a]
	Contaminant concentration[1]	[g/l]
Mineral material	"realistic" hydraulic conductivity, kf-value	[m/s]
	Diffusion coefficient in free solution plus tortuosity factor or effective diffusion coefficient	[m²/s]
	Porosity	[%]
	Thickness of the sealing layer	[m]
Synthetic material	Distribution coefficient (σ) and/or solubility (s)	[-]
	Diffusion coefficient	[m²/s]
	Thickness of the sealing layer	[m]

A contaminant concentration of 1 g/l is used to show the protective potential of the chosen bottom liner systems. The emission rate is then estimated by using the mass transport equations, a summary of advective and diffusive transport under the assumption of a contaminant concentration of 1 g/l. The results are referred to the total emission rate, the product of leachate amount and assumed contaminant concentration, in that case 1 g/l.

Thereby it has to be mentioned that with an increasing leachate amount the potential of the sealing layer increases and with a decreasing of leachate amount also the potential decreases. In that context the presentation of relative targets are in front against absolute targets. Figure 4 shows the protective potential of sealing layers from different materials or combinations referring to two different reference scenarios. Depending on the reference scenarios and chosen sealing layer characteristics different protective potentials can be reached.

[1] If the protective (contaminant reduction) potential will be shown and different bottom liner will be compared, a contaminant concentration of 1 g/l can be assumed.

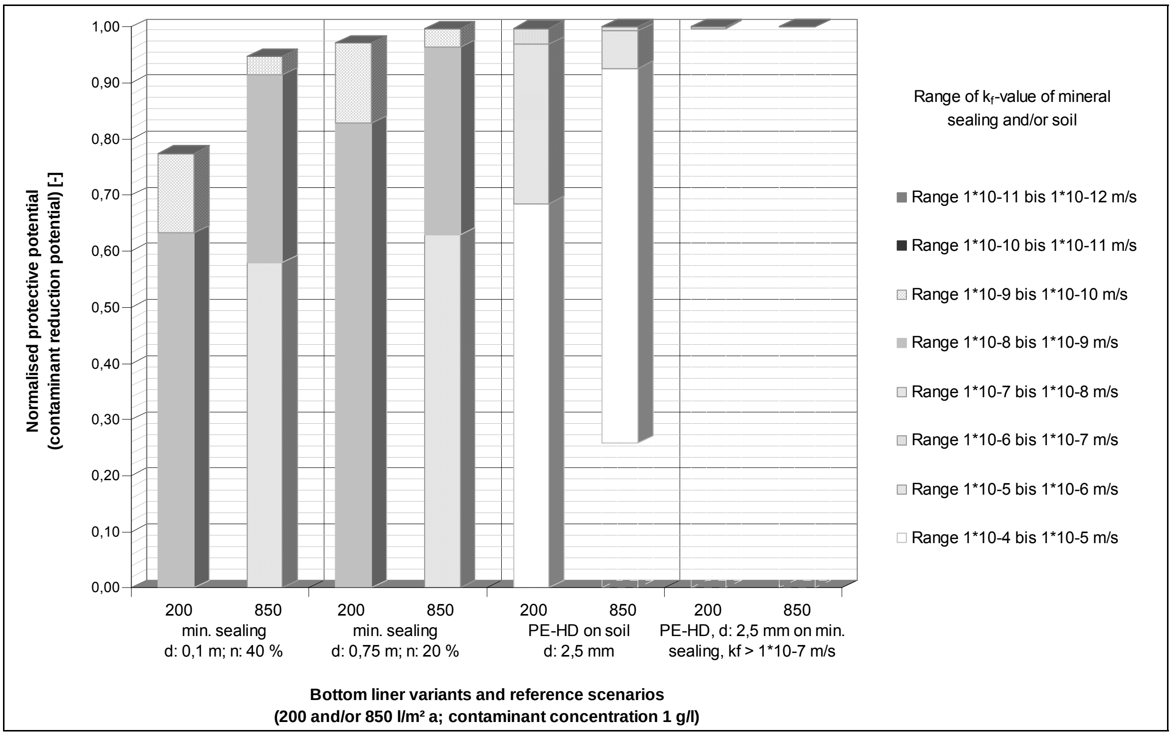

Figure 4 Graphical illustration of protective potential of different bottom liner systems displayed as factor between 0 and 1 referring to two reference scenarios (200 and 850 l/m² a; contaminant concentration 1 g/l) and organic pollutant discharge

The economical and technical effort can be deduced from the process flow chart and the estimated use energy demand. The use energy demand varies depending on the chosen bottom liner system. According Egloffstein (2006) a use energy demand of ca. 139 MJ/m² is necessary for a 0.5 m thick mineral sealing layer from natural mineral material including a mineral drainage layer. To transfer that data into use energy demand per unit weight of waste, a emplacement density of 0.6 Mg/m³ for untreated waste and 1.0 for pre-treated waste (Santen 2008) as well as landfill high of 15 m are assumed. As result use energy demand per unit weight is between 9.3 (pre-treaded waste) and 15.4 (untreated waste) MJ/Mg. As higher the emplacement density and the landfill body is as lower is the mass specific use energy demand.

Leachate Treatment

Each organic loaded leachate can be biological treated practically. Biological processes are integrated normally as first step in process chains combining biological and mechanical/ physical/ chemical processes because it leads to an increasing effectiveness of subsequent treatment steps. A BOD_5-reduction > 95 % and effluent values of < 20 mg/l can be reached with an adequate biological treatment process. The COD-reduction is in range of 80 to 90 % relating to leachate with a BOD_5/COD-ratio ≥ 0,4 (acid phase) till 40 to 60 % relating to leachate with a BOD_5/COD-ration of < 0,2 (methane phase) (Axmann, 2002; BMU, 2002). The simples biological treatment facilities are non-aerated and aerated lagoons, whereas the second one is described more often in literature referring leachate treatment. According Widmann (1994, 10-02) the treatment of leachate in an aerated lagoon can reach a BOD_5 decomposition of 98 %, whereas a CSB-reduction of 30 – 60 % is achievable. Difficulties can occur by temperatures under 10°C. In contrast in non-aerated lagoons the BOD_5 reduction is between 50 % and 70 % (LfU 1993). According DWA-A 201 (2005) non-aerated and aerated lagoon are recommended up to a specific dimension only. Non-aerated lagoons require no energy during operation, whereas aerated lagoons require energy for aeration equipment.

CASE STUDY KHULNA

Currently an activity is running intending implementation of an integrated waste management in the Bangladesh city Khulna, whereas one focus is on professional and improved disposal of waste.

Amongst others a controlled landfill is being constructed in this context first time outside the capital Dhaka. Khulna, capital of the correspondent division, is located in the Southwest of Bangladesh at the river Rupsha. It is the third biggest city of the country after the capital Dhaka and Chittagong and has a population of ca. 1.5 mill. The population density is ca. 18,424 person per km². The city is subdivided in 31 wards. Around 530 Mg of municipal solid waste are produced daily in Khulna, whereas ca. 85 % are from households. The waste consists mainly of biodegradable organic substances like kitchen and food waste as well as paper and paper products respectively, as indicated in figure 5.

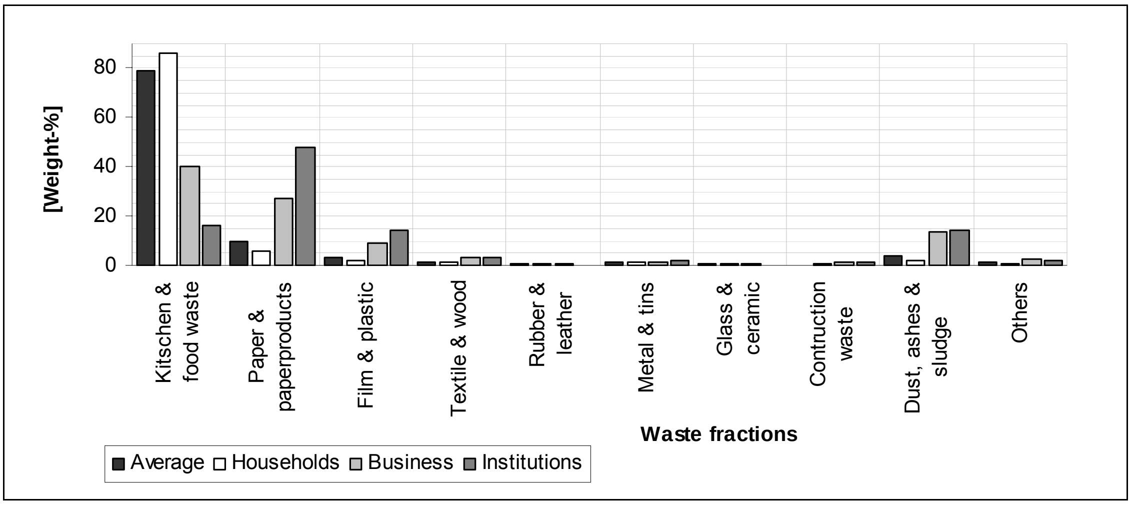

Figure 5 Waste compositions referring to average and source (Alamgir et al. 2005)

Non-governmental organisations and community-based organisations collect the waste at households and deliver it to intermediate storage stations, the so called “secondary disposal sites”. The ward administration collect the waste from public dustbins and deliver it together with the waste from secondary disposal sites to the dump sites, the so called “ultimate disposal sites”. That are defined uncontrolled tipping areas along the streets and canals.

A controlled landfill in pilot scale is being constructed at one tipping area called “Rajbandh” covering a area of a half hectare, whereof the disposal area is a quarter hectare. The bottom liner of the pilot landfill consists of a double clay liner of 40 cm thickness. The hydraulic conductivity is around $1*10^{-9}$ m/s and the porosity can be assumed with circa 35 %. A leachate collection layer of 20 cm and a leachate collection pipe are placed above.

The precipitation in Khulna is around 1,850 mm/a and the evaporation in that region is between 800 to 1,600 mm/a (Middelton et Thomas 1997), whereas an average on save side of 1,000 is assumed. Hence a long range leachate amount of 850 mm/a can be estimated as basis for further assessment. Thus a protective potential of 0.95 can be assumed.

Currently the leachate is pumped into a non-aerated leachate pond with a sealing system similar to the landfill. Considering literature data and current conditions a BOD_5 reduction of 50 % and a COD-reduction of 30 % is estimated, assuming that the pond has a sufficient size. Thus a protective potential of 0.475 can be estimated referred to sealing system and BOD.

A pre-treatment of the delivered waste does not take place at the present time. If a proper pre-treatment would be installed resulting in a lower BOD_5 and COD concentration, the BOD_5 and COD-reduction would be low because of less biological degradable substances.

RESULTS AND DISCUSSIONS

Following table 4 shows a potential result of the scheme, the impact of the case study and three different scenarios. Different barriers and its combination can be compared regarding protective potential (in that example referring to leachate path) and economical and technical effort, here presented as use energy demand. The assumed leachate amount for the case study is ca. 850 mm/a and the emissions are from biodegradable organic carbon.

Table 4 Introduction of potential results assuming a leachate amount of 850 mm/a, a scenario with pre-treatment of waste and two different sealing systems (comprising drainage layer)

	Variants	Case study	Scenario I	Scenario II	Scenario III
Barriers	Mbt (PP)	Without mbt (0.0)		With mbt (0.9)	
	Bottom liner (PP)	Natural mineral material* (0.95)	PE-HD on min. sealing** (1.0)	Natural mineral material* (0.95)	PE-HD on min. sealing** (1.0)
	Leachate treatment (PP)	Non-aerated lagoon (0.475)	Non-aerated lagoon (0.475)	Non-aerated lagoon (low)	Non-aerated lagoon (low)
Reference scenario (nothing is done)		100 % leachate emissions			
Protective potential (PP)	Mbt	100 % leachate emissions; 0 % degraded		10 % leachate emissions; 90 % degraded	
	Bottom liner	5 % leachate emissions; 95 % send to treatment facility	0 % leachate emissions; 100 % send to treatment facility	0.5 % leachate emissions; 9.5 % send to treatment facility	0 % leachate emissions; 10 % send to treatment facility
	Leachate treatment	50 % leachate emissions; 45 % degraded	52,5 % leachate emissions; 47,5 % degraded	high leachate emissions; low degradation	high leachate emissions; low degradation
Total protective potential [-]		0.450	0.475	> 0.900	> 0.900
Total use energy demand [MJ/Mg]		ca. 12 + leachate treatment + aftercare	ca. 22 + leachate treatment + aftercare	ca. 67 – 97 + leachate treatment + aftercare	ca. 73 – 103 + leachate treatment + aftercare

* k_f-value $1*10^{-9}$ m/s, d = 0.4 m, n = 35 %, considered substance: organic acid
** k_f-value $1*10^{-9}$ m/s, d = 0.4 m, n = 35 %, considered substance: organic acid

Regarding the exemplary data shown in Table 4, it has to be noticed, that the leachate emission path is considered only. Furthermore the mechanical-biological pre-treatment and leachate treatment reduces the emissions into the environment by degradation whereas the bottom liner does not degrade potential emissions but redirects it. The high protective potential of the bottom liner from natural mineral material (case study and scenario II) compared to PE-HD on mineral sealing is caused by the high leachate amount (emission potential) of 850 mm/a and the relative small amount of leakage through the natural mineral bottom liner of 42,5 mm/a in that case. Furthermore leachate from pre-treated waste (scenario II and III) is indicated by a small BOD_5/COD-ration similar to leachate from methane phase. Thus a low biological degradation has to be expected, indicated a low degradation.

CONCLUSIONS AND FORECAST

By using the assessment scheme it will be possible to create respective define stepped and appropriate landfill concepts, that considers the economical and technical situation in the target regions of low and middle income countries. Concepts can be defined in a way providing best possible protective potential in dependency of the economical situation and technical feasibility. Furthermore the assessment scheme supports the choice and priority of different components of the multibarrier concept. In this manner adapted landfill concepts can be generated considering local conditions. The assessment algorithm will serve as a decision tool for decision makers and professionals within the activity field of landfilling and waste management. In this context, it want to serve as component in a wide grid of integrated sustainable waste management strategies and do not want to take up the status of completeness as well.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.427-429

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Air Quality around Ariyamangalam Dumping Yard in India

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ABSTRACT

Tiruchirappalli is Tamil Nadu's fourth largest city after Chennai, Madurai and Coimbatore with an estimated population of 1,067,915 (as of 2008). It is situated in the centre of Tamil Nadu state, on the banks of the River Cauvery. Tiruchirappalli is a Municipal Corporation and the administrative headquarters of Tiruchirappalli district. Ariyamangalam dumping yard is the only dumping yard in the city. Which have 12 lakh tonnes of solid wastes? At least 350 tonnes is added every day. Apart from solid waste problem, air pollution is another big problem around this dumping yard. The wind flows over this open dumping yard and carries enormous amount of particles of various size and harmful gases .A study has been conducted to evaluate ambient air quality around the dumping yard by selecting four sampling sites(one each at four different directions). Three parameters SPM (Suspended Particulate Matter), SO2 (Sulphur dioxide) and NOx were considered for the studies. High volume air sampler Envirotech APM430 has been used to know the above said three parameters. The result reveals that SPM concentration is more in all four sampling sites. And beyond the standards prescribed by Central Pollution Control Board (CPCB).Whereas concentrations of SO2 and NOx are will within the prescribed limits of CPCB.

INTRODUCTION

Municipal solid waste (MSW), also called urban solid waste, is a waste type that includes predominantly household waste (domestic waste) with sometimes the addition of commercial waste collected by a municipality within a given area. They are in either solid or semisolid form and generally exclude industrial hazards wastes. The term residual waste relates to waste left from household sources containing materials that have not been separated out or sent for reprocessing. Solid waste creates not only ground water pollution and soil pollution but is also play a vital role in urban air pollution. The status of air quality around the Arimangalam dumping yard has been evaluated and a questionnaire survey was conducted to estimate the allergic symptoms and exposure to assess the respiratory disorders. The data are analysed to evaluate the critical situation arising out of the emission of air pollutants and the impact on human health due to respirable diseases (RDs) around the Ariyamangalam dumping yard of Tiruchirappalli city.

STUDY AREA

Tiruchirappalli city (10.5°N , 78.43°E,78.8 MSL) the heartland of Tamil Nadu , is situated on the banks of river Cauvery and spread over an area of 146.90 sq. Km with an estimated population of 1,067,915 (as of 2008).Tiruchirappalli the fourth largest city (after Chennai, Coimbatore and Madurai) of Tamil Nadu, is one of the fastest growing city in terms of its population in Tamil Nadu of India. Uncontrolled growth contributes various environmental problems. Solid waste pollution is one among them. As the population increases, the waste generated in that particular region also increases. More population leads to more waste generation, which intern leads to severe air and ground water pollution, apart from the health hazard posed by the conditions of squalor. Ariyamangalam dumping yard is the only dumping yard in Tiruchirappalli city. Which consist of a spread? Which have 12 lakh tonnes of solid wastes? At least 350 tonnes is added every day. The wind flows over this open dumping yard and carries enormous amount of particles of various size and harmful gases.

MATERIALS AND METHODS

Ambient air quality was monitored for major air pollutants viz Suspended Particulate Matter (SPM), Sulphur dioxide (SO2) and Oxides of Nitrogen (NOX) around Ariyamangalam dumping yard of Tiruchirappalli city. High volume air sampler (Envirotech APM-430) is used for sampling.SO2 and NOX were absorbed in Sodium tetrachloromercurate and Sodium hydroxide. Analysis of this solution by West and Gaeke method, and Griess – Saltzman method, respectively. SPM was collected on pre weighed glass fiber filter (Whatman). Filter paper was again weighed after sampling and the difference in weight were used to calculate concentrations of SPM in respective areas and expressed as µg/m3 of air. The monitoring was done for 24 hours. This research work was carried out from February to July 2009. Four sampling stations were selected to represent 4 different directions (that is East, West, North & South). At each of these places monitoring was done 3 different days to get the average concentration of pollutants major air pollutants viz SPM, SO2 and NOx. A questionnaire was prepared and survey was conducted particularly in case of suspected allergic population by inquiring the recurrence of the type of allergic symptoms. The occasions of this onset was recorded with each individual to assess the allergic status.

RESULT AND DISCUSSION

Table-1 shows average concentrations of SPM, SO2 and NOx at each sampling station of Ariyamangalam dumping yard of Tiruchirappalli city. The highest concentration of SPM is recorded at Eastern part of dumping yard, and lesser one in the west of yard. Concentration of SO2 is more at south side and less at northern side of the Ariyamangalam dumping site. NOx concentration is more at north side and less at west of yard. SPM concentration at all four side exceeded ambient air quality standards of Central pollution control board (CPCB) around Ariyamangalam dumping yard. The solid waste may have more dry organic matter and might be mixture of soil and sand. But both SO2 and NOx are well within the limits prescribed by CPCB around the dumping yard.

Table 1 Average concentrations of SPM, SO2 and NOx (µg/m3) at different sampling stations of Ariyamangalam dumping yard from February to July 2009

Sl.No	Sampling Station	SPM	SO2	NOx
1	EAST	330.32	21.80	78.67
2	WEST	230.13	19.00	68.00
3	NORTH	326.65	12.00	82.93
4	SOUTH	318.43	31.00	79.21

Source: Compiled from Primary data

Total exposure to an individual to a specific pollutant is determined by the concentration of contaminant and the duration of its exposure (Spengler and Dockery 1981). Exposure to indoor and outdoor air quality is different because they always change with time and diurnal pattern (TERI 1995). Exposure to SPM is also an equally serious risk to health SPM includes all air-borne particles in the size range of 0.5 μ to 100 μ.

Table 2 Estimation of allergic symptoms

Complaint	Total no. cases	Condition	No. of person	Percent of incidence.
Neck block	20	Allergic	17	85
		Non- Allergic	3	15
Sneezing	35	Allergic	30	86
		Non- Allergic	5	14
Cough	60	Allergic	50	83
		Non- Allergic	10	17
Hyperacidity	29	Allergic	18	62
		Non- Allergic	11	38

Source: Compiled from Primary data

The actual health damage caused by dust particles depends upon its nature and composition (Binder *et al.*, 1976). The effects attributed to mild eye irritation mortality (David 1995). The data generated from the survey were analysed to assess the percentage of allergic population and the suspected allergy causing agents. The results are shown in Table-2.The assessment of respiratory disorders (RDs) was obtained from the questionnaire survey from the doctors. On the basis of the survey of the SPM-related RDs each disease was recorded for indexing the imprint class I to IV. The highest imprint score depicts the maximum severity of RDs.

Table 3 Imprint classification of respiratory diseases

Imprint class	Imprint score	Symptoms
I	0.0	No RD: healthy, free from any respiratory disease
II	2.5	Mild RD: suffering from only upper track respiratory infections (UTRI)
III	5.0	Moderate RD: suffering from UTRI as well as lowest track respiratory infections
IV	10.0	Severe RD: Suffering from bronchitis, asthma, allergic thintis, fibrosis, asbestosis, pneumoconiosis and non-malignant RDs

Source: Compiled from Primary data

CONCLUSIONS

From the results, it can be concluded that Suspended Particulate Matter (SPM) is the main air pollutant around theAriyamangalam dumping yard of Tiruchirappalli city,India. The concentration of SPM exceeded the ambient air quality standard by CPCB . The reason is DRY dry and untreated matter (waste) .This problem can be overcome by adapting advance ecofriendly solid waste management techniques and switch over to biovermicompositing technologies. Proper environmental awareness and personal protective devices may be useful in avoiding health problems of residents of Ariyamangalam area of Tiruchirappalli city.

ACKNOWLEDGEMENT

Our grateful thanks to Noorjahan.S and Sayed Mustafa research scholars from Tiruchirappalli, for their valuable suggestions.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.431-440

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Field Performance of Compacted Clay Liner Used in a Pilot Scale Sanitary Landfill at Bangladesh

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ABSTRACT

This paper demonstrates the field performance of Compacted Clay Liner (CCL) used in a Pilot Scale Sanitary Landfill (PSSL) at Bangladesh. The base liner used as a barrier of PSSL has been studied in the site of Khulna City Corporation (KCC) open dump area at Rajbandh, Khulna. The performance of base liner has been measured by collecting the leakage on areas from 2500m^2 compacted clay without using of geomembrane. The evaluated result reveals that the performance of CCL having 400mm thickness constructed in two layers with the reasonably good degree of compaction, however, decreased severely within one year due to desiccation and shrinkage. The maximum leakage rates have increased from 36 x 10^{-3} m^3/day to 46.6x10^{-3} m^3/day. The CCL desiccated during the first dry summer of the study after drying form a wetting condition. High percolation rates through the CCL were measured during the monsoon. Based on the field experience, it can be concluded that wetting of CCL did not significantly reduce the percolation rates. However, investigation for a longer period is required to make final comments on the performance of CCL.

INTRODUCTION

This study describes the field performance of CCL used in a PSSL in Khulna to establish the appropriate Bangladesh standard to maintain safe and sustainable management of Municipal Solid Waste (MSW). The first PSSL has been constructed at Rajbandh, the ultimate disposal site (UDS) of MSW of KCC in close cooperation of WasteSafe II project partners which is conducting by the Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh. The location of PSSL is at Rajbandh as depicted in Figure 1 with respect to Khulna city map.

Base liner for landfills and contaminated sites has a variety of tasks. Usually they prevent the direct uptake of contaminants by organisms, control gas fluxes and reduce the infiltration of rainfall and snowmelt. The design of liner depends on several factors such as the climatic conditions of the site, the geotechnical properties and the environmental risks of the contaminated area, the planned use of the site, and costs. Sites to be used for industrial purposes are sealed by the layers of asphaltic concrete. The service life of a liner usually is long compared to most other engineered constructions. It varies from several decades to hundreds of years. Though there is a lot of practical experience with the design and construction of base liners, little is known of their practical performance. Unlike base liners of landfills, covers are exposed to a variety of environmental stresses (e.g. erosion, heat, frost, desiccation, biological turbation, transport and precipitation of colloids, hydroxides, carbonates) in addition to the impact of the waste body (gas and gas condensate, contaminated liquids, subsidence). Therefore it is hard to predict the long-term performance of a base liner on the basis of theoretical considerations and laboratory data. For this reason a team of researchers and technicians has set up and operated several in situ test facilities during the last one year to study and monitor the field performance of CCL constructed in a pilot scale sanitary landfill at Khulna. This paper illustrates a brief overview of the most important results. The field performance of CCL was found satisfactory to that 400mm thick which is examined by measuring the quantity of leakage rate per unit area in liters per day and comparing the physical and chemical properties of leakage water with leachate.

OVERVIEW OF PILOT SCALE SANITARY LANDFILL

A suitable location for the construct of PSSL has been selected. The overview of the site, location, sub-soil conditions and the nature of MSW to be deposited in the PSSL and the design aspects as well as operation are discussed in the following sections in brief. The details can be obtained in Alamgir and Islam (2009) and Islam et al. (2009).

Site Conditions and the Layout

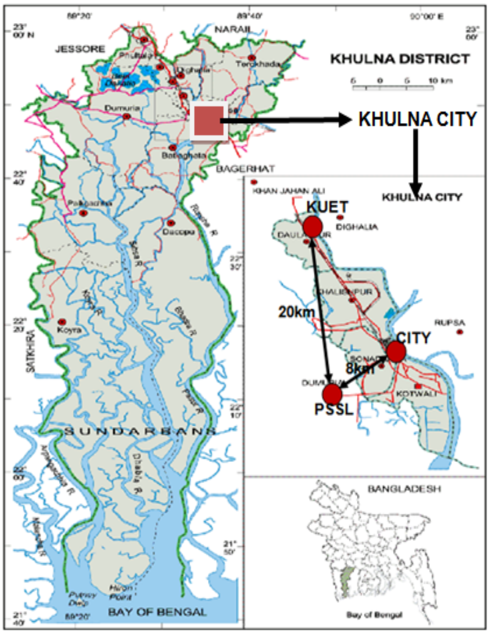

Figure 1 Location of PSSL with respect of Khulna city map

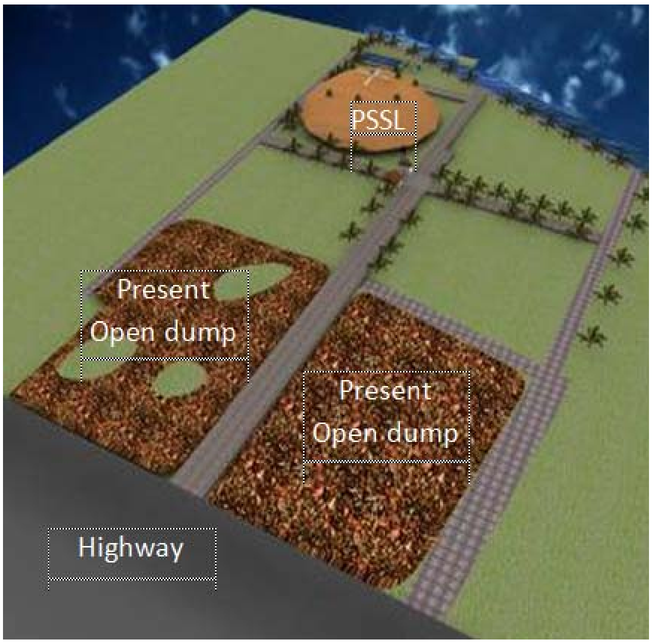

Figure 2 Layout of the PSSL at new Rajbandh

It was decided by the WasteSafe II Team member to select a site in the same location of ultimate disposal site (UDS) of KCC at Rajbandh for the construction of PSSL. The site is located about 8km far from the city centre i.e. 'Royal-Castle Salam Square' of Khulna city and situated along the North-side of Khulna-Satkhira highway as shown in Figure 1 with respect to Khulna city map.

The USD consists of 5 cells (shallow depth pond) surrounded by earthen embankment, where paddy plantation and fish cultivation were continued till the costruction of PSSL started. However, still it has significant capacity to accommodate the solid waste. In the New Rajbandh waste deposition is started since January 2007 into first two cells along the Khulna-Satkhira Highway were started to fill as shown in Figure 2. The site of the PSSL is located at the north-west corner with an area of 1.1acres. The ground surface of the site 1m below the top of the surrounding earthen embankment and site has the dimension of 52x64x85x55m. There is a public natural stream in the North side and private paddy land in the west. The sub-soil investigation was revealed that the gray clay minerals with organic forms to a depth of 1.5m followed by silty clay having clay minerals content ranges from 23 to 30% and hydraulic conductivity varies from 2.45×10^{-6} to 2.5×10^{-8} cm/sec at different molding water content. Swelling clay minerals are present in varying the amount of 0 to 11% of the composition.

Design Criteria

In design all the relevant aspects of a standard sanitary landfill is considered. Emphasis is also given for the best use of locally available building materials and construction techniques. However, scientific and technical considerations, guided by field experiences, are given while fixing up the dimensions and materials specification of the various components of the landfill.

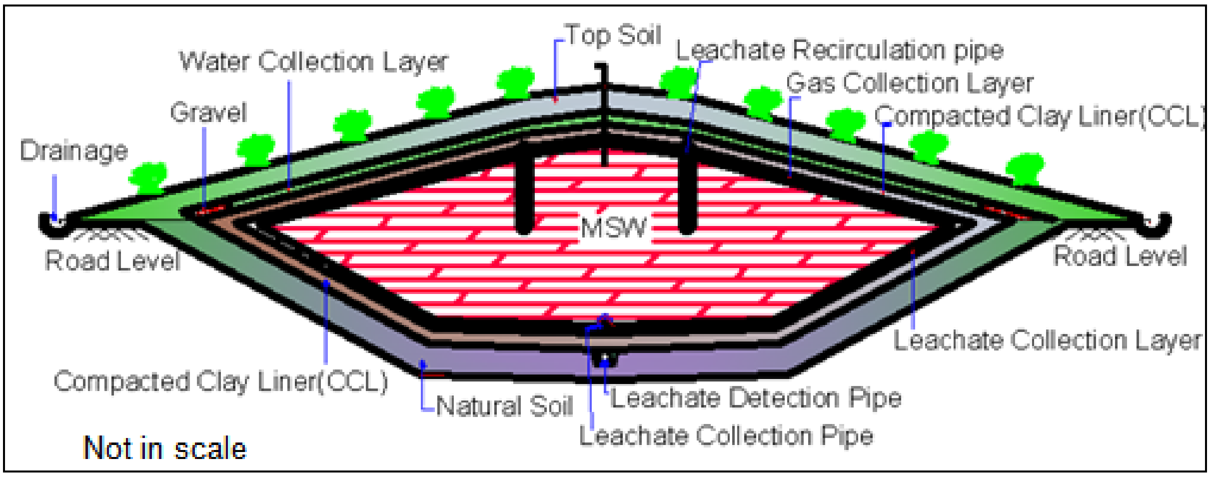

Figure 3 Cross-section of the PSSL

The PSSL consists of the main components of a standard landfill such as (i) Waste deposition cell, (ii) CCL on a geological barrier with a drainage layer on top (iii) Top Cover with CCL, drainage layer, top soil as vegetation cover, surface run-off and percolated water collection system, (iv) Gas measurement and management facility, (v) Leachate detection and collection system with leachate holding tank, (vi) Leachate pond with leachate treatment facility, (vii) Vehicle inspection and washing facility, (viii) Access Road and Site office, (ix) On-going and post closure monitoring facilities.

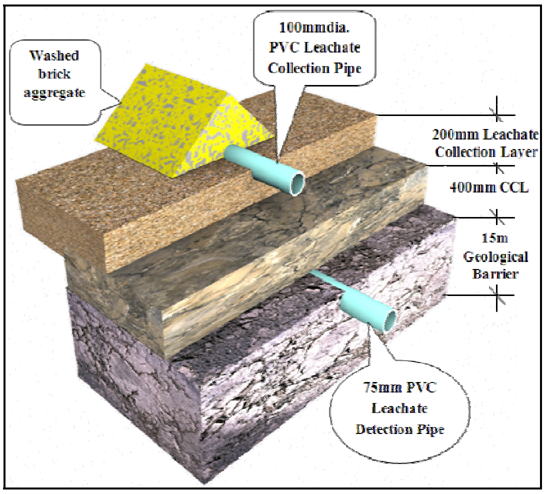

Figure 4 Schematic diagram of base liner

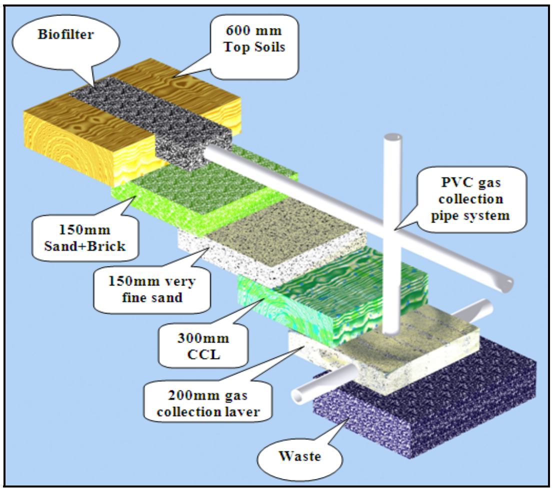

Figure 5 Schematic diagram of the top cover

The size of the waste containment is 50x50x6m, which is 3m below and 3m above the ground surface with a side slope of 26°, with a capacity of 11000m^3; the schematic diagram is presented in Figure 3. The base liner, the most important component, includes a leak detection sump system, compacted clay liner, leachate collection pipe system with a leachate collection layer. It is designed considering hydrological data of the site, the size of landfill, suitability of construction and locally available of material as shown in Figure 4. The base liner has a 400mm thick of CCL just above the geological barrier of 15m clay deposits, over which as drainage layer a 200mm thick sand layer is placed. Leachate collection pipe is placed in the drainage layer, while the leachate detection pipe is placed just below the CCL. The generated leachate will be stored in leachate holding tank of 2x2x4m through gravity flow and later transfer to the leachate treatment pond of 10x20x3.5m. The leachate detection pipe is also designed and connected in the leachate holding tank by ensuring gravity flow.

The final cover of PSSL as shown in Figure 5, consist of top soils, percolation water collection layer, compacted clay liner and gas collection pipe system with gas collection layer. The top has gas collection layer at the top of 200mm thick just over the waste, then 300mm CCL, 150mm fine sand and 150mm sand plus brick aggregates as percolation and drainage layer which is followed by 600mm top soil. The combination of fine sand layer and then sand and brick aggregates is given to ensure capillary rise of water for the keeping CCL wet as much as possible to prevent possible desiccation and cracking.There is a Leachate Recirculation System that will maintain moisture and enhance degradation of waste. To control possible soil erosion, mild slope is maintained at the top cover, which is 15^o at the edge to middle and then 7^o from middle to top (Alamgir et al., 2009). A provision is also kept to include biofilter for methane oxidation.

(a *(b)* *(c)* *(d)*

Figure 6 Construction of base liner. Execution of (a) earth excavation, (b) leachate detection system, (c) preparation of CCL and (d) placing of leachate collection pipe

Construction Process

The construction works have been conducted based on the design and the locally available construction techniques, equipments and building materials. The earth excavation, construction of various components of the landfill such as approach road, inspection point, site office, base liner, leachate collection and detection systems, leachate holding tank, leachate pond and the small scale leachate treatment option. The construction process of base liner is shown in Figure 6 were constructed properly based on the design and using locally available facility with very close supervision. After the completion of base liner, the waste depositon has been startd since 11 July, 2008.The detail of waste deposition is discussed in a companion paper by Rahman et al. (2009).

COMPACTED CLAY LINER (CCL)

The total surface area of the landfill base including side slope is 2683m^2. The base liner consists of properly compacted clay liner of 400mm in thickness. A Leachate collection and removal system in combination with Leachate and leakage detection system has been developed intending to receive the entire surface run off and leachate. This may flow across the landfill floor to a sump through waste into a drainage media and on to the sump. The downward percolation of water is prevented by the CCL. The landfill with leak detection sump system is intending to collect water which passes or leaks through the CCL only. Both collection and sumps are perforated at definite elevations and both sumps rest in a concrete basin. The CCL was prepared applying hand compaction by locally fabricated hammer of weight 5kg in three layers and at the wet side of proctor curve to achieve the optimum hydraulic conductivity,1x10^{-9}m/sec.

Properties of the Component Materials

The sub-soil investigation reveals that 15m of clay-gray existed beneath the landfill will act as Natural soil Barrier to prevent spreading of contaminant. The mineralogical composition of CCL material are find out which illustrates that the non clay minerals such as Quartzs are 19% and Feldspar and Carbonates both are less than 1%. The non-swelling cay minerals such as Illite are around 50%, Kaolinite is around 10% and Chlorites are less than 1%. The swelling clay mineral such as Smectite is 20%. The details can be obtained at Roehl et al. (2007).

The soil liner is typically designed to have a hydraulic conductivity ≤1x10^{-7} cm/s. The origin of this design criterion is unclear; 1x10^{-7} cm/s was evidently selected on the assumption that this was an achievable value that would result in negligibly small seepage through the liner (Daniel & Keorner 2007). CCL and drainage layers are uniform in all fields Tthe CCL (0.4 m) has plasticity index >20% and compacted at the wet side of proctor curve, the leachate collection layer (0.20 m) is nothing but sand (56% < 2 mm, 38% from 2 mm to 6.3.mm) with CaCO3 are shown figures 7, 8 and 9 respectively, the grain size distribution curve of CCL and in leachate collection layer and the washed brick aggregates.

Low-permeability compacted soil liners, also referred to as CCL is the historic engineered component used in landfills. Clay-rich soil is placed in layers and compacted with heavy equipment to form a barrier against the movement of liquids and gases. The soil liner is typically designed to have a hydraulic conductivity ≤$1x10^{-7}$ cm/s. The origin of this design criterion is unclear; $1x10^{-7}$cm/s was evidently selected on the assumption that this was an achievable value that would result in negligibly small seepage through the liner (Daniel & Keorner 2007). The low hydraulic conductivity of clay minerals makes them potential materials to use as CCLs in sanitary landfill for environmental protection.

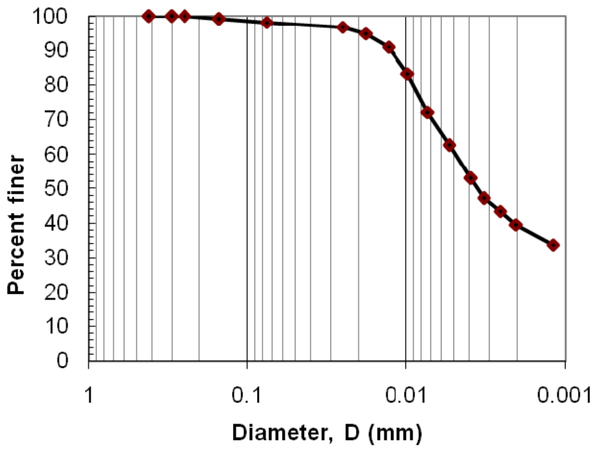

Figure 7 Grain size distribution curve of clay used in CCL

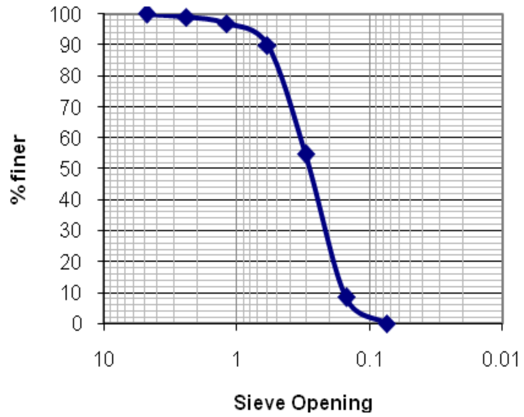

Figure 8 Grain size distribution curve of the sand used in leachate collection layer

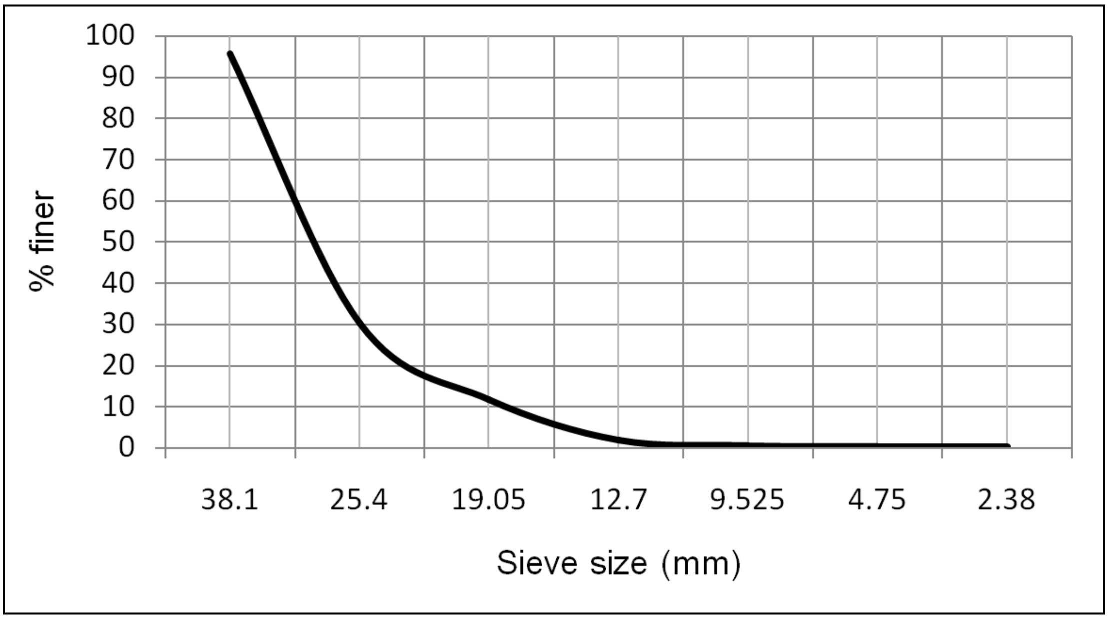

Figure 9 Grain size distribution curve of washed brick aggregates

The attenuation positively charged chemical species in leachate through a clay liner is a function of CEC of the liner material. Higher CEC of a clay liner material will result in greater amount of cationic containments being removed from the leachate (Kayabali 1997); Rowe et. al.(1995) recommended that soils with a minimum CEC of about 10 meq/100g of soil might be specified for clay liner. Soils classified as inorganic clay with high plasticity (CH) is considered as the suitable material for landfill liner (Oweis & Khera 1998). If naturally available clay or clayey soil is not suitable for liner, kaolinite or commercially available high swelling clay such as Bentonite can be mixed with local soils or sand. In Bangladesh these materials are not locally available and would have to be imported from elsewhere and could significantly increase the cost of construction (Alamgir et al. 2005). For Khulna soils, it is shown earlier that soils compacted at water content less than optimum tend to have a relatively high hydraulic conductivity, while soils compacted at water contents greater than optimum tend to have a low hydraulic conductivity. Figure 10 shows the acceptable zone based on the hydraulic conductivity of the clay.

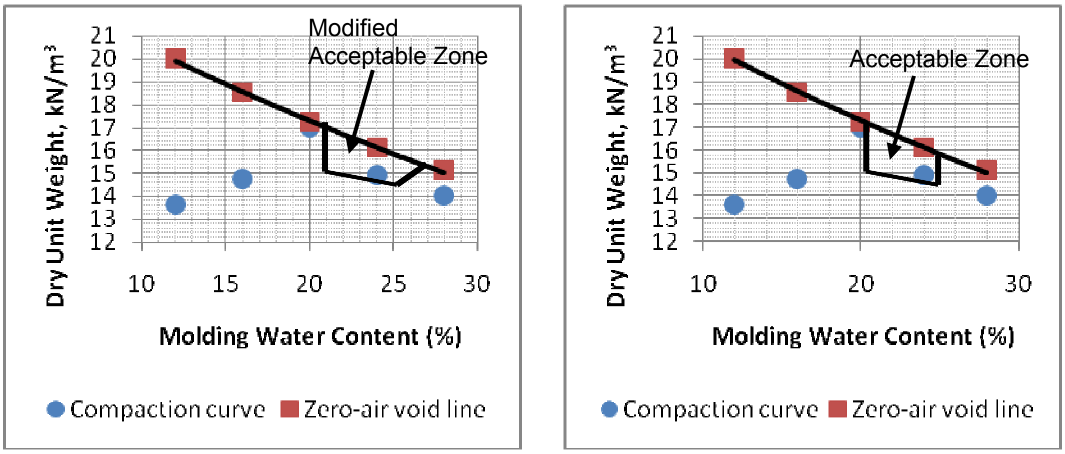

Figure 10 Determination of Acceptable Zone of Water Content-Dry Unit Weight Values Based on Hydraulic Conductivity for Clay in PSSL.

Construction Process

In the PSSL, the clayey soils collected from the depth of 0 to 2m of the site, were used for the construction of CCL as the test results revealed the suitability of the clay. The excavated clay was stock piled and later used to construct CCL through proper compaction after spreading over the bed. The compaction of soil was done manually in three layers by using locally manufactured hammer made of cast iron connected with timber handle. The clay were placed uniformly over the bed and then compacted by adding required amount of water to ensure uniformity of compaction, a locally practiced technique is maintained while applying the hammer drop by a group of female worker. The thickness of the layer was maintained in such a way that the resultant thickness of the CCL reached as 400mm.

The degree of compaction of the CCL was ensured using commonly checked in the field by sand cone test method as shown in Figure 11, usually used as field compaction test. Initially, it was planned to prepare the CCL by using heap foot or Smooth wheeled roller, however, due to the soften nature of soils; later compaction was done using manual intensive practice following traditional local approach. However, finally a very impressive CCL was constructed with locally available technology and equipments without heavy machineries and skilled people as shown in Figure 12.

Figure 11 Field density test of the CCL

Figure 12 Complete bed of CCL

Leachate Collection System

Leachate Collection System (LCS) is a typical component of most modern landfills. These system commonly comprises of perforated leachate collection pipe at regular spacing in a continuous blanket of granular material. The primary function of leachate collection system is to control the leachate head acting on the liner system. The construction of 200mm leachate collection layer of sand with 100mm dia. of perforated leachate collection pipe surrounded by washed brick aggregate. Leachate Collection System (LCS) is considered as one of the most important components of sanitary landfill. The system commonly comprises perforated pipe at regular spacing in a continuous blanket of granular material to collect leachate. The primary function of leachate collection system is to control the leachate head acting on the liner system. Controlling of leachate head minimizes the advective transport of contaminants and also controls side slope leachate breakouts. Lowering height of leachate mounding, leachate seeps can be minimized. Leachate pressure head on liner gets reduced, hence gradient through liner gets reduced resulting flow reduction through liner. Finally, removing contaminants from the landfill reduces the available amount contaminants for transport.

Figure 13 Leachate collection pipe with brick aggregates as filter media

To collect the leachate through gravity the bed was constructed maintaining a 3^o slope and the leachate collection pipe is placed at the middle of the cell. The leachate collection layer of 200mm thick was construction to accommodate a perforated leachate collection pipe with 100mm dia. and surrounded by washed brick aggregates as shown in Figure 13. The collection was laid maintaining a slope of 3^o towards the leachate holding tank to ensure the easy movement of leachate through gravity flow as mounded on the leachate collection pipe (Islam et al., 2009).

WATER BALANCE DATA

The water balance data related to the performance analysis of CCL is listed in Table 1. Evapotranspiration and lateral drainage above the liners are the dominant parameters in the water balance. Significant detection runoff occurred during the first year which is found as very low and almost independent of inclination. During the fourteen months of measurements, however, there have been unusually some thunderstorms with high rainfall intensities and no snowmelt events compared to the this short-term average. Lateral drainage within the collection layer (inter-flow) only occurred under steep slope conditions and even then contributed only a few liters to the water balance (maximum flow rates vary from 36.0 L/d or 46.6 L/d). There is some variation in the drainage and evapotranspiration data over the years and between the individual fields. In general, the amount of drainage discharge per year is independent of inclination. The short-term flow rates however are higher on the steep fields than that of the flat. The annual evapotranspiration is higher on the flat fields than that of the steep due to a higher input of solar radiation in winter, spring and monsoon. In consequence the annual drainage rates are lower on the flat fields. The landfill has been closed since October, 2009. After the detection of high concentrations of leachate a small scale treatment action program is started in July, 2008. The temperature within the landfill is 48°C.The vegetation will formed by grasses and perennial weeds later. The climate of Khulna is humid and tropical, influenced by the Bay of Bengal. The average precipitation is 1982 mm/a, distributed almost inconsistently over the year. Rainfall intensity usually is high, maximum intensities being around 6 mm/10 min and rarely above 20 mm/h. The long-term average air temperature is 26°C with average values of 18°C in January and 31.1°C in April. An average of 60 days per year (d/a) show a maximum temperature above 25°C, 60 d/a have a maximum temperature below 15.5°C. The potential evapotranspiration is above 700 mm/a. The schematic diagram of base liner system is shown in Figure 4. The Landfill is ‘flat’ with an inclination of 3%, the leachate collection pipe have a slope of 2%. All fields were constructed with the aim of Bangladesh local technology, materials and quality control as used during the construction of the liner of the whole landfill. No artificial materials cut through the liners at the boundary of the test fields to avoid the formation of preferenial flow paths (details in Melchior et al. 1994). Meteorological data, soil hydrological parameters of the site as well as the leakage through the liners are measured directly.

PERFORMANCE OF CLAY LINER

CCL of the PSSL has been monitored in the field. On field, soils have been compacted to a total thickness of 400mm after compaction. It has the following average properties: 33% clay, 57% silt and 10% fine sand Rafizul et al. (2009); 50% of the clay minerals are illite, 20% smectite, 1% chlorite and 10% kaolinite; liquid limit, 53.0%; plasticity index, 20; bulk density, 1.950 gm/cm^3; water content >25%; Proctor density, 17 kN/m^3; compacted >90%; Proctor density on wet side of optimum water content; pore volume, 27.0%; degree of saturation, 0.87; geometric mean of saturated hydraulic conductivity in the laboratory, ≤1.0 x 10^{-9} m/s. Due to its graded particle size distribution, its high silt content, and the dominance of relatively inactive clay minerals, it shows a low potential for shrinkage compared to other 'clay liners'.

Table 1 Variation of leak detection with ppt. and temperature of CCL

Month	ppt (mm)	Drainage above CCL(L/d)	Leakage through CCL(L/d)	Max. avg. temp. (°C)
July'08	301			31.5
Aug'08	203	146	42	32.4
Sep.'08	379	145	41	32.8
Oct.'08	187	142	42	31.8
Nov.'08	0	120	37	29.6
Dec.'08	0	108	36	26.1
Jan.'09	1	85	37	26.2
Feb.'09	6	83	39	29.8
Mar.'09	10	82	40	33.2
Apr.'09	23	85	46.6	36.6
May'09	137	100	44.2	35.6
June'09	233	130	44	34.8
July'09	347	144	42	32.3
Aug.'09	570	145	43	32.6

Figure 14 shows the discharges in the drainage layer above the liner and the liner leakage. The drainage discharge above the liner is high during winter, monsoon and spring, whereas little happens during the summer. The measured soil hydrological data (water content and matric potential) clearly show that upward directed water transport into the dry drainage layer and topsoil has caused a desiccation of the liner and consequently the formation of cracks. The variation of leak detection through CCL is compared with ppt. and temperature is shown in Table 1.

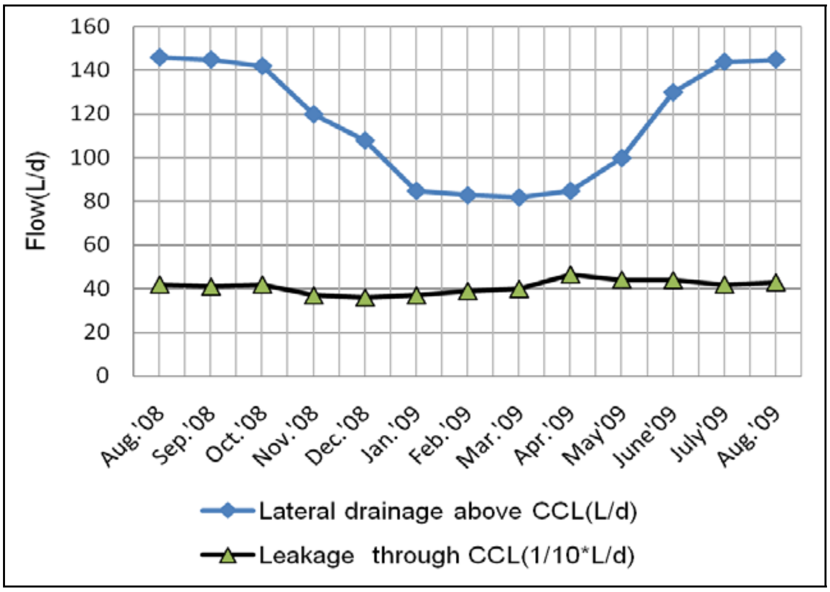

Figure 14 The discharges in the drainage layer above the CCL and the CCL leakage.

The resuts show that the CCL is very sensitive to desiccation and shrinkage. Upward water transport into dry soil and water has caused an irreversible formation of cracks and preferential flowpaths in the tested liners. If Plant root penetration occurs, no means are known to control the properties of clays in order to prevent the formation of preferential flowpaths during desiccation or to rapidly re-seal cracks in shrunken cohesive surface liners. The base liner should be designed to maximize lateral drainage. However, in humid climates and tropical areas with huge precipitation like Khulna, Bangladesh, a liner is needed to effectively limit the infiltration into a landfill or contaminated site. Capillary barriers are promising components for covers on slopes. However, they must be protected against high infiltration rates into the capillary layer.

Composition of Leachate and Leak Detection through CCL

Under normal conditions, leachate is found in the bottom of landfills. From there, its movement is through the underlying strata, although some lateral movement may also occur, depending on the characteristics of the surrounding material. As leachate percolates through the underlying strata, many of the chemical and biological constituents originally contained in it will be removed by the filtering and adsorptive action of the material composing the strata. In general, the extent of this action depends on the characteristics of the soil, especially the clay content. Because of the potential risk involved in allowing leachate to percolate to the groundwater, best practice calls for its elimination or containment. Landfill liners ate now commonly used to limit the movement of leachate from the landfill site. The use of clay as a liner material has been the favored method of reducing or eliminating the seepage of leachate form landfills. Clay is favored for its ability to adsorb and retain many of the chemical constitutes found in leachate and for its resistance to the flow of leachate (Tchobanoglous and Kreith 2002). In PSSL 400mm of locally available clay is used as CCL and its performance is explored. Table 2 shows the difference in composition of landfill leachate and leak detection through the CCL.

Table 2 Composition of leachate and leak detection through CCL in the PSSL

	Leachate above CCL	Leakage detection through CCL
pH	7.6	7.43
Chloride	1672.0	975.0
Iron	321.0	6.04
Alkalinity	8936.0	2975.0
Hardness	1869.0	1727.0
TDS	12349.0	6835.0
BOD_5	5816.0	3.70
COD	21858.0	40.00
Lead	0.39	0.001
Nickel	0.18	0.001
Cadmium	0.02	0.001

applicable to all parameter except pH; Mean value, mg/L

CONCLUSIONS

The PSSL is a very useful tool to monitor the performance and water balance of landfill liner. An appropriate technical set-up design is required and time is needed to collect and interpret valuable data. Based on the experimental results it can be concluded that CCL with leachate drainage system is very effective and durable systems. It is potential and cost-effective in Bangladesh for landfill construction by reducing geomenbrane or by replacing the soil liner by a different geomembrane or a capillary barrier. Planners can choose it with an option to design a cost-effective and sustainable base liner of landfill. However, the use of only CCL should be controlled by proper construction method, efficient leachate collection system and the type of deposited waste.

ACKNOWLEDGEMENTS

The financial supports provided by the European Commission through the project WasteSafe II of EU-Asia Pro Eco II Programme (Grant Contact No. ASIE/2006/122-432) are gratefully acknowledged.

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Viability of the Two-Stage Treatment System of Sanitary Landfill Leachate in the South West Coastal Settings of Bangladesh

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ABSTRACT

The Treatment of Landfill Leachate (LFL) is critical but very much essential for protecting the environment especially the soil and ground water which may ultimately affect the human health. Most of the under developed and developing countries yet do not take into consideration seriously the treatment of LFL as the practiced methods in the developed countries are very much costly to implement. The study has taken an attempt to innovate a less costly treatment system and to observe its performance in Khulna City from September of 2008 to February of 2009. It is a two stage treatment system and combines a bio-filter portion and a wetland system. The bio-filter consists of a bed of coarse material (brick chips) over which leachate is applied. As the leachate trickles through the bed, a microbial growth establishes itself on the surface of the brick cheep in a fixed film which allows degrading the organic materials of the leachate. And the vegetated wetland helps to be more aerated and reducing the nutrient (nitrate, phosphate, calcium etc) content through the uptake by the vegetation. Generally, heavy metals are not very soluble in LFL and can therefore be removed by physical means, such as settling or filtration. After the experiment it is found that heavy metals like iron, zinc become less in amount such as iron comes to 2.1 ppm from 4.1 ppm. Cataions (K^+, Na^+, Ca^{2+}, Mg^{2+}) are reduced mainly in the first step of the treatment. But anions (PO_4^{2-}, SO_4^{2-}, NO_3^-) are increased in their amount due to different causes. DO before the treatment was 0.51mg/l whereas after the first step treatment it comes into 0.64 mg/l and lastly it becomes 1.84mg/l. And BOD was 1330mg/l before the treatment and 980mg/l and 910mg/l is after the first and second step treatment. The COD content also reduce from 2024 mg/l to 1480 mg/l. The filter is found effective for the cations and BOD, COD and DO but needs and improvement to treat the anions.

INTRODUCTION

Landfill leachate is a concentrated mixture of biophysical and chemical properties along with complex hazardous pollutants that is produced from the solid waste dumping site where solid waste and water are the major inputs, and landfill gas and leachate are the principle outputs. The treatment of LFL is critical but very much essential for protecting the environment especially the soil, surface water and ground water which may ultimately affect the human health. Most of the under developed and developing countries yet do not take into consideration seriously, the treatment of landfill leachate as the practiced methods in the developed countries are very much costly to implement. However, LFL treatment systems and the management systems are nowadays developed in the least developed countries that are very much economically viable (Salequzzaman et al. 2007).

Disposal of solid waste to sanitary landfills[1] is mostly the scientific and applied method of disposal worldwide due to environmental and socio-economic reasons (Carra and Cossu, 1990). Depending on the location and the availability of land, up to 95% of generated solid waste of developing countries

[1]An engineered land burial facility for the disposal of solid waste that does not pose a substantial present or potential hazard to human health or the environment and has the facility of different resource recovery processes.

is disposed to the crude landfills[2] directly (Gendebien et al. 1992). In some cases, in place of direct land filling, some form of volume reduction processes, such as incinerations are used (Tchobanoglous *et al.*, 1993). As no alternative processes are used in Bangladesh, almost all of the solid waste has been collected after separation of recyclable material in some cases (normally done by Tokai[3] in an unhygienic condition), is disposed to the crude landfills. Water percolated through solid waste and has extracted dissolved or suspended materials produce leachate and migrated to the groundwater causes contamination. Leachate is composed of the liquid that has been entered the site from external sources such as surface drainage, rainfall, ground water and water from underground springs and the liquid produced from the decomposition of the wastes (Alamgir et al. 2005).

Surface water is contaminated because solid wastes are dumped at or near the ponds that uses for fishing purposes even sometimes for households. Contaminated water is harmful for fish and aquatic lives have possibility of different diseases by reducing the amount of oxygen in the water. Ground water is very an essential source for drinking water and other purposes like agriculture and industry. Hand tube-wells are situated at 50 m to 310 m afar from the disposal sites and peoples of adjacent houses are drinking water regularly which is not recommended due to high probability of ground water contamination (Alamgir et al. 2005).

OBJECTIVES OF THE STUDY

The overall objective is to gain an acceptable level of composition of the LFL for dumping into the environment. The specific objectives reveals as:

1. To design and develop a locally available resource based sanitary LFL treatment system;
2. To find out the efficiency and viability of the innovated treatment system.

MATERIALS AND METHODS

The method has followed for the study, is comprehensive method i.e. it includes primary data collection and secondary literature review. It also includes the planning for designing a leachate treatment filter, construction of the filter which has two different stage of treatment, finding out the efficiency of the filter by treated leachate collection, subsequent preservation, and preparation of sample for analysis and so on.

The study was done at Rajbandh in Khulna City of Bangladesh. The research time was from September of 2008 to February of 2009. The month of September and October of 2008 was spent to review the literature and designing the leachate treatment filter with the analysis of pros and cons of the model. Then in the month of November the site selection was done for the construction of the filter and also the filter was being constructed. Leachate is being flowed through the filter media to grow the algal film on it. Samples are collected from three points such as leachate holding tank, after the first step of the treatment and lastly after the second stage or final point of discharge. The samples were analyzed in different laboratory of Bangladesh and abroad. In Bangladesh mainly the laboratory of Department of Environment (DoE) and laboratory of KUET was used and some samples are also analyzed in the laboratory of Yamaguchi University of Japan.

Designing the filter

Landfill leachate treatment options include recycling, on-site treatment, discharge to a municipal sewage treatment plant, or a combination of these approaches. A great variety of treatment technologies such as precipitation (hydroxide/oxide, carbonate, and sulfide), co-precipitation, ion exchange, membrane procession, electrolytic recovery and evaporative recovery are reported in use for control of cationic metals toxicants (Ford 1992).

In the study for leachate treatment system the technology that has been used is simple and no complex and extraordinary system will be included that has the chance to increase the cost of the treatment system. So that it is easy to adapt the technology for the country. It is a two stage system. First portion includes the ‘bio-filter system’ and the second portion includes the ‘wetland system’.

Leachate from the retention pond is transferred to the bio-filter through an electric pump. The filter helps to reduce Biological Oxygen Demand (BOD) and increase Dissolved Oxygen (DO). The bio-

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[2] A solid waste dumping places where no scientific basis exits, i.e. it is simply a wetland or a depressed low land or an earthen pond.

[3] Street children those generally live in slum in urban locations.

filter media consists of a bed of coarse material, such as stones, slats or a plastic material, over which leachate is applied. For the study small pieces of bricks are used a filter media. Over the circular bed of brick cheeps there have spraying arms that spray the leachate on the bed. The space between the rocks allows air to circulate easily so that aerobic condition can be maintained. As the liquid waste trickles through the bed, a microbial growth establishes itself on the surface of the stone or packing in a fixed film. The liquid waste passes over the stationary microbial population, providing contact between the microorganisms and the organics.

The second portion of the overall treatment system the collected leachate will be brought in a constructed or artificial wetland system where leachate will be remained for a while. In this portion sedimentation occurs. The wetland stage of the system also removes the nutrients. This stage is done by using a vegetated gravel bed through which the water flows (separated from the water table with a plastic or concrete barrier), defined here as an *artificial wetland* (Parker 2002).

Leachate flows form the filter output point to the final point of discharge. As the first point (output of the first portion) is situated at elevated height, flow is being continued to the final point of discharge. The vegetation of the wetland will restrict the flow velocity of the leachate so that more retention in the wetland of the leachate occurs. The second reservoir can be termed as retention pond. It may work as an aerobic stabilization pond. So that, during day light hours, large amounts of oxygen are supplied by the active algal photosynthesis process and during the hours of darkness, wind mixes with the shallow water mass (Davis et al. 1998).

Construction of the wetland system and bio-filter

- **Size of the wetland**
  - Size of the first reservoir: 8 feet * 8 feet * 3 feet / or the existing one
  - Size of the Second reservoir: 12 feet * 8 feet * 2 feet
  - Size of the wetland: 4 feet * 10 feet 7 inch* 1 feet 3 inch
- **Size of the bio-filter**
  - Height: 3 feet
  - Diameter: 6 feet (inner side)
  - Arm length : 5.5 feet
  - Ports: 1.5 inch in diameter
  - 30 cm above media

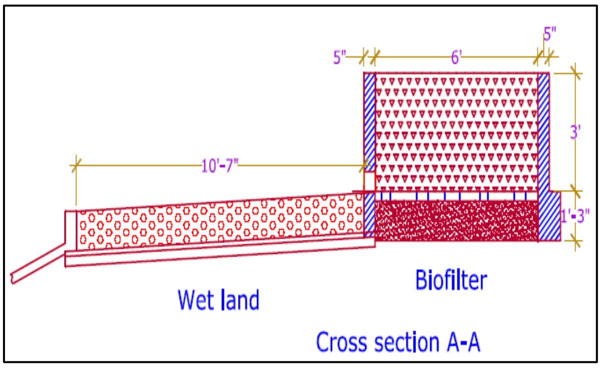

Figure 1 Cross section of the leachate treatment bio-filter

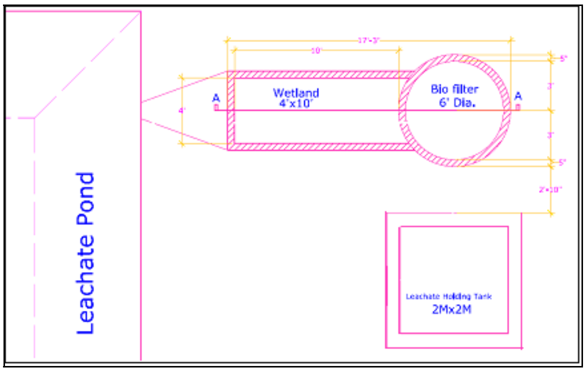

Figure 2 Upper view of the leachate treatment bio-filter model

Applicability of the filter

The filter enables organic material in the wastewater to be adsorbed by a population of microorganisms (aerobic, anaerobic and facultative bacteria; fungi; algae and protozoa) attached to the medium as a biological film or slime layer which is approximately 0.1 to 0.2 mm thick (EPA, 2000). As the wastewater flows over the medium, microorganisms already in the water gradually attach themselves to the rock, slag, or plastic surface and form a film. The organic material is then degraded by the aerobic microorganisms in the outer part of the slime layer. As the layer thickens through microbial growth, oxygen cannot penetrate the medium face, and anaerobic organisms develop. As the biological film continues to grow, the microorganisms near the surface lose their ability to cling to the medium, and a portion of the slime layer falls off the filter. This process is known as sloughing. The sloughed solids are picked up by the under drain system and transported to a clarifier for removal from the wastewater.

Physico-chemical analysis of leachate

Color; Odor; Temperature; pH; EC; TDS; (Na^+); Potassium (K^+); Calcium (Ca^{++}); Magnesium (Mg^{++}); Chloride (Cl^-); Ortho-Phosphate ($H\text{-}PO_4^{--}$); Sulphate (SO_4^{--}); Nitrate (NO_3^-); (DO); (BOD); (COD) and some heavy metals.

Location and layout

Khulna city, the third biggest industrial city of the country, is located at the southwestern part and situated on the banks of the Rupsha and the Bhairab rivers. It is a divisional headquarters, which serves as a gateway to the seaport of Mongla, the second largest seaport of the country and the Sundarbans, the largest mangrove forest of the world. The city extends from southeast to northeast along the Bhairab-Rupsha River. Its elevation is 7 feet above the mean sea level. Total area of Khulna city is about 47 sq.km comprising 31 wards and about 1.5 millions of population.

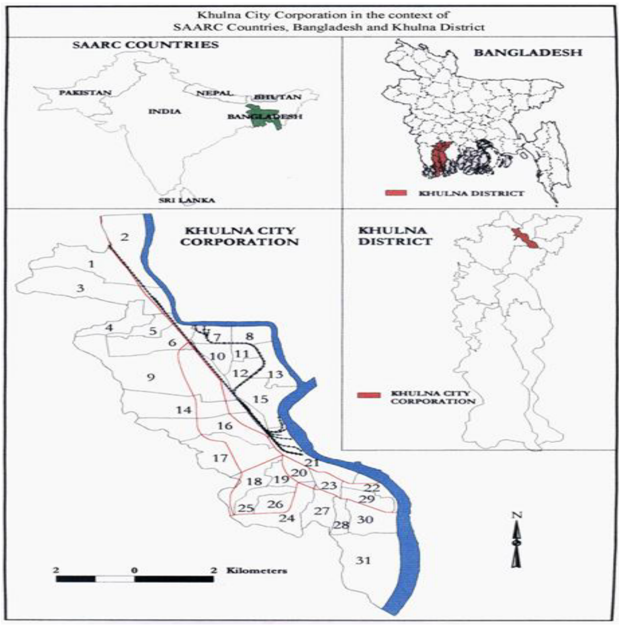

Figure 3 Location map of the study area and the three sampling points

Figure 4 Construction of LFL treatment bio filter

Figure 5 Leachate holding tank, bio-filter and leachate pond

RESULTS AND DISCUSSIONS

The first one is the bio-filter system which reduces the BOD and COD contents of LFL and the also increase the DO of it. When the spraying arms spray the LFL it comes into contact of air and thus increase the DO.

Figure 6 Filter media after a few days

Figure 7 Filter media and growing slime layer

And when leachate passes through the filter media, the microorganisms (aerobic, anaerobic and facultative bacteria; fungi; algae and protozoa) that are attached with it utilize the organic matter for their growth. As the organic matter reduces from the leachate the BOD as well as COD become reduces from the LFL.

Figure 8 The condition of the wetland before and after flow of the leachate

Physico-Chemical Characteristics of Sanitary Landfill Leachate of Rajbandh

Table 1The characteristics of sanitary landfill leachate of Rajbandh

Parameter	Concentration
pH	6.78
EC	5.2ms
TDS	3.93 g/l
Temperature	23°C
Color	Black
Odor	Strong
Salinity	280 ppm
Sodium	298 ppm
Potassium	275 ppm
Calcium	163 ppm
Magnesium	93 ppm
Sulphate	160 ppm
Nitrate	97 ppm
Ortho-phosphate	84 ppm
Chloride	1055 ppm
Dissolved Oxygen	0.51 mg/l
Biochemical Oxygen Demand	1330 mg/l
Chemical Oxygen Demand	2024 mg/l
Chromium	0 ppm
Cobalt	0 ppm
Copper	Below detection limit*
Iron	4.1 ppm
Manganese	0.6 ppm
Nickel	0 ppm
Led	0 ppm
Zinc	0 ppm

*Source: Laboratory analysis, 2000, *Below 0.04 mg/l*

Performance and viability of the two stage treatment system of leachate

One of the major objectives of the research is to see the efficiency of bio-filter; more specifically which portion is more effective for the leachate treatment. For this at the same time samples were collected from the filter to find out the efficiency of it. Samples are collected from three points, they are leachate holding pond (without any treatment) that is the leachate directly from the landfill, from the output point of the bio-filter that is after the first step of the treatment and lastly form the final point of discharge. From this pattern of sampling and subsequent analysis the effect of different stage of the treatment filter could be assessed. The analyzed results of the three sampling points are presented in the Table 2.

Table 2 Comparison of the different stage of treatment of the bio-filter

Parameter	Leachate holding tank	After first step of treatment	After second step of treatment
pH	6.78	6.78	6.94
EC	5.2ms	7.85 ms	7.78 ms
TDS	3.93 g/l	2.64 g/l	3.89 g/l
Temperature	23°C	24°C	23.5°C
Color	Black	Blackish	Blackish
Odor	Strong	Less strong	Less strong
Salinity	280 ppm	310 ppm	298 ppm
Sodium	298 ppm	214 ppm	236 ppm
Potassium	275 ppm	180 ppm	164 ppm
Calcium	163 ppm	156 ppm	175 ppm
Magnesium	115 ppm	93 ppm	109 ppm
Sulphate	160 ppm	210 ppm	224 ppm
Nitrate	97 ppm	110 ppm	117 ppm
Ortho-phosphate	84 ppm	79 ppm	133 ppm
Chloride	1055 ppm	980 ppm	1012 ppm
Dissolved Oxygen	0.51 mg/l	0.64 mg/l	1.84 mg/l
Biochemical Oxygen Demand (BOD)	1330 mg/l	980 mg/l	910 mg/l
Chemical Oxygen Demand (COD)	2024 mg/l	1700 mg/l	1480 mg/l
Chromium	0 ppm	0 ppm	0 ppm
Cobalt	0 ppm	0 ppm	0 ppm
Copper	Below detection limit*		
Iron	4.1 ppm	2.8 ppm	2.1 ppm
Manganese	0.6 ppm	0.5 ppm	0 ppm
Nickel	0 ppm	0 ppm	0 ppm
Led	0 ppm	0 ppm	0 ppm
Zinc	0 ppm	0 ppm	0 ppm

*Source: Laboratory analysis, 2008, *Below 0.04 mg/l*

Efficiency of the Filter

Efficiency of the filter depends on how much it can minimize or reduce the concentration of different elements in the leachate. As the filter is designed on the principle of biological treatment, so that the efficiency will not be as high as found for chemical treatment. But biological treatment is environmentally friendly and has no side effect like chemical treatment. Most of the cases the filter can reduce the concentration of the parameters but fail to decrease or instead, increase some elements like sulphate, nitrate and phosphate.

Drawbacks of the filters

The main limitation of the filter is not to reduce the anions at all. And a second limitation lies in the wetland system. Some elements become increase after the second step of the treatment where as they become reduces in the first step. As there is no chemical application the anions become increase in the first and second step due aeration and in the presence of different types of microorganisms that are responsible for that. On the other hand there is a systematic problem in the construction of the filter. That is the wetland is constructed by the soil of the surrounding which is contaminated by the overflowed leachate. So, though after the first step of treatment the concentration of sodium, calcium and magnesium become reduce their concentration become increase after the second step. Aeration should be more than the present status. So that DO level will increase more and BOD and COD will decrease more.Sometime the spraying pipe is being clogged and so that there is no continuous and enough spray. This is due to the suspended and grit materials into the leachate. The clogged point is needed to be cleaned manually so that it needs a continuous maintenance of it. Another drawback is the requirement of energy for the pump. As here an electric pump is being used electricity is needed. When there is no supply of electricity there is no pumping and no processing of leachate.

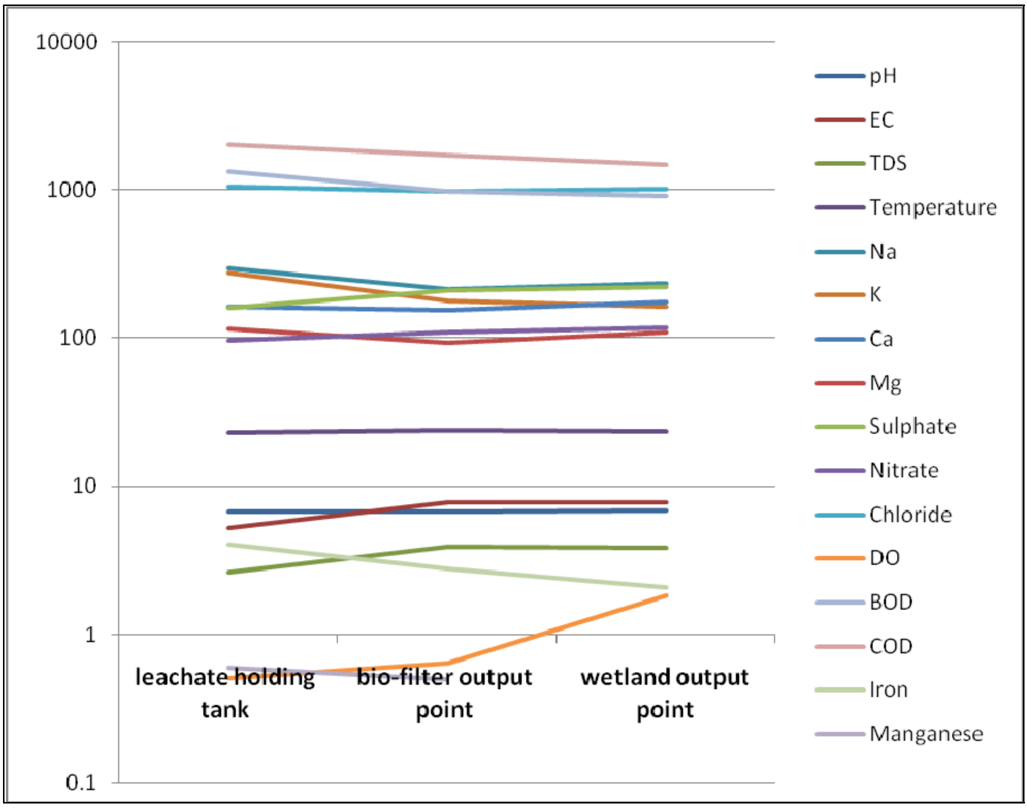

Figure 9 Trends of different elements of leachate after the treatment by bio-filter

Maintenance

The concentration of nutrients in the effluent should be checked when planning the maintenance program.

Net Nutrient Gain

The system works by acting as a nutrient sink, that is, it uses more nutrients than it releases. Over time the plant material in the wetland system builds to a point where it actually contributes to the nutrient load in the water. While this is a natural result of a biological system, it is unwanted for obvious reasons. Maintenance of the system requires removal of plant material so that the system continues to use nutrients by growing more plants.

Phosphorus Saturation

Phosphorus tends to stick to sediments, such as clay particles, but the sediment can only hold a limited amount of phosphorus. Eventually the system becomes full, and no more phosphorus can be removed. The sediment trap could use sand and lime to increase the capture of phosphate. From time to time this sand is replaced to remove the phosphorus from the system.

Advantages of the Filter

- Simple, reliable, biological process.
- Suitable in areas where large tracts of land are not available for land intensive treatment systems.
- May qualify for equivalent secondary discharge standards.
- Effective in treating high concentrations of organics depending on the type of medium used.
- Appropriate for small- to medium-sized communities.
- Rapidly reduces soluble BOD_5 in applied wastewater.
- Efficient nitrification units.

- Durable process elements.
- Low power requirements.
- Moderate level of skill and technical expertise needed to manage and operate the system.

CONCLUSIONS

Leachate generation from the solid waste landfill sites is inevitable. The movement of leachate from the landfill boundaries and their release into surrounding environment poses the serious environmental threats at both existing and new facilities of landfill sites. Because health problems and its associated effect is must, if not dealt with properly to its pollution to the groundwater and its surroundings. For this leachate treatment is a must. In the study a locally available resource based biological treatment system is tried to be established. It is a two stage treatment system. The viability of the filter depends on the efficiency of it. Most of the cases the filter was capable of reducing the concentration of the highly concentrated elements. The most considering parameter for leachate was the BOD and COD which were to be reduced must and the DO which was to be increased. The filter reduces BOD from 1330 mg/l to 910 mg/l and COD from 2024 mg/l to 1480 mg/l. And also increase DO from 0.51 mg/l to 1.84 mg/l. It also can reduce the iron and manganese form 4.1 ppm to 2.1 ppm and 0.6 ppm to 0 ppm respectively.

The efficiency depends on the filter bed thickness and aeration amount. The more the bed thickness the more travel of the leachate and so that more contact with the microorganisms and more oxygen mixing. The wetland bed material should be selected more carefully. So that contamination by the wetland bed materials will not happen. The filter is proved not effective for the anions in the leachate. So, further improvement is needed for it.

FINDINGS OF THE STUDY

From the study it is found that-

- The two stage bio-filter for leachate treatment is efficient mainly for BOD, COD, DO, some heavy metals (Fe, Mn) and some cations
- The first stage is more efficient than the second stage
- The filter is not effective for the anions like phosphate, sulphate, nitrate
- The filter has the capability to treat the heavy metals
- The grit materials of the leachate make clogging of the spraying pipe
- It needs a continuous maintenance
- The more microbial growth the more removal of BOD and COD

RECOMMENDATIONS

On the basis of the study some recommendation are given here. They are

1. The grit materials should be removed first before it is flowed to the pump so the clogging does not occur
2. More aeration for more effective treatment
3. The filter bed should as thick as possible
4. The wetland system should be as larger as possible
5. To protect the surrounding land from the overflow of the leachate
6. The leachate from final point of discharge should be managed in a pond where more aerobic and anaerobic process occur
7. The wetland system acts as a filter net and it becomes saturated with nutrients. So the bed materials and the plants should be removed periodically. Otherwise it will not work.

ACKNOWLEDGEMENT

The authors gratefully acknowledged the financial support provided by European Commission through the project of EU- Asia Pro Eco II Programme (ASIE/2006/122-432).

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Options for Significant Environmental Impact Assessment at Rajbandh Pilot Scale Sanitary Landfill in Khulna of Bangladesh

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ABSTRACT

*Significant Environmental Impact Assessment (SEIA) process of sanitary landfill includes a high level investigation involving a multi-disciplinary, comprehensive and detailed study that envisages the development planning towards minimizing environmental degradation, hazards and loss. The research involves a detailed SEIA study by utilizing the tools and techniques of Rapid Impact Assessment Matrix (RIAM) at Rajbandh Pilot Scale Sanitary Landfill (*PSSL*) at Khulna of Bangladesh for a duration of 1 (one) year from June' 2008. The key components of the analysis were physical, chemical, biological, ecological, social, cultural, economic, environmental and operational factors. The research finds out that around 80% of local species both flora and fauna were destroyed during the excavation, construction and soil filling processes of the sanitary landfill construction. On the other hand, bacteria, viruses, protozoa, fungi, rotifers, flies, rats and other harmful microorganisms and animals were increased. Odor, CH_4, CO_2, and SO_2 were measured and found that they were significantly increased to the potential threat levels, where CH_4 poses a potential fire hazard. The leachate that containing high organic content, soluble salts and other constituents was not treated properly. The water-soluble organic acids generated in this practice, entering into the water media and diffusing the landfill soils where bacteria and fungi metabolized aerobically and produced CO_2. This way the sanitary landfill has been posing serious environmental threats to the ground and surface water contamination, soil and air pollution. To overcome these constraints, the project recommended and implemented timely soil sealing layer after the daily's dumping along with monitored the surface and ground water contamination and settled an area specific tree plantation around the sanitary landfill site. Some implementation yet to initiated but recommended for future activation, for example construction of a biogas plant. Hence the research recommended options for a proper planning, analysis and design of the sanitary landfill system of Coastal Bangladesh after the assessment of options for scientific, engineering, architectural, economic, socio-cultural and environmental factors that could mitigate pollution and ensure hygiene, environmentally friendly, sustainable and safe disposal practices of municipal solid wastes.*

INTRODUCTION

The proper governance of a country's environment and natural resources with respect to development projects such as Sanitary Landfill, as typified by the Environment Impact Assessment (EIA) is the key to its sustainable development and towards the fulfillment of Millennium Development Goals (MDGs). Since independence in 1971, Bangladesh has implemented a number of environmental initiatives, and is prominent in the global push for sustainable development. EIA has a key role in achieving this goal. It has recently been introduced through the Environment Conservation Act, 1995 and the

Environment Conservation Rules, 1997 but there are a number of inadequacies with the current process. This study critically examines the development of EIA methodology for Sanitary Landfill in Bangladesh. While local environmental governance process is most important to project advocacy, it should bear in mind that international financial institutions (IFIs) such as the World Bank (WB), Asian Development Bank (ADB), European Bank for Reconstruction and Development (EBRD), and co-financers like the Japan Bank for International Cooperation (JBIC) give paramount importance to EIA requirements. Bangladesh is a developing country with a population of 150 million (BBS 2004). Every day about 16,380 tons solid waste generates in Bangladesh and in an average per capita waste generation is 0.48 kg. The people of Bangladesh face a great problem for their SWM due to unavailability of relevant developed technologies and fund for better management. Khulna is the third largest city in Bangladesh. About 1.50 million people are living in Khulna City and it's area is 47 sq. Km (Alamgir et al. 2005) and population growth rate is 2.96% per year (Census 2001).The average per capita waste generation rate in KCC 0.346Kg/day and major portion of generated wastes is organic in nature. Total organic wastes are 88.4% and out of total organic wastes, 90% are residential. Per day about 420-520 tons of solid wastes are generated in Khulna City. The total amount of organic wastes is 459.68 tons; among them about 413.72 tons are residential solid wastes (Alamgir et al. 2005). All of these generated solid wastes are dumped in Rajbandh low land traditional un-engineered landfill area at Khulna of Bangladesh which has significant environmental and social impacts to the surrounding areas. But very few studies have been conducted yet to assess such impacts and taken steps to recommend / suggest the appropriate remedial measures.

OBJECTIVES OF THE STUDY

The main objective of this study is "how the potential environmental impacts related to SWM of a Sanitary Landfill could be identified by developing an authentic EIA methodology". The specific objectives are as follows:

1. To examine the most appropriate EIA methodology for Sanitary Landfill and recommend its suitability for the overall Sanitary Landfill Cases in reality; and
2. To develop an appropriate EIA methodology for Sanitary Landfill in the south-west coastal region of Bangladesh.

METHODOLOGY

The study was done at Rajbandh solid waste dumping site in Khulna City in 2008. Firstly it is being conceptualized and problem is identified for the study. Then the study area was selected and detail concept about EIA was taken. Different EIA methodologies were reviewed in alliance with different policies, rules and regulations. Then a draft EIA methodology was developed on the basis of primary and secondary data collection (Figure 1). The methodology was implemented on the pilot scale sanitary landfill of Khulna City at Rajbandh. It is important to include environmental assessment to the economic analysis of the project. An environmentally sensitive project can be justified as good under a conventional cost/benefit analysis. The developed EIA methodology directly involved the cost/benefit analysis so that the Sanitary Landfill can reach to its sustainability and suitability.

RESULTS AND DISCUSSIONS

Within EIA methodology there are several tasks that are fundamental to the successful delivery of an EIA of a Sanitary Landfill. EIA methodology can be thought of as a data management process with three components. First, the project related and appropriate information necessary for a particular decision must be identified and collated. Secondly, changes in environmental parameters resulting from the Sanitary Landfill must be forecast and compared with the situation without the project. Finally, the actual changes must be assessed and communicated to the decision makers.

Site Plan of the Rajbandh Sanitary Landfill

The area is situated at the site of Khulna-Satkhira high way. The site is composed of an Open dump, Site Office, Washing Platform, Open Holding (OH) tank, Proposed and Selected Sanitary Landfill (PSSL) (50mx50m), Leachate Treatment Pond, Leachate Holding Tank, Access road and Fencing.

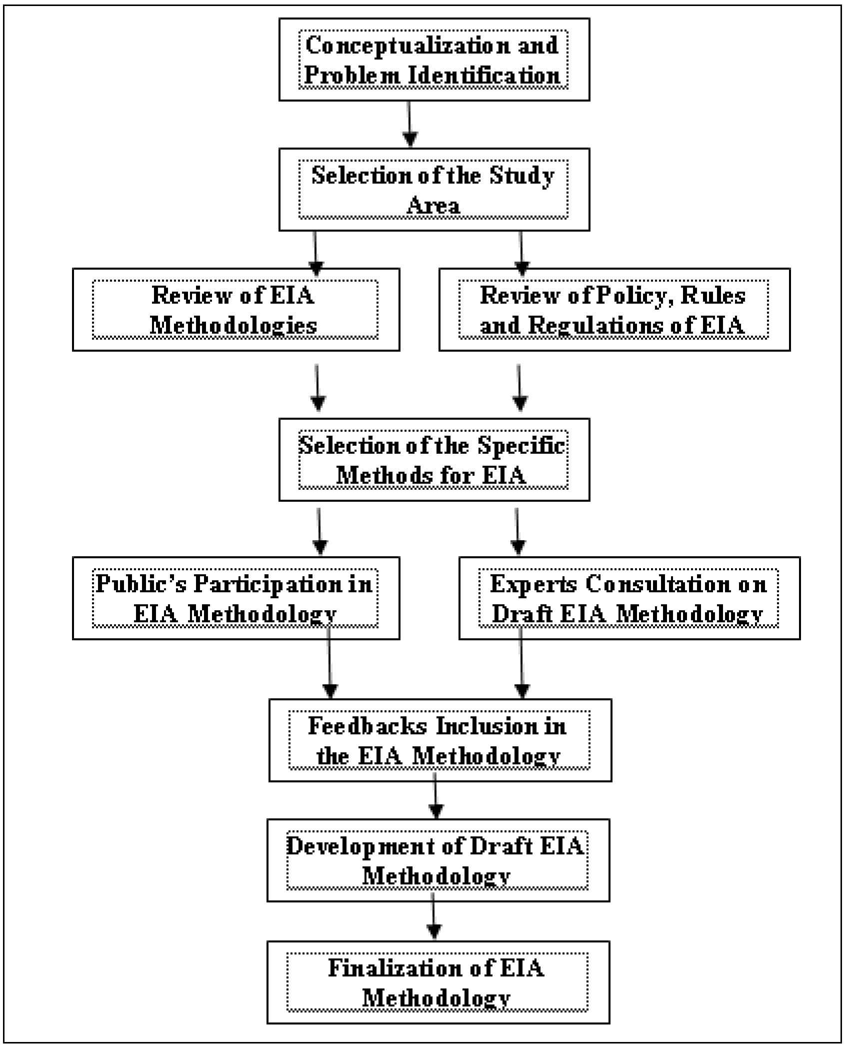

Figure 1 The flow chart of the methodology

Physical Changes

The most important physical changes are those associated with the compacting of the MSW, the migration of gases within and outside the sanitary landfill, the intake of water and the movement of liquids in the interior and toward the substratum, and settling caused by the consolidation and decomposition of the organic matter present in the waste. The migration of gases is of particular importance for the operational and maintenance control of the system. For example, when biogas is trapped, internal pressure can cause cracking of the cover and fissures. This condition allows rainwater to penetrate inside the Sanitary Landfill. This water, in turn, causes a greater production of gases and leaching, contributing to differential sinking and settling at the surface and the destabilization of the fill banks due to the greater weight of the mass of wastes.

Chemical Reactions

Chemical reactions that occur within the sanitary landfill and also in open garbage dumps include the dissolving and suspension of matter and products of biological conversion in the liquids that filter through the mass of MSW, the evaporation of chemical compounds and water, the adsorption of volatile organic compounds, the dehalogenation and decomposition of organic compounds, and the reactions of oxidation reduction that affect the dissolving of metals and metallic salts[1].

[1] The significance of the decomposition of organic products is that these materials can be transported out of the Sanitary Landfill or out of the garbage dump with the leachates.

Biological Reactions

The most important biological reactions that occur in sanitary landfills are carried out by aerobic and anaerobic microorganisms, and are associated with the organic part of the MSW, which produces gases and leachates. The methodology of decomposition starts with the presence of oxygen (aerobic phase); once the waste is covered, the oxygen starts to be consumed by biological activity. During this phase the principal product is carbon dioxide. Once the oxygen is consumed, decomposition takes place without it (anaerobic phase): at this stage the organic matter is transformed into carbon dioxide, methane, and traces of ammonia and hydrogen sulfide.

Impacts and Impact Rating of the Rajbandh Sanitary Landfill

Table 1: Impacts and impact rating of the Rajbandh sanitary landfill

Impacts	Rating of Impacts	Type of Impacts
Surface water contamination	A	1
Surface water pollution	A	1
Ground water contamination	B	2
Land use changes	A	1
Land erosion	B	2
Soli pollution	A	1
Emission of dust particles	A	1
Odor pollution	A	1
Gas emission	A	2
Local vegetation loss	B	3
Local biodiversity loss	C	3
Excavanger	A	1
Health effects to the workers	A	3
Health effects to the nearby residents	B	3
Fire hazards	C	4

NOTE: *A = adverse, always occur, B = averse, usually occurs, C = adverse, sometimes occurs, D = not necessarily good or bad, E = beneficial, always occurs, F = beneficial, usually occurs, G = beneficial, sometimes occurs, 1 = strong, permanent, 2 = moderate, permanent, 3 = minor, permanent, 4 = strong, temporary, 5 = moderate, temporary, 6 = minor, temporary, Blank = no impacts.*

Health Hazards

The workers those are working (mainly female) for maintaining the Sanitary Landfill are in serious health hazards. They are facing inhalation, skin; asthma etc problems and they have no proper washing station, even the dress and other requirements for perform such type of activities. The flowing figure shows the real picture of the workers of the Sanitary Landfill.

Environmental Regulations in Bangladesh

The Environmental Conservation Act 1995 (ECA) and the Environmental Conservation Rules 1997 (ECR) provide for regulatory measures concerning industrial waste and pollution. Besides, the Factory Act 1965 and the Factory rules 1979 are directed to regulate industry related environmental problems. The Department of Environment (DoE) headed by the Director General (DG) under the Ministry of Environment and Forest is the regulatory body responsible for enforcing the ECA'95 and ECR'97. As per provisions of the ECA'95 and ECR'97 all new projects, industrial units and also existing industrial units are obliged to apply for an Environment Clearance Certificate (ECC) from the DoE. For the purpose of granting ECC, industrials units are classified into four categories depending upon their environmental impact. The four categories requiring a gradually higher level of regulations are: *Green, Orange A, Orange B and Red*. For Green category, there no need to conduct any IEE/EIA but for others category it is must necessary to conduct IEE/EIA according to the Environmental Conservation Rules, August 1997. The Sanitary landfill project is included under orange B category so EIA and EMP are required for its smooth operation.

Figure 2 Landfill operations by the workers

Conceptual Planning and Management Approach for Environmental Studies

To provide a basis for addressing the EIA process, 10 steps or 10 activity models is recommended for the planning and conduction of the study. The model is flexible and can be adapted to various projects by modification, as needed, to facilitate the addressing of special concerns of specific project in unique location. It should be noted that the focus in this model is on project, although it could be applied to plans, programs, policies, or regulatory actions.

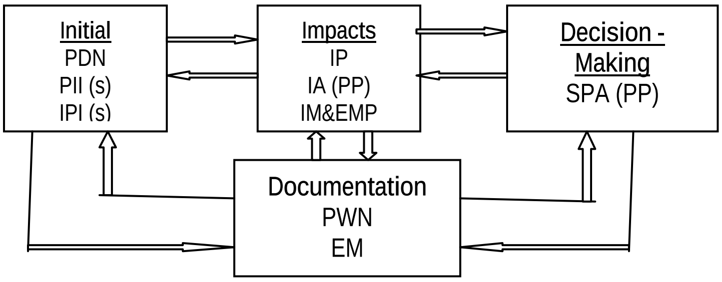

Figure 3 Conceptual frameworks for environmental impact studies of a sanitary landfill project

Identification of Potential Impacts (IPI)

The methodology of impact identification is based upon an appreciation of how of the Sanitary Landfill project might interact with its receiving environment. As such, this requires an appreciation of what are considered to be the valued environmental and community resources within the vicinity of the proposal. A projection is then required of the future state of these resources without the proposed project. From this a series of environmental design objectives can be established to aid both the EIA and project design methodology.

Socio-economic Analysis

The socio-economic characteristics of the existing location should be identified. The impacts of the proposed project on the socio-economic environment should then be analyzed. The analysis should include the use of land, the main economic activities e.g. tourism, agriculture, the social level within nearby communities, employment levels and the existence of archaeological or historical sites. Impacts should be categorized in terms of positive and negative. Examples of negative impacts are conflicts between existing businesses and new project workers, potential pollutants discharged that have an adverse effect on a water body of economic importance, and creation of increase in fees to be charged for services which used to be free. Positive impacts include creation of jobs, decrease public health risks, upgrading of physical infrastructure, and training of workers.

Impact Mitigation and Environmental Management Plan (IMP)

Impact Mitigation Plan (IM) recognizes that it is seldom possible to eliminate an adverse environmental impact altogether, but it is often feasible to reduce its intensity. This reduction is referred to as mitigation. For each potential adverse impact the plan for its mitigation at each stage of the project should be documented and its cost assessed. It is essential that these costs of mitigation be adequately assessed and be fully documented. This is very important in the selection of the preferred alternative. In the case of beneficial impacts it should be demonstrated how these can be maximized. Environmental mitigation can often result in reduced project costs and lower community costs when incorporated as a fundamental part of project design rather than as an add-on exercise. Often simple design changes such as the type of bridging strategy or the time of year that major earth moving activities take place can have a dramatic effect upon improving environmental performance. The mitigation and enhancement measures identified should be capable of being delivered in a cost effective manner and be fully justified.

Environmental Management Plan (EMP) helps in signaling the potential problems that may result from a proposed project. This will allow the prompt implementation of effective corrective measures. Under the plan, environmental monitoring will be required during the construction and operational phases. The main objectives of environmental monitoring are: (1) To assess the changes in environmental conditions (2) To monitor the effective implementation of mitigation measures (3) Warn significant deteriorations in environmental quality for further prevention action.

Selecting of the Proposed Action (SPA)

All the alternatives taken into account in developing the Sanitary Landfill project should be documented. The analysis of alternatives represents the heart of EIA methodology. There are numerous systematic procedures which can be used to compare and evaluate the environmental consequences of alternatives. Many of these can be incorporated in multiple-criteria decision-making techniques and can include public participation (PP) components. If the project were to be sited elsewhere, the impacts associated should be reviewed and the associated mitigation action and costs defined. Each alternative should be evaluated in respect of its potential environmental impact and capital and operating costs. The environmental losses and gains must be combined with the economic costs and benefits to give the full picture for each alternative. An analysis of the "no action" alternative should be included.

Environmental Monitoring (EM)

The monitoring of environmentally sensitive project would make certain that no harm is posed to the environment. In effect, this also dissuades the violation of environmental policies and legislations at the national level and of the ADB. Further, it is also important to monitor the proper implementation of the proposed EMP mitigation measurement. In this regard, environmental monitoring is vital to the environmental management document. There are three basic environmental monitoring tasks to assess the success of mitigation and identifying residual impacts. These are:

1. Pre-construction monitoring to determine baseline conditions such as noise, air and water quality impacts, mitigation measures, and the costs to respond to the conditions in the local legislations and conditions in the environmental approval;
2. Construction compliance monitoring; and
3. Post-construction monitoring of maintenance and operations, including air, noise, and water quality baseline conditions

As a pre-condition under the Environmental Policy and the Operation Manual of the ADB, you have to make sure that a functioning EMP is in place, and is complemented by an ACTIVE monitoring committee to ensure that the plan's provisions are properly implemented.

Table 2 Budgetary planning worksheet for EIA of sanitary landfill

Activity	Person-days			Travel	Other costs	Calendar time
	Professionals	Technical Staffs	Secretarial			
PDN						
PII						
IPI						
DAE						
IP						
IA (PP)						
IM &EMP						
SPA (PP)						
PWN						
EM						
Totals						

NOTE: *PDN = Project Description and Need, PII = Pertinent Institutional Information, IPI = Identification of Potential Impacts, DAE = Description of the Affected Environment, IP = Impact Prediction, IA = Impact Assessment, IM & EMP = Impact Mitigation and Environmental Management Plan, PWD = Preparing the Written Document, SPA = Selecting of the Proposed Action, EM = Environmental Monitoring.*

Environmental Audit / Evaluation

When the project is in existence, then an environmental audit may be required in order to satisfy IFIs that it is operating to an appropriate environmental standard. The audit seeks to confirm the operational practices and to highlight any deviation from the accepted norm. An environmental evaluation is increasingly undertaken to confirm that the performance of the project, once constructed and operational, conforms to the specification and environmental performance standards specified as part of the consent or funding arrangements. Frequently, the environmental evaluation seeks to examine the EMP and review the monitoring data in order to reveal aspects where improved practice is possible and where future EIAs can be enhanced.

Commenting on the Environmental / Extended Cost Benefit Analysis

Cost/benefit analysis is an integral part of the EIA. However, there is no value assessment for the environmental impacts in typical cost/benefit analysis. Therefore the extended cost/benefit analysis of environmental costs is crucial to environmentally-sensitive project. On this basis, cost/ benefits analysis consider environmental impacts as off-site, non-marketed items. An extended cost/benefit analysis identifies the environmental impacts, its quantification and its corresponding values. It is important to include environmental assessment to the economic analysis of the project. An environmentally sensitive project can be justified as good under a conventional cost/benefit analysis. However, when you factor in the environmental costs, the project may rendered not be feasible anymore. You should be find adequate information to analyze the EIA on this basis. If you require further support, you may identify suitable experts to provide these comments.

CONCLUSIONS

Sanitary landfill is now addressing as the prominent and significant environmental impacts including air pollution from methane, carbon dioxide and other such factors, water and soil pollution from leachate, excavation activities, noise pollution from vehicles, fire hazards, scavenging activities, etc. The main sources of impacts are construction, operation and maintenance of Sanitary Landfill. These impacts are the severe to human health and sustainable environmental development. As a result, the study has developed an integrated approach based model of EIA methodology which containing the following steps: Preliminary Activities, *Screening, Environmental policy, laws and regulations,* Selecting Consultants/ Specialists, Team Leader Selection, Conceptual Planning and Management Approach for Environmental Studies, Project Description and Need (PDN), Pertinent Institutional Information (PII), Identification of Potential Impacts (IPI), *Interaction Matrix Methods, Network Methods, Checklist Methods, Simple Modified Checklist,* Description of the Affected Environment, *Conceptual Framework*, *Agency Guidelines or Regulations*, Environmental Indices and Indicators for Describing the Affected Environment, Impact Prediction (IP), Impact Assessment (IA), Potential Health Impacts Identification, Socioeconomic Analysis, Impact Mitigation and Environmental Management Plan (IM&EMP), Preparing the Written Document (PWD), Selecting of the Proposed Action (SPA), Environmental Monitoring (EM), Environmental Audit/Evaluation, Commenting on the Environmental / Extended Cost Benefit Analysis. Most of the experts/specialists agreed and suggested to follow up this methodology for EIA of Sanitary Landfill because it encompassed all the EIA techniques, magnitude and ranking/rating scale of the potential environmental impacts. It can also be facilitated to select suitable alternatives and immediate action for mitigation measures as well as monitoring, evaluation and auditing. The methodology is maintaining national and international policies, rules and regulations of EIA of Sanitary Landfill. It is less time consuming, systematic, suitable, sustainable, logical, and economically efficient and effective. Thus it can fulfill the basic requirements for pollution free environment and ensure reliable and desirable sustainable development for the present and future at local, national, regional and global levels.

RECOMMENDATIONS

1. The developing countries are turning to the Sanitary Landfill for their huge SWM but lack of actual EIA methodology; their sound dream is not bringing positive results. So, the country's targeting goal is not fulfilling as well as not reaching to the sustainable environmental development.
2. For achieving much more authentic results of the developed methodology, it should be needed further consultation with the experts of the national and international level.
3. The developed EIA methodology should be tested more than once in the field level for its practical examined and experienced knowledge will have to include in this methodology.

For the suitability and sustainability of the Sanitary Landfill the followings should have mined during the Sanitary Landfill establishment;

a. The location for Sanitary Landfill should be determined based on EIA which would be carried out by experts drawn from various departments. so that it can be ideal for Sanitary Landfill operation;
b. The basement and surroundings of the Sanitary Landfill should be prepared on the basis of detailed soil analysis so that leachate can not penetrate into the underground and nearby lowland or pond's water;
c. The leachate should be properly handled, treated (with suitable option creation) and also its quality should be monitoring and examined;
d. The Sanitary Landfill should be fenced by net (Tar Jali) and ringed with area specific tree plantation so that dogs, rats, crows etc can not enter into the Sanitary Landfill;
e. The day cover should be regularly maintained so that flies, mosquitoes etc can not breeding their number of population;
f. The workers should have to be used regularly the health protection dresses;
g. The MSW carrying vehicles should be covered, protected properly and cleaned suitably after pull down its loading; and
h. The exact gas utilization technique should have to be developed so that the gas can not release into the atmosphere.

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Establishment and Operation of a Landfill and Recycling Center in Bais City of Philippines during the Time Period 2003-2008

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ABSTRACT

As in other developing countries, financial means to manage solid waste are limited in the Philippines. Cost for municipal solid waste management can often not being recovered due to lack of local regulations and a low "willingness-to-pay" by users for provided municipal waste management services. As one consequence, local governments lack funds to upgrade their waste disposal systems. Hence, waste disposal remains to be performed on dumpsites almost everywhere in the country, whereas disposal sites lack management and basic environmental protection measures such as liner systems, leachate and gas collection/treatment as well as waste coverage, compaction, monitoring and aftercare. Besides, the locations chosen for waste disposal often neglect the sensitivity of surrounding natural systems. In this context, Republic Act 9003, also called Ecological Solid Waste Management Act of 2000, was released as a new waste management law. This law promotes waste minimization, material recovery, reuse and recycling and especially requests to establish a composting component and to close dumpsites prior to 2007.

Bais City is a medium-size, agricultural dominated city on Negros Island. The main sources of income relate to agricultural activities and especially to sugar cane farming and sugar production. Due to the environmental sensitiveness of the Bais City lowlands, the threats of uncontrolled waste disposal were already recognized during the 1990ties. Consequently, the local government established a waste management ordinance in 1997, whereby the establishment of a landfill was proposed within the Comprehensive Landuse Plan at the same time. Following, the local government designed and constructed a municipal Waste Management and Recycling Center, which integrates a landfill. This waste management facility is operational since July 2003. In order to safe investment costs, the local government had decided to implement a Bentonite-enhanced clay-lined landfill and to use appropriate technologies instead of imported equipments and materials whenever possible. This paper summarizes the technical outline and experiences made during six years of landfill operation.

INTRODUCTION

Bais City is a fast developing component city in the Province of Negros Oriental, located 45 km north of Dumaguete City along the Tañon Strait. The city comprises 35 administrative units, which are called barangays (2 urban, 33 rural) with a total population of roughly 74,000 (census 2007). According to local waste characterization studies the average per capita waste generation is 0.48 kg/day for the urbanized areas and around 0.35 kg/cap/day for rural areas, which translates to roughly 13,000 tons solid waste generation annually. However, further economical development and population growth is expected, especially for the urban center which more and more attracts new commercial establishments and housing developments. To tackle issues related to waste management the Local Government Bais City established a Waste Management and Recycling Center already in 2002, which includes the first clay-lined landfill constructed in the Philippines (Paul 2003). The landfill is operational since July 2003. Ever since, Bais City operates a Sanitary Landfill (Category 2). Simultaneously, the former operated dumpsite at Barangay Talungon was closed and rehabilitated in 2003. The application of Bentonite to establish a clay liner for the landfill instead of a more costly synthetic liner was chosen to lessen investment cost and to allow a project implementation in line with the available equipment and Local Development Fund of Bais City. With the chosen approach, expensive material import could be avoided, whereas the needed Bentonite to enhance the clay liner was acquired from a nearby clay deposit in the Municipality Ayungon located 45 km north of Bais City. The project planning, construction and landfill operation was supported by the German Development Service, whereas the actual development and construction of the Bentonite-enhanced clay-liner was assisted by the national Department of Science and Technology (DOST) through its Industrial Technology Development Institute (ITDI).

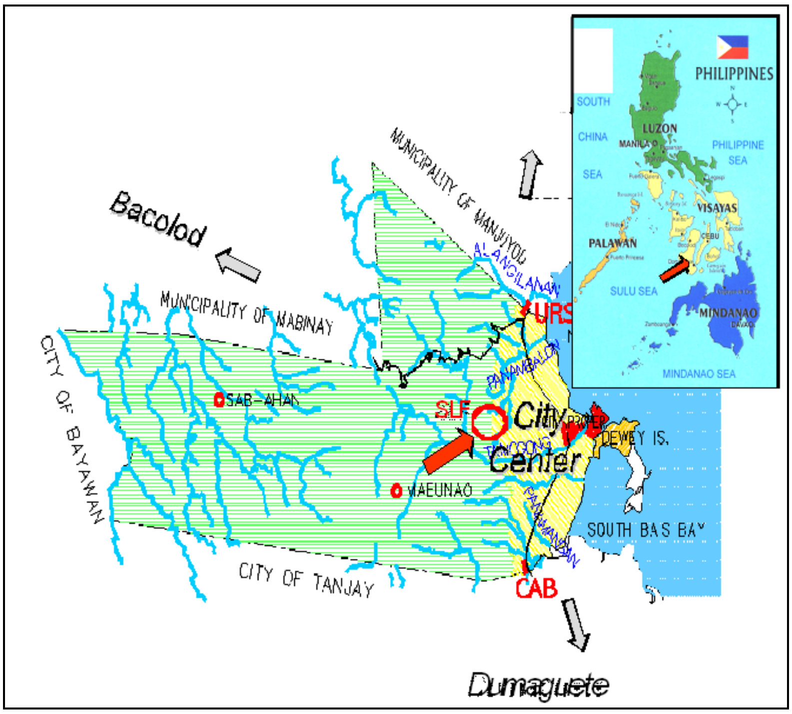

Figure 1 Location of Bais City, Negros Oriental

LEGAL CONTEXT FOR LANDFILL CONSTRUCTION AND OPERATION

The legal requirements for the establishment of a Sanitary Landfill in the Philippines are provided by RA 9003, Chapter III, Section 41. This section states under (a):

Liners are a system of clay layers and/or geosynthetic membranes used to collect leachate and to reduce or prevent contaminated flow to groundwater.

And for the leachate generation and treatment under (b):

Leachate Collection and Treatment system – Installation of pipes at the low areas of the liner to collect leachate for storage or eventual treatment and discharge.

The Implementing Rules and Regulations (IRR, 2002) of RA 9003 provide further details for liner construction and leachate treatment. Rule XIV, Section 1 of the IRR states under (j):

Except as provided by Section (m) of Rule XIV, for landfills located in sensitive resource areas, landfills shall be provided with a base liner system consisting of clay and/or geosynthetic membranes (geomembrane). If clay is used, it shall have a minimum thickness of 0.75 m and a permeability of 1 x 10^{-6} cm/sec or less. Geomembranes shall be at least 1.5 mm thick with a permeability of 1 x 10^{-14} cm/sec. Geosynthetic Clay Liners (GCL) shall have a thickness of at least 6.4 mm and a permeability of 1 x 10^{-9} cm/sec or less. If a composite liner is used (clay under geomembrane), the thickness of the clay liner may be reduced to 0.60 m. To design geosynthetic liners, international standards (e.g. Geosynthetic Research Institute, or applicable ASTM standards) shall be used for its design and specifications in terms of properties, manufacturing, testing and construction quality assurance.

And for the Leachate storage and treatment under (k) and (l):

(k) Leachate collection and removal system shall be provided and designed such that leachate build-up in the landfill will be minimized. For design purposes, an allowable leachate level of not more than 0.60 meter over the liner system shall be maintained. If leachate is discharged, the discharge shall meet effluent discharge and water quality criteria prescribed by DENR.

(l) Leachate storage facilities shall be designed with containment systems to prevent leachate from spillage and its migration into underlying groundwater or nearby surface body of water. For leachate impoundment ponds, the design shall include a geomembrane liner system, underlain by a low permeability soil layer of at least 0.30 meter thickness. The geomembrane liner shall be at least 1.5 mm thick with a permeability of 1×10^{-14} cm/sec or less. Liner specifications and engineering certification requirements shall be per provisions of Section 1m of Rule XIV. Adequate freeboard including allowance for rainfall volume and other safeguards shall be provided to prevent pond overflowing.

With the release of a Department Administrative Order (DAO) by the Department of Environment and Natural Resources (DENR) in 2006, waste disposal facilities were categorized into four classes, whereas the classes are only based on the quantity of residual waste input and quality criteria are neglected (DENR 2006). Main differences between categories are technical requirements such as thickness and permeability factor for the base liner or applied technology of leachate treatment. However, the following criteria and operating requirements are mandated regardless of category:

- planned capacity with phased cell development,
- site preparation and containment engineering,
- compaction of waste to minimum specified target densities,
- specified operational procedures to protect amenities,
- fence, gate and other site infrastructure with surfaced primary access road,
- full record of waste volumes, types and sources,
- separate cells for municipal solid waste, treated toxic hazardous waste (THW) or health care waste (HCW). Handling and management of THW and HCW should be in accordance with the provisions of Republic Act 6969 and Joint DENR-DOH Administrative Order No. 02, respectively,
- facility operation by a pool of fully-trained staff,
- prohibition of open burning,
- provision of aftercare following site restoration and closure,
- prohibition of waste pickers at the immediate disposal area.

WASTE MANAGEMENT AND RECYCLING CENTER BAIS CITY (WMRC)

Waste Generation Situation

According to the latest population count of the National Statistics Office in 2007, roughly 74,000 residents lived in Bais City in the year 2007. Based on prior conducted waste characterization studies, the average waste generation in Bais City was estimated with up to 0.48 kg/cap/day for urban households and 0.35 kg/cap/day for rural areas. In total, around 13,000 tons/year of domestic type waste are generated in Bais City. From that 61 % were classified as organic waste, 6 % used paper and cardboard packages, 3.3 % glasses, 2.1 % metals and 7.5 plastic wastes (hard plastics, bags, foils), whereas remaining wastes were a mixed fraction of fines with grain sizes < 2 cm such as sweepings, ashes, fine organic materials and broken components (Paul 2002).

At present, the Waste Management and Recycling Center (WMRC) serves only 8 out of the 35 local administrative units, also called barangays, which form the lowland part of the 31,000 hectares Bais City jurisdiction. All other barangays can not be reached by the waste collection due to lacking road development. So far, only 35 % of the households are covered by the public waste collection. The public waste collection delivers roughly 3,500 tons/year to the WMRC respectively 10 tons/day.

Design of Components and Functions of the WMRC

To provide the needed facilities to manage solid waste at a central location, the City of Bais established a Waste Management and Recycling Center (WMRC) in 2003, which included a clay-lined landfill. The application of Bentonite to enhance the base clay liner for the landfill instead of a synthetic liner was chosen to lessen investment cost and to allow a project implementation in line with the available equipment and municipal funds.

The WMRC is located 4 km away from the city center. The site covers an area of 5 hectares with 3 hectares for landfill establishment and further 2 hectares for the operation of a composting facility, a waste water treatment plant with a total storage capacity of 820 m^3, a material recovery facility and an office building with sanitation facilities. Further infrastructures are a water supply system with deepwell and 7,000 liter storage tank, 3 rainwater tanks with a total storage capacity of 25,000 liter, a perimeter fence with tree plantations, energy supply, operation roads, entrance gate and storage facilities.

The development of the Bentonite enhanced clay liner was supported by the Department of Science and Technology (DOST). The clay liner itself reached a laboratory permeability of 1.54×10^{-6} cm/s in a mixture of 90 % host soil from Bais City landfill area and 10 % Bentonite, whereas the host soil alone did not comply with the legally prescribed permeability factor of $< 1 \times 10^{-6}$ cm/s. The locally available soil was gathered during the excavation of landfill cell 1 (compare Figure 2) and stored at site.

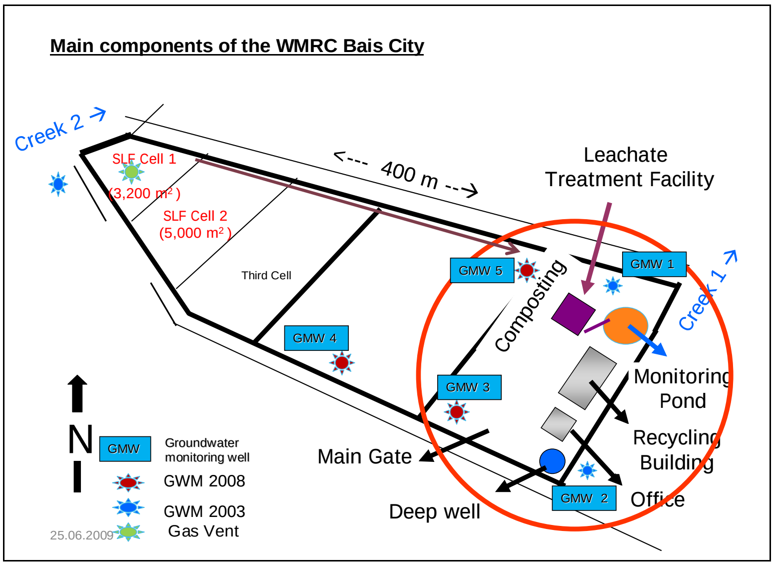

Figure 2 Main components of the Waste Management and Recycling Center Bais City

The upper 20 cm of living soil cover were cleared and utilized to establish small side dams surrounding cell 1. Excavated materials up to a depth of 1.5 m below surface were gathered and stored beside cell 1. A slope of roughly 3 % (longitudinal) was provided and the final base layer compacted with a heavy roller. Following, the interstored host soil was returned into cell 1 with a thickness of 0.30 m and mixed with 10 % Bentonite. The mixing itself was conducted with agricultural equipment using a tractor with attached discs and harrows. After mixing, the clay layer was compacted and the process repeated for the second layer. The clay base liner in Landfill cell 1 was constructed with 2 layers (each 0.3 m with total 0.6 m thickness).

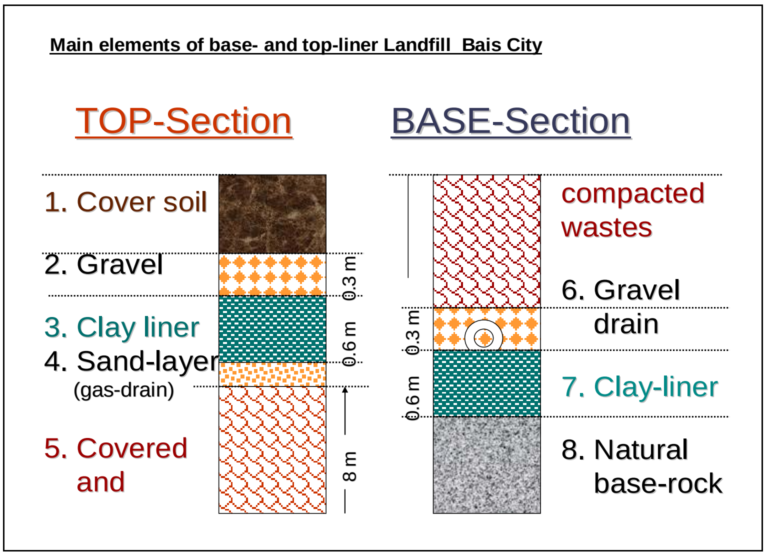

Figure 3 Main elements of base and top liner systems of the landfill Bais City

The liner construction took place in the dry season (February and March 2003). It has to be mentioned that the water content during clay liner construction could not be controlled sufficiently due to lacking equipment and infrastructure resulting in sub-optimal compaction rates (Paul 2003).

However, the finished clay-liner was sampled and analyzed by the Department of Science and Technology, whereas the gathered three core samples of the clay liner from cell 1 all complied with the legally prescribed permeability factor of $1x10^{-6}$ cm/s for landfill category 2 (DAO 2006). After final clay liner compaction a sand protection layer (0.15 m) was provided to cover the clay liner and to protect it against drying. Finally, a gravel drainage layer of 0.3 m thickness was placed on top of the sand protection layer. The provided gravel, however, had a poor sorting with too many fines.

Waste Delivery at the WMRC in the Time Period 2004 -2008

As shown in Table 1, around 10–12 Tm^3 of solid wastes were collected and delivered to the WMRC every year since start of operation. Gradually, the envisioned waste diversion increase could be accomplished during the 5 years of operation with now>1,000 tons or 28.2 percent waste recovery alone by segregation at source and further end-of-the-pipe segregation of organic materials conducted at the composting facility at the WMRC in 2008. Data data from household composting are not available so far. Although the material recovery is increasing over time, > 70 % of the collected wastes are still disposed at the landfill, meaning a significant portion of organic waste can not be segregated but is disposed together with residual wastes at the landfill.

So far, the WMRC serves only the public waste collection whereas incoming trucks and delivered wastes are inspected and waste volume is assessed by ocular inspection and recorded. The following table 1 summarizes the trends of total delivered waste to the landfill and segregated organic waste which is processed at the composting facility for the time period 2004 – 2008.

Table 1 Waste delivery, composting and disposal statistics at the WMRC from 2004 - 2008

Year	A. Total collected waste	B. Total segregated organic waste		C. Total waste disposed at the landfill	
[truck tours]	(m^3)	(m^3)	(% of A.)	(m^3)	(% of A.)
2004	13,436	1,628	12,1	11,808	87,9
2005	11,865	1,463	12,3	10,402	87,7
2006	12,952	3,576	27,6	9,376	72,4
2007 [1,613] [1)]	12,331	2,954	23,9	9,377	76,1
2008 [1,667] [2)]	13,040	3,680	28,2	9,360	71,8
TOTAL (m^3)	63,624	13,301	12.1- 28.2	50,323	71.8 - 87.9
TOTAL (tons)[3)]	20,996	4,389		16,607	
Average tons/yr.	4,200	878		3,321	

1) - 1,613 trucks delivered 12,331 m^3 waste in 2007, which translates to an average truck load of 7.64 m^3

2) - 1,667 trucks delivered 13,040 m^3 waste in 2008, which translates to an average truck load of 7.82 m^3

3) - weight estimation of collected waste is based on an average waste density of 0.33 tons/m^3

Fill cell 1 of the landfill comprises an area of 3,200 m^2 with an average fill height of 8 m. This fill unit was filled and closed in the end of 2008. The provided fill volume of cell 1 is estimated with 25,600 m^3. Based on the waste delivery documents around 16,600 tons of residual waste were disposed in cell 1. Calculating an additional 15 % of integrated cover soil, the disposal density (in situ) in cell 1 can be estimated with 0.75 ton/m^3, which is a comparable low disposal density (Ramke 2002) whereas the low compaction rate is explained by the use of a backhoe instead of a bulldozer with a much lower compaction force. However, this estimation is only a rough approximation since the WMRC lacks a weighing bridge and the incoming trucks are only assessed by volume based on ocular inspection.

Landfill Operation

Due to financial constraints, the regular landfill operation in Bais City utilizes a backhoe instead of a more costly bulldozer. The backhoe was also chosen because it can compact and cover incoming waste but can also gather cover soil from the adjacent next landfill cell and conduct other excavation works. Incoming waste at the landfill is compacted and regularly covered with local soil.

The needed soil is gathered from the adjacent next landfill cell, which is simultaneously developed during the landfill operation to reduce later construction works and cost for the following landfill unit. Considering the amount of waste disposed during the time period 2004-2008 in landfill cell 1 with 3,200 m^2, the lifespan of the remaining 2,5 hectares for waste disposal may well reach > 25 years. However, the municipality acquired already an adjacent extension area of 7 hectares, which could be utilized in case waste disposal will still be needed in the long-term.

Figure 4 Waste compaction and soil coverage at the landfill Bais City in 2004

Generated leachate from waste disposal is collected via the gravel drainage layer at the landfill base, forwarded to a central collection pipe and released to a pre-filtering unit which connects to a 200 m^3 tank, which is subdivided into 4 treatment tanks. The treatment process provides a physical treatment (sedimentation) and oxygenation to support biological treatment, whereas the latter is accomplished by recirculation and back-spraying of leachate into tank 4 of the leachate treatment facility using a small pump station.

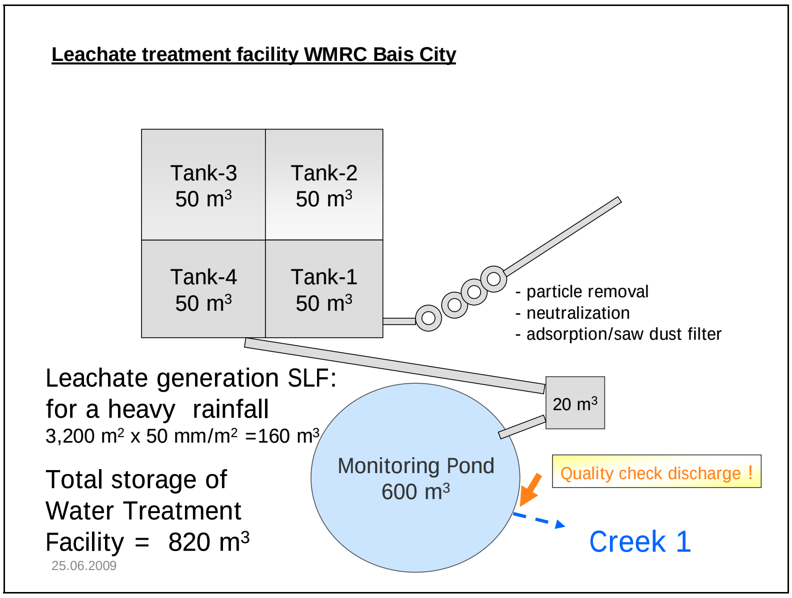

Figure 5 Main elements of the leachate treatment facilty at the WMRC Bais City

Treated leachate is forwarded to a 600 m^3 buffer pond (Monitoring Pond) which allows inter-storage and natural treatment of effluent. Within this pond nutrients are utilized by a small wetland whereby a larger portion of the stored water is evaporated. To avoid clogging, small catchment basins along the main leachate drainage pipe were established in intervals of 50 meter, which are regularly checked and if needed desludged. Likewise tank 1 of the treatment facility, which was designed as a sedimentation tank, is cleaned every year during the dry season (March–May). The gathered sludges are disposed at the landfill.

Although some waste pickers started to visit the landfill illegally in the beginning of the landfill operation, the local government managed to integrate a group of 10 volunteer waste reclaimers by allowing them to enter the site under certain conditions such as simple work safety precautions e.g. reporting to the WMRC management prior to waste recovery, waring of shoes and gloves, washing after work and by working in a group of at least 2 workers.

Landfill Monitoring

The leachate collection and treatment facilities, perimeter fence and access road are regularly inspected and maintained to secure a sound landfill operation. Furthermore, an environmental monitoring program was proposed, which observes selected parameters of leachate composition and ground and surface water quality. This program also acts as an "*early warning monitoring system"* and informs decision-makers from the city and the responsible Environmental Management Bureau in case "*warning levels*" of water quality are surpassed. Main aspects of monitoring local water conditions are the leachate effluent from the landfill (chambers 1 and 4 of the leachate tank), the monitoring pond, two small creeks located upstream and downstream of the WMRC, 5 shallow groundwater monitoring wells with depths up to ten meter below surface and a deep well for water supply, which taps water from a depth of 40 m. The regular field monitoring includes the observation of water levels, pH, temperature, conductivity and oxygen concentrations. Laboratory analyses were only conducted in connection with prior received support from the Department of Science and Technology in the years 2003/2004. Table 2 summarizes the trends observed for the parameters temperature, conductivity and ph-values within the period 2003-2008.

Table 2 ph-values, conductivity, COD/BOD, NH_4 and Chlorine concentration trends for raw leachate from chamber 1 at the WMRC Bais City for the time period 2003 - 2008

Year	ph-value	Conductivity (µS/cm)	NH_4 (mg/l)	COD (mg/l) [BOD] (mg/l)	Clorine (mg/l)
2008	6.8-7.1	1,400-2,800	-	-	574
2005	6.5-7.8	2,700-3,300	-	-	-
2004	7.1-8.8	1,400-2,900	405	630 [340]	320
2003	5.9-6.9	3,300-4,400	32.5	820	130

Temperature values of leachate varied from 28-33 degree Celcius during the monitoring period. Field measurements to test oxygen concentrations were started in 2003. Due to the sensitivity of the oxygen field probe, widely scattering results were documented and hence the oxygen measurements terminated. Although the observed COD and BOD values from 2003 respectively 2004 seem comparatively low, leachate stored in tanks 1-4 is commonly brown to black in colour indicating significant organic loads. The parallel conducted field monitoring on surface and groundwater observation points revealed comparable normal and stable ph-values in the magnitude 6.3 to 7.1 and conductivity values of < 230 µS for surface waters (creek-1 and creek-2) respectively 133-420 µS for the shallow groundwater monitoring wells 1-5. A COD analysis conducted for creek-2 in 2004 showed a low COD concentration of 22 mg/l. Likewise, a laboratory investigation on chlorine resulted in concentrations < 19 mg/l for all shallow groundwater monitoring wells in April 2009. The deepwell at site, which provides the water for the WMRC, showed relatively uniform ph-values in the magnitude 6.8-7.1 and conductivity values between 460-625 µS over the monitoring period 2003-2008. Laboratory analyses conducted for a water sample from the deep well on ammonium and COD revealed concentrations < 0.1 mg/l in the year 2004. Leachate analyses conducted for various heavy metals in November 2004 such as for Lead (< 0.1 mg/l), Nickel (0.027 mg/l), Cadmium (<0.01 mg/l), Zinc (0.56 mg/l) and Copper (0.14 mg.l) showed relatively low concentrations if compared with research results from other landfills (El-Fadel et al. 1997). The field measurements conducted so far do not hint that leachate generated from the landfill caused a recognizable, local water pollution. The observed changes in conductivity values at the shallow wells may indicate that they easily interact with rainwater recharge. The stored, treated leachate at the monitoring pond shows a trend of increasing dissolved components over the monitoring period. However, the obtained data from the leachate and water monitoring are insufficient and do not allow to evaluate the leachate treatment efficiency and changes in water quality of surrounding surface and ground water systems in the needed detail.

Financing the WMRC and Local SWM Program

In 2000, the Local Government of Bais City had decided to develop the WMRC gradually by utilizing their local, annual development fund. To develop the first two landfill cells, which cover an area of 0.82 hectare, roughly 123,300 US-$ (compare table 3, sum of positions 1-3) were spent to conduct excavation works and to establish the Bentonite enhanced clay-liner, sand protection layer and gravel drainage layer. This translates to cost of 15 US-$/m^2 landfill (compare table 3). To acquire the 5 hectare site for the WMRC 106,260 US-$ were spent with a cost equivalent of 2.11 US-$/m^2. The establishment of support facilities and infrastructures such as composting facility, leachate collection, recycling and storage building, water and energy supply, perimeter fencing, tree plantations and monitoring wells resulted in total cost of 140,990 US-$ respectively 2.82 US-$/m^2 if calculated for 5 hectares WMRC. The following table summarizes the provided investments to establish the WMRC.

Table 3 Provided investment to establish the Waste Management and Recycling Center Bais City

Cost unit	Total (US-$) 1)	US-$ / m^2 landfill
Land acquisition 5 hectares	106,260	2.11
Investment cost to develop landfill cell 1 & 2 (0.82 hectare) 2)		
1. Excavation works	37,120	4.53
2. Cost for base clay liner	52,260	6.37
3. Cost for gravel liner and sand protection layer	33,930	4.14
Investment to establish infrastructures for the WMRC (5 hectares) 3)		
4. Drainage, leachate collection and treatment	25,600	0.51
5. Site fencing and perimeter tree planting	19,160	0.38
6. 1 deepwell & 5 groundwater wells (shallow)	7,240	0.15
7. Energy supply	10,600	0.21
8. Composting facility	53,060	1.06
9. Recyling, storage and office buildings	25,330	0.51
Total	**370,560**	**19.98 4)**

1) – cost calculation based on an exchange rate of 47 Philippine Peso per 1 US-$
2) - Costs calculated under positions 1-3 are divided by 8,200 m^2 landfill area to establish cost/m^2
3) – Costs calculated under positions 4-9 are divided by 50,000 m^2 WMRC area to establish cost/m^2
4) – The average fill height for the landfill is projected with 8 m, whereas only 3 hectares of the WMRC area will be developed as landfill. Hence, the cost per m^3 disposed waste are: $[(50{,}000\ m^2/30{,}000\ m^2)/8] \times 19.98 = 4.16$ US-$/m^3

Based on the data from table 3, the construction cost of landfill cells 1 and 2 cover 33.3 % and the land acquisition cost for the WMRC 28.6 % of the total provided investment. These cost items have to be considered as the main initial cost factors for the WMRC implementation. With the chosen gradually project implementation, the Local Government was able to finance the WMRC without a bank loan. Table 4 summarizes the various investment and operation costs provided by the Local Government to implement their solid waste management program in the time period 2000 to 2008.

Table 4 Cash-Flow (US-$)1) for the development of the Waste Management and Recycling Center

Year	Dumpsite Closure	WMRC and SLF	Composting Facility	Public Education	M & E 2)	Operation & Mngmt	*Sub-Total*
2001	-	41,000	-	2,150	-	3,900	*47,050*
2002	-	36,200	4,220	-	-	2,150	*42,570*
2003	3,220	37,250	-	-	1,070	1,070	*42,610*
2004	3,220	23,450	-	-	3,220	2,150	*32,040*
2005	-	19,150	8,510	2,150	5,360	5,360	*40,570*
2006	-	21,300	12,730	2,150	2,150	14,870	*53,200*
2007	-	12,700	14,870	3,220	2,150	12,730	*45,670*
2008	-	10,600	12,730	-	2,150	10,590	*36,070*
Total	6,480	201,650	53,060	9,670	16,100	52,820	*339,780*
%	*1.9*	*59.4*	*15.6*	*2.8*	*4.8*	*15.5*	*100*

1) – the cost calculation was based on an average exchange rate of 47 Philippine Peso : 1 US-$
2) - cost for monitoring and evaluation (included in cost for landfill establishment for the years 2000 - 2002)

The cost for public waste collection and street cleaning are not included in table 4 but were in the magnitude of 85,000 to 105,00 US-$ during the last years. Including the latter costs, the operation of the WMRC and related municipal waste management services correspond with an average budget need of around 137,500 US-$/year. In order to recover these cost and to provide a sustainable operation of the WMRC the Local Government either needs to recover 1.90 US-$/cap/year from the 74,000 residents respectively 10 US-%/household/year or to charge a tipping fee in the amount of 41 US-$/ton respectively 13.70 US-$/$m^3$ for disposed waste, whereas aftercare cost are not included in this cost estimation.

DISCUSSIONS AND CONCLUSIONS

Bais City is one of the few Local Governments in the Philippines which implemented the new waste legislation. The approach to establish a Bentonite enhanced clay-lined landfill by utilizing appropriate technologies proved successful since the available manpower and equipment could be adjusted to the planning concept and technology more easily. With that, expensive equipment and material import could be reduced as well as the dependency on external companies, experts and foreign technologies. The fact that the municipality has managed to maintain a sound landfill operation over a time period of six years underlines these statements. The chosen gradual development by utilizing own budgets instead of searching for external funds proved successful as well. Additional planning steps, e.g. to conduct a feasibility study as well as internal meetings of local decision-makers and lengthy negotiations with donor organisations could be avoided. Besides, the actual borrowing capacity of the most municipalities in the Philippines is comparable low and may not be sufficient to avail of a bank loan respectively to establish a high-tech landfill.

The local government Bais City was capable to establish and maintain a Waste Management and Recycling Center over a time period of 8 years with a total investment of 340,000 US-$ until end of 2008. This corresponds with an average annual budget need of 42,500 US-$ for the WMRC, whereas cost for waste collection and street cleaning sum up to a total annual budget need of 137,500 US-$ for all provided municipal waste management services. However, cost for site rehabilitation and aftercare measures are not included in this cost estimation. With the provided budget around 3,300 tons of solid waste can be delivered, treated and disposed at the WMRC. From the delivered waste at the WMRC around 70 % are disposed at the landfill and 30 % are recovered, mainly as organic waste and treated at the provided composting facility. The projected 240,000 m^3 of total landfill capacity would serve the community for a total length of around 30 years, provided the waste disposal rate remains in a comparable magnitude as observed at the WMRC so far. The total project cost for he WMRC are estimated with at least 1.27 Mio US-$ whereas inflation, increasing cost for equipment, cost for waste collection, street cleaning and aftercare are not included in this cost estimation.

The environmental benefits of the established and operated WMRC are multifold. Generated leachate is collected and treated in a comparable simple way, whereby the leachate treatment facility releases effluent only in peak times of run-off on less than 10 days/year. Effluent discharged on such occasions usually correlates with heavy typhoon rains. Since the leachate storage facility was slightly oversized, released leachate can be stored during the rainy season (July-January). Stored leachate is mainly evaporated during inter-rainfall periods and especially within the dry season (February – June). So far, the observed leachate loads remain comparable low with < 4,400 µ-Siemens and comparable low ammonium and COD/BOD levels if compared with leachate loads observed on many other waste disposal sites (El-Fadel et al. 1997).

During the five years of operation no indication of surface or groundwater pollution was observed. However, it has to be mentioned that the availability of needed expertise and field equipment to conduct and evaluate environmental monitoring is a bottleneck in the context of the Philippines. Likewise, standard procedures, expertise and qualified laboratories are hardly available as well as service providers for consultancy and environmental monitoring, except for the capital region Metro Manila. Hence, landfill gas monitoring could not be started in Bais City yet.

Bais City demonstrated that the enhancement of waste disposal is feasible and can be maintained, even with restricted budgets and in the context of a developing country. In the meantime five other Local Governments in the Visayas region adapted this approach and established similar, low cost landfills in their municipalities, which underlines the good potential for project replication.

As one of the main threats to sustain the started WMRC project, the lack of cost recovery from waste generators has to be emphasized. The most municipalities in the Philippines tend to provide waste management services out of their annual budget and fail to collect user fees. Although the refinancing of a low-cost landfill as established in Bais City seems feasible with cost of only 13.70 US-$/$m^3$ disposed waste or only 1.90 US-$/resident/year, so far the City of Bais could not implement a corresponding local ordinance. As one hindrance, the comparable short intervals of municipal elections with only 3 years have to be mentioned. Although local decision-makers may agree to establish a waste management ordinance, which requests residents and private users to pay for provided waste management services, they usually fail to implement the same in their comparable short administrative time.

ACKNOWLEDGEMENT

The Authors wish to thank Mr. Jun Braganza and Mr. Ruben Loberi from the Department of Science and Technology for their support in developing and testing the Bentonite enhanced clay liner system for the Bais City landfill. Further thanks go to Mr. Eric Laxina, Ms. Lilibeth Cadiz and Ms. Lorna Filosofo who supported the project in the time period 2002 – 2005 by coordinating and documenting many of the key activities and experiences. Furthermore, the authors would like to acknowledge the generous project support provided by the German Development Service in the time period 2000 to 2004.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.469-473

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Effectiveness of Technical Criteria for Landfill Liner in China

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ABSTRACT

Over the past two decades, Municipal Solid Waste (MSW) generated in China is increasing with dramatically. To avoid the illegal dumping of solid waste, technical criteria for the construction and management of sanitary landfill of MSW were enacted in China. According to the technical criteria for MSW, hydraulic conductivity of clay used as liners and thickness of liners are the two dominant factors in the design of landfill liners as a barrier. Effectiveness of the technical criteria for landfill liner in China was evaluated by a 1-D advection-dispersion transport model in this paper. The results revealed that high thickness and low hydraulic conductivity of clay in landfill liner were the major reasons for preventing contaminant transportation through the liner. Therefore, it is reasonable to adopt the two factors as the control parameters for landfill liner design in China. The limitation of the water head should be considered in the technical criteria for MSW in China.

INTRODUCTION

Due to the population growth and economic development, MSW generated in China is increasing with dramatically. In 2006, the quantity of MSW in China is up to 148.4 million tons. Among them, 66.9 million tons is disposed by landfill method, accounting for 45.1% of the total amount of generated MSW. To deal with the enormous mass of solid waste, over 100 sanitary landfills for MSW are constructed in China during the past decade.

To avoid illegal dumping of solid waste, technical criteria for the construction and management of sanitary landfill of MSW were enacted in China. The earliest technical criteria were promulgated in 1988. In these criteria, requirements for the location, design, construction, and running of a typical sanitary landfill have been specified. Two revisions on the technical criteria have been performed in 2001 and 2004, respectively, to meet the change on the nature of solid waste and the new requirements of environment. According to the 2004 technique criteria of MSW landfill in China (CJJ17-2004), requirements for clay liner are that the thickness of the liner is no less than 2m and the hydraulic conductivity of the clay in the liner was not larger than 10^{-7}cm/s. However, there is little explanation for choice of these regulated values in Chinese criteria. And the applicability of these criteria still needs to be verified in field and/or by laboratory test.

Nowadays clay is still the major material for the construction of bottom and cap liner system of MSW landfills in China due to economic reason. According to the technical criteria for MSW, thickness of clay liner L and hydraulic conductivity K_w of clay in landfill liner are two dominant factors in the design of landfill liner. However, high water head are frequently detected above bottom liner in many landfills in China due to the clogging of leachate collection system. Therefore, water head above clay liner should also be considered in the design of landfill liner. To these attempts, impacts of geotechnical characteristics of clay and water head in landfill on the liner were analyzed by a 1-D advection-dispersion transport model and hence discussed. Then, the effectiveness of the technical criteria for landfill liner in China was also evaluated.

TRANSPORT EQUATION

In clay liner, there are three ways for contaminants to transport through the clay soil: advection, dispersion and adsorption (Sasaki 1996; Du et al. 2002). Advection transport of contaminants is arose by leaching action resulted from the hydraulic gradient of clay liner. Contaminants dispersion consists of two components: mechanical dispersion and ionic or molecular diffusion. Mechanical dispersion is the mixing process of ion or molecule due to the variety of pore size, while diffusion is the movement of ionic or molecular constituents aroused by concentration gradients. Moreover, contaminant transport is also influenced by chemical reactions, such as adsorption-desorption reactions, solution-precipitation reactions, etc. The relationship of contaminant between the solution and the solid is generally described by linear isotherm equation at low to moderate concentrations.

To simulate the contaminants transport through clay liner, the advection-dispersion equation for solute transport in porous medium is generally adopted (Foose et al. 1996; Devulapalli et al. 1996; Chen et al. 2002). Since the area of landfill liner is much larger than its thickness, the contaminant transport through clay liner is generally represented by a 1-D advection-dispersion transport equation, which is shown as following:

$$R_d \frac{\partial C}{\partial t} = -\frac{q}{\theta}\frac{\partial C}{\partial z} + D_s \frac{\partial^2 C}{\partial z^2} \qquad (1)$$

Where C is the contaminant concentration in liquid phase; q is the discharge quantity through unit cross-sectional area in unit time and accords with Darcy's law; θ is the volumetric water content of clay, equaling to the volume of water to total volume; R_d is the retardation factor, which is equal to or larger than 1.0; D_s is the dynamical dispersion coefficient, which is approximate to diffusion coefficient when hydraulic gradient is small.

ANALYSIS OF CHINESE CRITERIA

For most landfills in China, the phreatic line is usually high because of high water content of MSW, improperly preventions of rainfall and surface runoff, and the clogging of collection system. The design criteria presented by U.S.E.P.A require that leachate collection system should be constructed to keep the depth of leachate over liner less than 12inch (about 30cm). But the water head over clay liner hasn't been limited in Chinese landfill design criteria. To verify the validity and applicability of the Chinese landfill criteria, technical requirements for clay liner is analyzed based on the experiment results of clay liner in Tianziling landfill, Hangzhou, China (Luo 2004). Breakthrough time T of contaminant through clay liner was adopted in this paper to represent the anti-pollutant capability of clay liner in landfill facilities.

The results of breakthrough time T under different cases as presented in Table 1, which was obtained from equation (1) by using the finite difference method. In all the cases, the initial concentration of contaminant in soil and in leachate is assumed as 0mg/L and 2000mg/L, respectively (Jiang et al. 2002). Based on the experiment results of clay used in Tianziling landfill, China, the retardation factor and diffusion coefficient is found as 1.5 and $2.0*10^{-7}$cm/s, respectively. Three factors are chosen to verify their effects on the transport of contaminant through clay liner, as presented in Table. The values of these factors are adjusted with need of analysis. In Table 1, case 1 is the result of the clay liner which meets with the basic requirements in Chinese landfill criteria.

In reference of Table 1, all the three factors, hydraulic conductivity, depth of clay liner and water head above liner, have effect on the breakthrough time T. Among them, impact of hydraulic conductivity of clay liner is the most remarkable. Therefore, it is feasible and effective to limit the hydraulic conductivity in the design of clay liner. Based on experimental results, the variation of leachate concentration and total leaching quantity with hydraulic conductivity was illustrated in Figure 1. This figure reveals that the contaminant concentration in leachate was small under low water head when hydraulic conductivity of clay was less than 10^{-7}cm/s. This is consistent with the Chinese technical criterion for landfill clay liner. When water head over liner goes up, total leaching quantity through liner increases evidently even if hydraulic conductivity of clay is still low. This means more dangerous for surrounding circumstance.

Besides hydraulic conductivity of clay, depth of clay liner is also restricted in Chinese criterion for landfill. Apparently, the quantity of contaminant leaching out of landfill liner decreases with the increasing of clay liner depth. But the thicker clay liner is, the more expansive it also is. Thus the depth of clay liner should be moderate to meet with the economic and environmental need at the same time. From Figure 2, it was noted that the minimum depth of clay liner in Chinese criterion can satisfy the anti-pollutant requirements when water head over liner was low. But with the increase of water head, the risk of contaminant leaching is raised.

Table 1 Breakthrough time of contaminant through clay liner

Case	K_w (10^{-7}cm/s)	L(m)	H(cm)	T(yrs)
1	1.0	2.0	100	10.5
2	0.1	2.0	100	19.5
3	10.0	2.0	100	8.2
4	1.0	1.0	100	3.5
5	1.0	4.0	100	31.0
6	1.0	2.0	30	11.2
7	1.0	2.0	1000	4.5

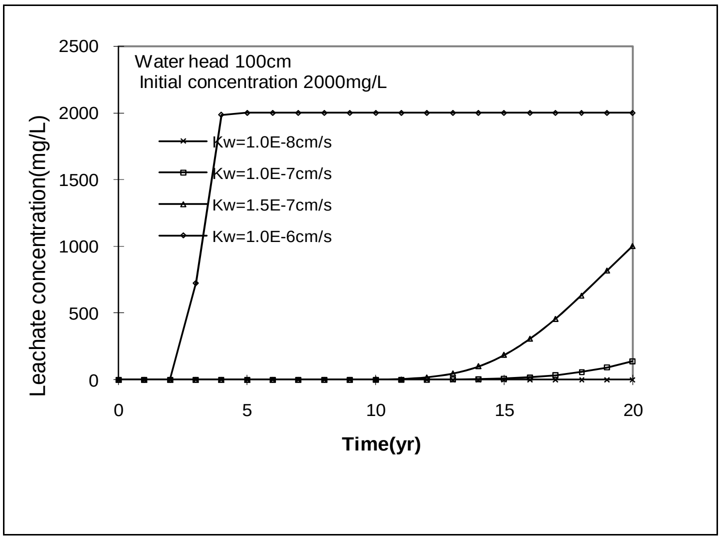

Figure 1 Variation of leachate concentration with different hydraulic conductivity

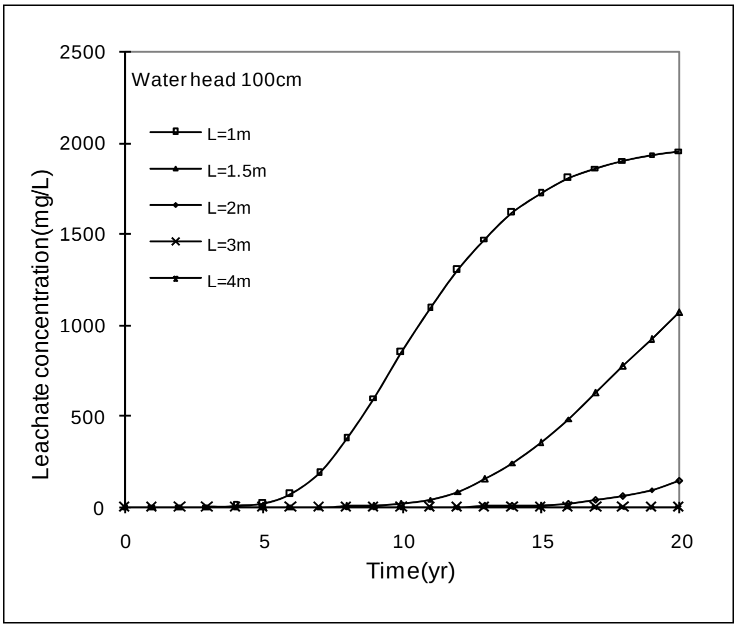

Figure 2 Variation of leachate concentration with different depth of clay liner

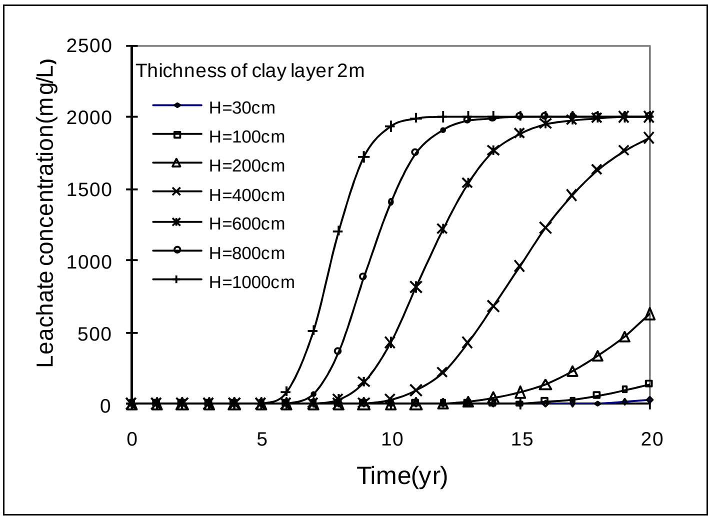

Figure 3 Variation of leachate concentration with different water head over liner

Based on the above analyses, the water head over liner has evidently influence on the selection of regulated parameters in Chinese criterion. In southern China, the rainfall is very rich and can reach 12mm/day in rainy season. Therefore, water level in landfill increases sharply during the filling-time of landfill for the absence of daily cover and clog of collection system. Some landfills, such as the Tianziling Landfill in Hangzhou, China, have the water level over liner reaching 20 meters high. From Figure 3, it can be conducted that the breakthrough time was shortened and total leaching quantity was raised with increase of water head. In addition, when the water head was larger than 2m, the relationship between total leaching quantity and water head was found as nearly a sharp straight line. Thus, the risk of high water head to around circumstance can not be neglected in landfill liner design. Though existing requirements for clay liner may be feasible in drought district in China, the impact of water head should be taken into account as supplement requirement in Chinese landfill criterion. To control the height of water head and reduce the risk of around circumstance, some technique are also necessary to strengthen the collection and drainage system in landfill and prevent rainfall and runoff infiltration into landfill. When it is difficult to control the water head in landfill, the composite liner is recommended instead of the clay liner.

CONCLUSIONS

The effect of geotechnical and geoenvironmental characteristics of clay used as landfill liner was evaluated by 1-D advection-dispersion transport model in this paper. The requirements in technical criteria and effectiveness of anti-pollutant of clay liner in landfill were analyzed under several conditions. Then some conclusions were carried out as follow:

1) High thickness and low hydraulic conductivity of clay in landfill liner were the major reasons for preventing contaminant transportation through the liner. Therefore, it is reasonable to adopt the hydraulic conductivity and the depth of clay liner as control factors for landfill liner design.

2) High water head over landfill liner will cause the advection of landfill leachate through clay liner and thus speed up the transportation of contaminant in the leachate. The limitation of the water head should be considered in the technical criteria for MSW in China.

ACKNOWLEDGMENTS

The research work described herein is supported by Shanghai Leading Academic Discipline Project (Project Number: B208).

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.475-484

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Construction and Evaluation of Sanitary Landfill Lysimeter in Bangladesh

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ABSTRACT

This paper depicts the design, construction and evaluation of sanitary landfill lysimeter test set-up at KUET campus, Khulna, Bangladesh. Three different situations of sanitary landfill were considered here. Both the aerobic and anaerobic conditions having a base liner and two different types of cap liner were simulated. After the design of reference cell, the construction of lysimeter was started in the month of January 2008 and completed in July 2008. In all construction process locally available civil construction materials were used. The Municipal Solid Waste (MSW) of 2860 to 2984kg having the total volume of 2.80m^3 (height 1.6m) and moisture content of 65% was deposited in each lysimeter by applying required compaction energy. In the laboratory, analysis was performed on the leachate samples collected periodically and several parameters were measured and monitored. In addition, both the composition and the flow rate of Landfill Gas (LFG) generated from MSW in lysimeter were measured and hence discussed.

INTRODUCTION

The most appropriate ways of managing of solid wastes are source reduction and recycling of materials but beyond that, the remaining solid wastes still have to be effectively managed with environmentally sound technologies as postulated by Alamgir et al. (2005). Numerous measures are available such as landfills, composting, anaerobic digestion, combustion or incineration, and gasification. The MSW dumps, which are common practice, are normally left uncovered, not compacted and daily cover system and there are two options for MSW dumping all over the world, one is cruded landfill (open dumping) another is sanitary landfill.

In South and South East Asia more than 90% of solid waste is disposed of in open dumps. Considering this issue, it is necessary to develop strategies to design and operate simple landfills, which are in-transition between open dumps and sanitary landfill (Visvanathan et al. 2002). To this endeavor, three lysimeters test set-up were designed and hence constructed for performance analysis of Pilot Scale Sanitary Landfill (PSSL) at Rajbandh of Khulna city, Bangladesh.

Sanitary landfill is one of the secure and safe facilities for the disposal of MSW. Lysimeter is a simulate form of sanitary landfill in the sense of control device. The word Lysimeter is a combination of the two Greek words *"Lusis" =Solution* and *"Metron" =Measure* and the original aim was to measure soil leaching as stated by Rafizul et al. (2009). To this attempt, three lysimeters test set-up were designed and hence constructed at KUET campus, to investigate the performance of both the base and cap liners. As for protection, cap and base liner made of Compacted Clay Liner (CCL) were used in Lysimeters. The base liner in terms of thickness, materials characteristics is the same as PSSL at Rajbandh of Khulna city. However, two different types of cap liners were constructed in the experimental study; one is exactly the same as PSSL, while the rest one is a simple and economic version. The deposited MSW in lysimeter was collected from Khulna city as depicted in Figure 1, similar to that of deposited in PSSL, average composition of MSW and moderate compaction density was maintained during the deposition of MSW in lysimeters. The functionality of the civil construction materials will be judged through the proper characterization of used civil construction materials and MSW, and required investigation of generated LFG and collected leachate from MSW in lysimeter.

The relative negative impacts of solid waste dumps on the environment are well known all over the world. So, it is necessary to adopt the concept of solid waste containment. It can be only achieved through the engineered designs in which a basal lining system as well as cover system that were isolated the open dump of solid wastes from the sanitary landfill. The sanitary landfill is not a well-suited method to adapt in Bangladesh as well as inadequate data and information are the basis of this study of behavioral patterns namely; leachate generation, LFG emissions etc (Visvanathan et al. 2002). In addition, the sanitary landfill lysimeter technology is complex and requires systematic approach in conducting research in this important field of study and the overall objectives were formulated as: (a) Evaluate the performance of sanitary landfill lysimeter at KUET Campus and (b) Evaluate the behavioral pattern of generated leachate and LFG emissions from MSW in lysimeter.

Figure 1 Collection of MSW from Khulna city

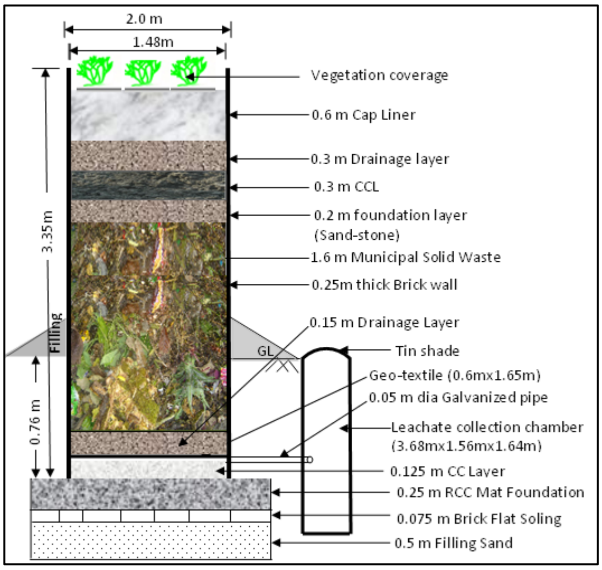

Figure 2 Schematic diagram of reference cell

DESIGN AND CONSTRUCTION OF LYSIMETER IN BANGLADESH

The detailed procedure for the design of reference cell and construction of lysimeters at KUET Campus can be obtained in the paper of Rafizul et al. (2009) and hence discussed in the followings.

Design of Reference Cell

It has been intended to construct of three lysimeters at KUET campus, a reference cell was designed. Figure 2 presents a schematic diagram of the lysimeter showing all the design components in details. In the reference cell, the MSW was deposited mainly consists of 93% of food/vegetables, 3% of plastic/polythene and 2% of leather/rubber and 2% of others. The organic content and moisture content of the deposited MSW was found as 52% and 65%, respectively, and the total volume was 2.80m^3 (height 1.6m) with a manual compaction to achieve the unit weight of 1,064kg/m^3. At the bottom of reference cell, a cement concrete layer of 125mm thick was provided then the lysimeters were filled with stone chips (dia 5-20mm) and coarse sand (dia 0.4-.05mm) to the height of 15cm of each to ensure uniform and uninterrupted drainage. The clay used as CCLs having the percentages of constituents of sand, silt and clay of 10, 56.6 and 33.4%, respectively, while, the value of optimum moisture content and maximum dry density of 18% and 16kN/m^3, respectively and the coefficient of hydraulic conductivity of 1.90x10^{-7} cm/sec.

Construction of Sanitary Landfill Lysimeters

The Lysimeter test facilities were set-up in the Geo-environmental Research Station at the backyard of Civil Engineering Building, KUET, Khulna, Bangladesh. Refer to Figure 2, as the technical details for the construction of desired three lysimeters. The three lysimeters as depicted in Figure 3, were constructed by using the brick wall of 250mm thick having outer and inner dia. of 2.0m and 1.48m, respectively, with a total height of 3.35m, resting on a 250mm thick of reinforced cement concrete mat foundation at a depth of 760mm below the existing ground surface. The lysimeters were plastered both the inner and outer sides with two coatings of waterproofing agent to avoid leakages and corrosion due to acidic environment. Further, the anaerobic lysimeters (A and B) consists of gas collection system above the MSW and leachate recirculation system below the MSW in lysimeter. At the bottom of each lysimeter, a cement concrete layer of 125mm thick was provided then the lysimeters were filled with stone chips (dia 5-20mm) and coarse sand (dia 0.4-.05mm) to the height of 15cm each to ensure proper leachate drainage. At the base of each lysimeter after placing the perforated leachate collection pipe, a geo-textile blanket having 0.60m wide and 1.65m length was placed on the top to avoid a rapid clogging of this perforated pipe by the sediments from the lysimeters. A leachate collection tank (3.68x1.56x1.64m) accommodating four separate leachate discharge pipes in the temporary collection and storage containers, were constructed using 250mm thick brick as shown in Figure 4. Brief descriptions of the constructed lysimeter of three different conditions were given in the followings.

Figure 3 Pictural view of KUET lysimeter

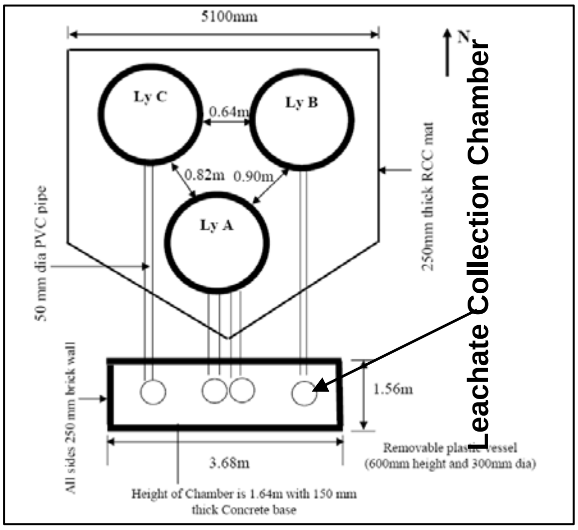

Figure 4 Layout of leachate collection chamber

Lysimeter-A (Aerobic Condition, Open Dumping)

The type and the volume of the MSW deposited in this lysimeter were same as deposited in the reference cell. A CCL of 400mm thick was prepared as the base liner and a layer of compost of 150mm thick was used in this lysimeter as the top cover to simulate the behaviour of present practice of open dumping in Bangladesh as depicted in Figure 5. At the base after placing the perforated leachate collection pipe, a geo-textile blanket having 0.60m wide and 1.65m length was placed on the top to avoid a rapid clogging of this pipe by the sediments from lysimeters.

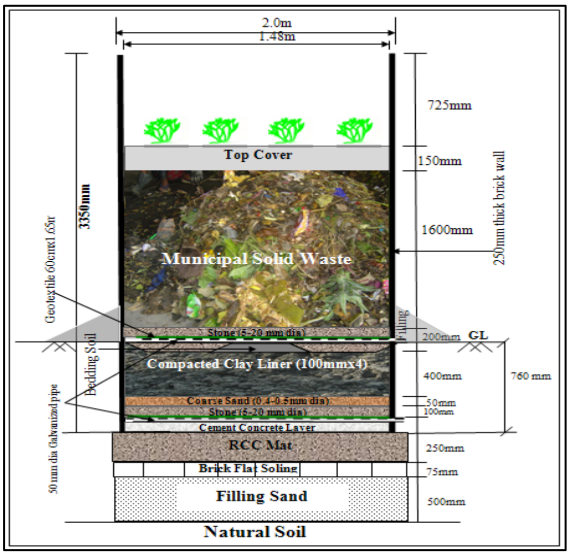

Figure 5 Schematic diagram of lysimeter-A

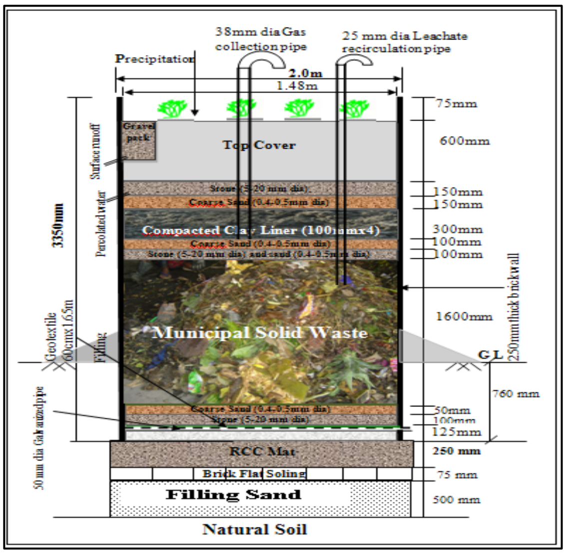

Figure 6 Schematic diagram of lysimeter-B

Lysimeter-B (Cap liner I, Anaerobic Condition)

In lysimeter-B as detailed in Figure 6, the characteristics and volume of the deposited MSW was similar to that of the lysimeter-A. However, it differs with Lysimeter-A, by a top cover similar to that of PSSL constructed at Rajbandh in Khulna, Bangladesh without having a base liner, because this cell aims to examine the applicability of the designed top cover. The top cover consists of stone chips (dia 5-20mm) and coarse sand (dia 0.4-.05mm) layer each of 100mm thickness, then a 300mm CCL was provided. On the CCL, there were 150mm of coarse sand (dia 0.4-.05mm) and 150mm of stone chips (dia 5-20mm), which was followed by 600mm thick top soil. In lysimeter-B, 38mm dia of gas collection and 25mm dia of leachate recirculation pipe were installed. During the installation of these pipes and penetration through the top cover, special arrangements i.e. disc shaped rubber gasket having 3mm thickness and 300mm dia was used for the protection of any possible leakage between the pipe and surrounding soil media as illustrated in Figure 7.

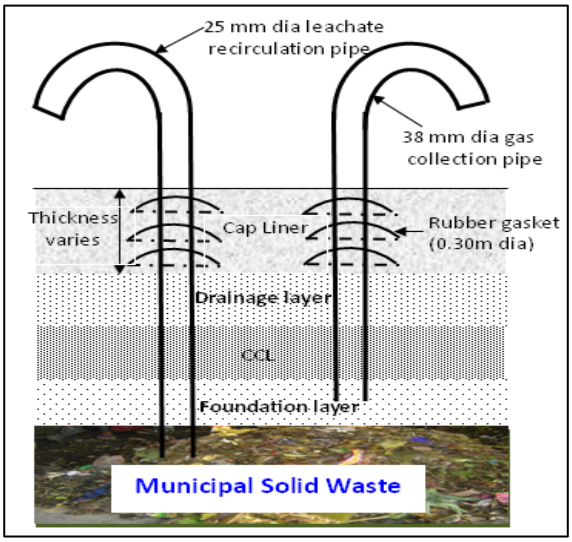

Figure 7 Gas collection and leachate recirculation system in lysimeter-B and C

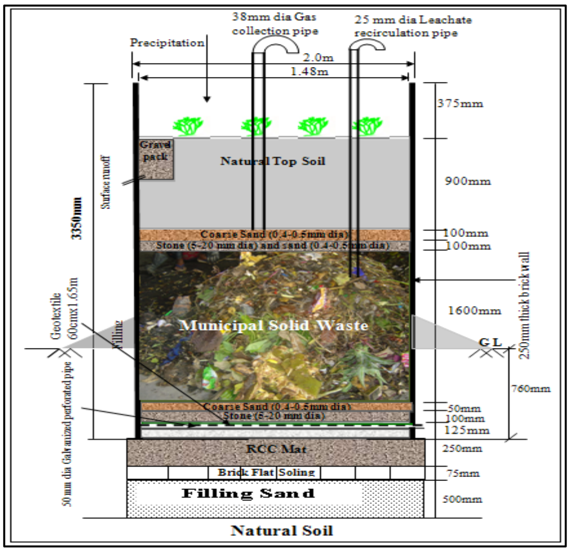

Figure 8 Schematic diagram of lysimeter-C

Lysimeter-C (Cap liner II, Anaerobic Condition)

In lysimeter-C, there was also no base liner and the top cover was different than that of the lysimeter-B. In this case no CCL was used; however, 900mm topsoil was used instead of 300mm CCL and 600mm top soil as depicted in Figure 8. But the drainage and gas collection layers remain same as the lysimeter-B. In lysimeter-C, 38mm dia of gas collection and 25mm dia of leachate recirculation pipe were installed is similar to that of lysimeter-B. Designated compaction energy was provided manually by a locally manufactured hammer similar to that of used in the PSSL, to prepare the CCL of required compactness.

CHARACTERISTICS OF MSW DEPOSITED IN LYSIMETER

The quality of generated leachate and the emissions of LFG from MSW depend preliminary on the type of MSW and the degradation of organic fraction from MSW, degree of compaction, depth of fill and the age of the MSW in landfill (Alamgir et al. 2006). In addition, the rate of leachate generation and LFG from MSW in landfill depends mainly on the precipitation and the type of surface cover. This information is enabled to formulate about the generation, accumulation, collection and finally the treatment scheme of leachate in landfill. To this attempt, the following parameters of the MSW deposited in lysimeters were determined.

Physical Composition

The quality of leachate mainly depends on the organic fraction and composition of MSW in landfill (Koener et al. 2007). The detailed methodology followed for the determination of physical composition of MSW deposited in lysimeters can be obtained in Rafizul et al. (2009). The obtained results revealed that the food and vegetable wastes was the predominant component and about 93% as depicted in Table1.

Table 1 Parameters of MSW deposited in lysimeter

Waste characteristics	Value
Fraction of Food/Vegetable waste (%)	93
Moisture content, w (%)	65
Organic content, OC (%)	52
Unit weight (kg/m^3)	1000-1064

Moisture Content

Moisture content plays an important role about the rate of decomposition of MSW and the rate of generation of leachate. Detailed procedure for the determination of moisture content of MSW in lysimeter can be obtained in Rafizul et al. (2009). The moisture content was found of 65% and these findings agree well with the statement given in a recent feasibility study (WasteSafe 2005).

Grain Size Distribution

The constituent of MSW deposited in lysimeter were determined with the use of a set of locally manufactured sieves, following the sieves opening sizes are 400, 300, 200, 100, 76.2, 38.2, 19.1, 9.52, 4.76 and 2.38mm considered as standard size (Diaz et al. 1996). Detailed procedure for the determination of constituent can be obtained in (Rafizul et al. 2009). Figure 9 represents the particle size distribution of MSW which was established by sieve analysis. The Figure 9 depicts that the average percent finer of MSW was 100% in 300 and 200mm sieve openings, whereas the values were found as 76.25, 63.72, 45.22 and 24.34% for the opening of 100, 76.2, 38.2 and 19.1mm, respectively, as well as gradually decreases for smaller sieve openings. The finding of this study agrees well with the postulation given in a recent feasibility study (WasteSafe 2005).

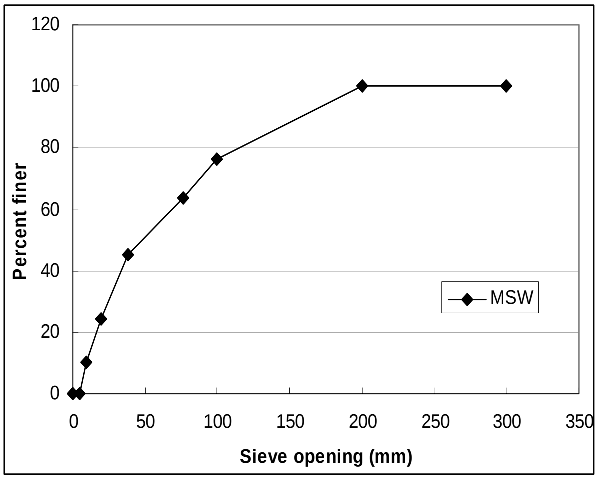

Figure 9 Particle size distribution of MSW deposited in lysimeter

Unit Weight

The unit weights were determined after the MSW deposited in lysimeter. The total weight of MSW deposited in Lysimeter A, B and C were 2860, 2984 and 2798Kg, respectively, and total volume was 2.80m^3 (height 1.6m). Details procedure for the determination of unit weight can be obtained in Rafizul et al. (2009) and the results as prersented in Table 1.

CHARACTERISTICS OF CLAY USED AS LINER IN LYSIMETER

The performance of all the geo environmental facilities such as landfill liners, covers, vertical barrier depends mainly on the basic characteristics of the soils (Daniel et al. 1995). It is therefore important to know the physical and mechanical properties of the soils as thoroughly as possible before assessing their physico-chemical or hydro-mechanical behavior. Based on these concepts, in the laboratory through standard ASTM (2004) methods, some physical and mechanical properties of clay used as CCL were determined. Based on the evaluated results, the average value of moisture content, plastic limit, liquid limit, plasticity index, and shrinkage limit were found as 22, 22, 43, 21 and 16%, respectively. In addition, the percentages of soil constituents were found as sand, silt and clay of 10, 56.6 and 33.4%, respectively as shown in Figure 12, while, the value of optimum moisture content and maximum dry density of 18% and 16kN/m^3, respectively and the coefficient of hydraulic conductivity of 1.90x10^{-7} cm/sec. The mineralogical compositions of clay used as CCL is presented in Table 2 as measured in the laboratory of the Department of Applied Geology, Karlsruhe University, Germany (Roehl 2007).

Table 2 Mineralogical compositions of clay used as CCL in lysimeter (Roehl 2007)

Minerals (amount in weight-%)		Sample (0-7m)	Sample (13-23m)
Non-clay minerals	Quartz	19%	17%
	Feldspars	<1%	<1%
	Carbonates	<1%	<1%
Non-swelling clay minerals	Illite	~50%	~50%
	Kaolinite	~10%	~10%
	Chlorite	<1%	1-2%
Swelling clay minerals: Smectite		20%	19%

Settlement Pattern of MSW Deposited in Lysimeter

Ashford et al. (2000) indicated the importance of settlement of MSW deposited in landfill. El-Fadel (1998) stated that the rate of settlement of the MSW deposited in landfill depends primarily on the refuse composition, operational practices and the factors affecting biodegradation of MSW in landfill was particularly moisture content. In this study, irregular characteristics of the settlement of MSW deposited in lysimeter having three different situations were observed. The Figure 10 summarizes the settlement rate of MSW deposited, observed in the lysimeters during the experimental period. Here it can be noted that lysimeter-B, with highest compaction density of an extra CCL had, the lowest settlement, indicating the importance of pre-treatment of MSW prior to landfilling. Whereas, lower compaction in lysimeter-C has resulted in the highest primary settlement than that of lysimeter-B. In addition, in absence of compaction effort or CCL in lysimeter-A has resulted in the highest primary settlement than that of lysimeter-B and C.

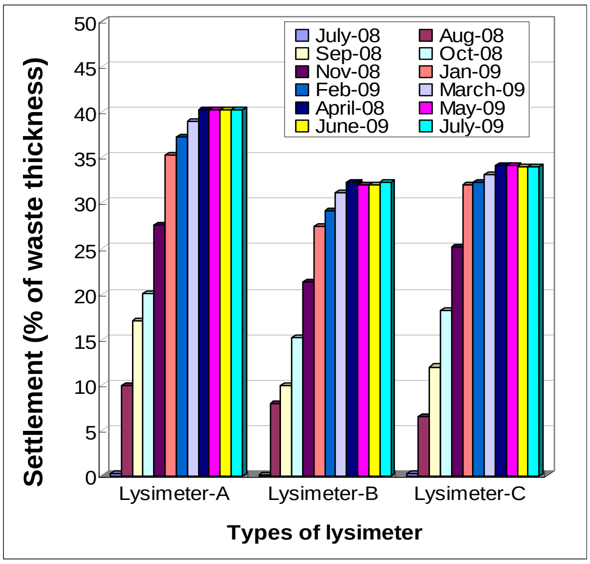

Figure 10 Settlement patterns of MSW in lysimeters

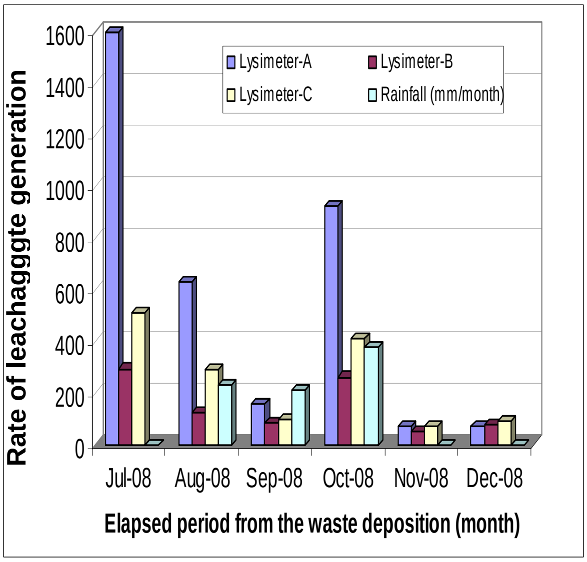

Figure 11 Generation of leachate of lysimeters

Rate of Leachate Generation from MWS in Lysimeters

Figure 11 summarises the cumulative leachate production rate in the lysimeters during the study period. Based on the leachate generation, the experimental observation period could be divided into different month of the year in which observation were taken place. It was observed that in the month of July 2009, although the amount of rainfall was negligible but due to the moisture content in the lysimeters (above the field capacity), leachate was continuously generated. In the month of August-

September 2008, due to a prolonged dry and hot climate during which no notable leachate generation occurred. During this experimental period although three significant rainfall events occurred on the 19 and 26 August and 27 September, there was no significant effect on the leachate production implying the lysimeters were operated well below the field capacity. In the month of October 2008, during this experimental period, the rainfall events occurred with the highest amount than the other experimental period, then the leachate generation rate was found as higher than that of previous phase. In the month of Nov-Dec 2008, during this experimental period, the rainfall events occurred with the lower amount throughout the experimental period and the leachate generation rate was found as very lower than that of other phases.

However, it is interesting to note that leachate generation rate changes rapidly in lysimeter-A during the full rainy season in October, where the top cover design selection played an important role. The cover design consists of only 150mm thick of compost, which was loose texture media. Here without a CCL, rain water rapidly infiltrated into the lysimeter compared to other cap liner types. In addition, the Figure 8 depicts that, the rate of leachate generation in case of lysimeter-A was found as higher than that of other two lysimeters because lysimeter-A consists of 150mm thick loose top cover of compost materials which leads to excessive moisture within the cell followed by rapid biodegradation and leachate generation. On the other hand, lysimeter-B and C display almost similar rate of leachate generation due to followed of almost similar design configuration of cap liner.

METHODOLOGY OF THIS STUDY

In the laboratory, analysis was performed on the leachate samples collected periodically and several parameters were measured and monitored. In addition, the composition of LFG emissions from MSW in lysimeter-B and C were measured by using the Infra-red gas analyzer that was borrowed from Bauhaus University Weimar, Germany as depicted in Figure 12. Also the flow rate of gas in m^3/minutes from MSW deposited in lysimeter-B were measured by using the flow meter device (G2.5) as shown in Figure 13 that was procured from Titas Gas Transmission and Distribution Company Limited, Dhaka, Bangladesh. To record the total daily rainfall, an Automatic Rain Gauge was installed in the CE Building which is very close to the test set-up.

Figure 12 Infra-red gas analyzer

Figure 13 Flow meter device

RESULTS AND DISCUSSIONS

The experimental results on the leachate samples obtained from laboratory investigations were presented in Table 3 and the variation of different parameters of leachate from detection system of lysimeter-A, and collection system of lysimeter-A, B and C were presented. In addition, the composition and production rate of LFG emissions from MSW in lysimeter also described in the followings.

Characterization of Leachate Samples

After the deposition of MSW and the completion of the lysimeter test setup to examine three different situations of landfill, the leachate samples were collected in regular interval. The collected samples were tested in the laboratory and hence analyzed. The variation of one parameter among them such as Total Dissolve Solid (TDS) with the varying of elapsed period of waste deposition in case of collection system of lysimeter-A, B and C as inlustrated in Figure 14. The detailed illustrated on the concentration of TDS can be obtained in Rafizul et al. (2009) and hence discussed in following.

Table 3 Characteristics of leachate generated from MSW in Lysimeter

Parameter	Lysimeter-A (leachate detection)	Lysimeter-A (leachate collection)	Lysimeter-B (leachate collection)	Lysimeter-C (leachate collection)
pH	6.38-8.47 (7.43)	5.88-8.75 (7.32)	7.38-8.43 (7.91)	6.33-8.49 (7.41)
Iron (mg/L)	0.2-12.06 (6.04)	0-52.10 (26.05)	0.5-12.40 (6.45)	0.0-72.0 (36.00)
Alkalinity (mg/L)	400-5,550 (2,975)	237-10,000 (5,118.5)	1111.2-8,000 (4,555.6)	2278-9,000 (5,639)
Hardness (mg/L)	370-3,084 (1,727)	463-10,000 (5,232)	324-10,000 (5,162)	324-10,000 (5,162)
COD (mg/L)	160-20,800 (10,480)	1,440-60,000 (30,720)	800-60,000 (30,400)	1,280-60,000 (30,640)
TDS (mg/L)	3,670-10,000 (6,835)	5,810-29,980 (17,895)	4,820-26,000 (15,410)	5,380-35,810 (20,596)

Range is given for maximum, minimum values, while the value of parenthesis indicates the mean values

Variation of Total Dissolved Solid (TDS)

The variation of TDS in leachate with the varying of elapsed period of waste deposition in case of collection system of lysimeter-A, B and C as depicted in Figure 14. This figure reveals that the values of TDS was significantly decreased in the range of 29980 to 5810mg/L, 26000 to 4820mg/L and 35810 to 5380mg/L for collection system of lysimeter-A, B and C, repectively, up to the waste deposition period of 17weeks and then it was increased upto the period of 23weeks for both the cases. Diaz (1996) introduced that the values of TDS varied from 0 to 42,276mg/L of leachate generated from MSW in landfill. In case of present study, the concentration of TDS varied from 4820 to 35,810mg/L and the maximum concentration was found in lysimeter-C of 35,810mg/L. The variation of the values of TDS due to the difference of three lysimeters in terms of base liner as well as cap liner and compaction condition. In general, the TDS values presents in the water less than 500 mg/L are the most pleasing for domestic use. The maximum allowable concentration of TDS for water supply is 1500 mg/L according to WHO standard. The TDS values are affected by the natural seasons especially during rainy seasons due to the dilution.

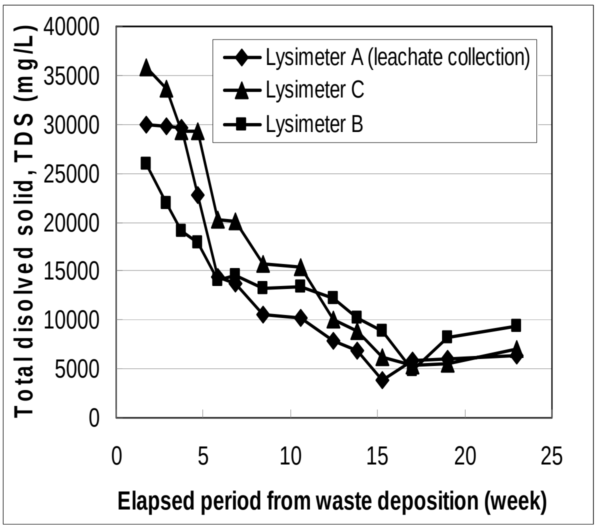

Figure 14 Variation of TDS in leachate from collection system of lysimeter-A, B and C

Composition of LFG Generated from MSW in Lysimeter-B

The Figure 15 illustrates the composition of LFG over a certain period of decomposition of organic fraction of MSW placed in Lysimeter-B. This figure reveals that the value of CH_4 changes in the range of 45.7 to 59.1%, from the deposition period of 3 to 60 days and then reduced to 58.3 to 21.8% from the deposition period of 60 to 150 days. In addition, the value of CO_2 varies from 25.7 to 35.9% from the deposition period of 3 to 60 days and then reduced to 33.3 to 15.1 % from the deposition period of 60 to 150 days. The value of O_2 varies in the range of 0 to 16.3% from the deposition period of 3 to 150 days. From the figure it can be recognized that there is a clear increasing tends of LFG composition as a liner variation with the increase of elapsed period up to a certain stage and then decreased. Typically, the composition of LFG is in the order of 40 to 60% of CH_4, 40 to 50% of CO_2 and 1% of O_2 (Tchobanoglous and Vigil, 1993). The finding of this study agrees well with the postulation given by Tchobanoglous et al. (1993).

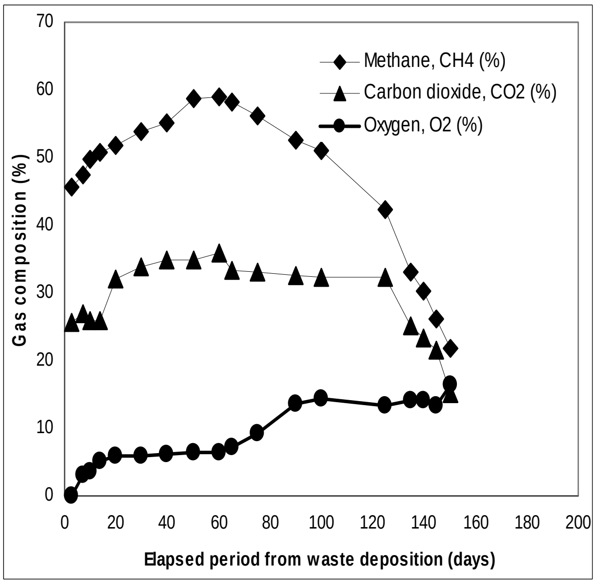

Figure 15 Composition of LFG in Lysimeter-B

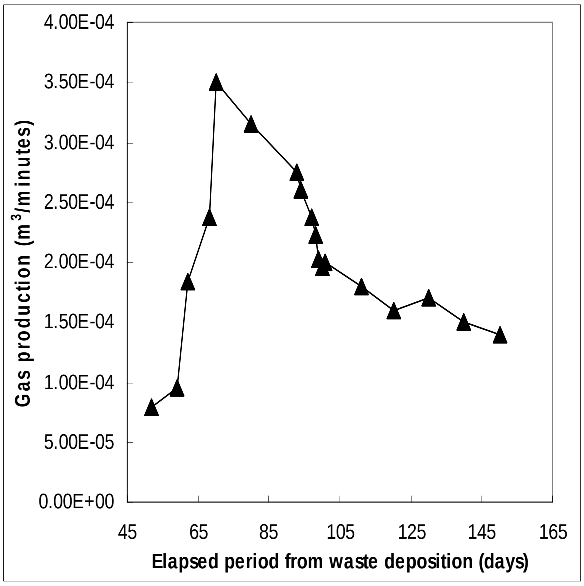

Figure16 Production rate of LFG in Lysimeter-B

Production Rate of LFG Generated from MSW in Lysimeter-B

The rate of LFG production over a certain elapsed period from the decomposition of organic fraction of MSW placed in Lysimeter-B as depicted in Figure 16. The Figure 8 depicts that the ranges of LFG production vary from $0.08x10^{-3}$ to $0.35x10^{-3}m^3$/minutes from the deposition period of 52 to 70 days and then reduced to $0.32x10^{-3}$ to $0.14x10^{-3}m^3$/minutes from the deposition period from 80 to 150 days. From the figure it can be perceived that there is a definite increasing trend of LFG production up to the elapsed deposition period of 70 days and then decreased. The rate of decomposition of MSW, as measured by LFG production, reaches a peak within the first two years and then slowly tapers off, up to the period of more than 25 years (Tchobanoglous and Vigil, 1993). The variation rate of LFG production for decomposition of organic fraction in MSW of the rapidly (5 years or less- some highly biodegradation wastes within days of being placed in landfill) and slowly (5 to 50 years) biodegradation organic fraction in MSW. Tchobanoglous et al. (1993) suggested that the rate of LFG production reaches to the peak at 1 and 5 years for rapidly and slowly decomposable material in MSW, respectively. This statement proved that rate of LFG production is increased up to a certain elapsed period of waste placed in a landfill and then decreased, which agrees well with the findings of this study. However, the time difference is very far between these studies and reported by Tchobanoglous et al. (1993).

CONCLUSIONS

Three sanitary landfill lysimeters were designed and hence constructed at KUET, Khulna, for the performance analysis of locally available civil construction materials used for the construction of both the base and cap liners of sanitary landfill in Bangladesh. Designated compaction energy was provided manually by a locally manufactured hammer similar to that of used in the Pilot Scale Sanitary Landfill (PSSL) at Rajbandh of Khulna city in Bangladesh, to prepare the CCL of required compactness. The base liner in terms of thickness, material characteristics is the same as PSSL. However, two different types of cap liners were constructed in the experimental study; one is exactly the same as PSSL, while the rest one is a simple and economic version. These field scale lysimeter studies revealed that the rapid leachate productions in open dumping cell of lysimeter-A than that of the other two, indicates the importance of the barrier layer and the cover materials selection in landfill design. In addition, the experimental findings in terms of LFG as well as leachate generation and its concentration at different situations of lysimeter agrees well with the postulation given by various researchers.

ACKNOWLEDGEMENT

The authors gratefully acknowledged the financial support provided by European Commission through the project of EU- Asia Pro Eco II Programme (ASIE/2006/122-432).

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.485-493

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Laboratory Investigations and Small Scale Biological Treatment of Leachate

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ABSTRACT

This paper reveals the analysis of relevant parameters of leachate samples collected from the leachate collection chamber of lysimeter at KUET campus, Khulna that was analyzed in the laboratory and biological treatment context. The adopted biological treatment make a "biological treatment friendly" condition and then to investigate the consequences of the different treatments against control system. This study demonstrated that leachate is one of the major problems to overcome in managing the landfill and treatment has become common practice in order to prevent environmental pollution. To this attempt, treatment that has low cost, need less maintenance and environmental friendly was the target on how to treat the leachate. This study has been tried to treat leachate by locally available aquatic reactor that does not require any expensive cost. The evaluated results reveals that the parameters of leachate were varied significantly for the different condition of construction materials used as cap and base liner in lysimeter as well as the adopted biological treatment were more effective when the concentration of leachate was low and no single treatment showing the better performance for the removal of all parameters.

INTRODUCTION

The Municipal Solid Waste (MSW) refers to the materials discarded in the urban areas for which municipalities are held responsible for collection, transport and final disposal (Alamgir et al. 2005). The management tier of MSW mainly prominence on waste generation, source storage and segregation, collection, transport and finally the ultimate disposal site. There are two options for MSW dumping all over the world; one is open dumping another is sanitary landfill (WasteSafe 2005).

Sanitary landfill is one of the secure and safe facilities for the disposal of MSW. Lysimeter is a simulate form of sanitary landfill. To quantify the leachate generated from MSW in landfill, a control mechanism is needed where it is accumulated and then collected properly. Based on this concept and to investigate the performance of both the base and cap liners made of Compacted Clay Liner (CCL), three lysimeter (designated as A, B and C) as a control mechanism test set-ups were designed and hence constructed at KUET campus, Khulna, Bangladesh. This three cylindrical lysimeter had been connected by a leachate collection tank (3.68x1.56x1.64m), accommodating four separate leachate discharge pipes in the temporary collection and storage containers, were constructed using 250mm thick brick wall resting on a 250mm thick of reinforced cement concrete mat foundation at a depth of 760mm below the existing ground surface.

The functionality of locally available construction materials will be judged through the proper characterization of used materials and MSW, and required investigation on the collected leachate from MSW in lysimeter. A MSW landfill can be conceptualized as a biochemical reactor with MSW and water as the major inputs and with landfill gas and leachate as the principal outputs (Tchobanoglous and Vigil 1993). The characteristics of leachate in case of MSW of Bangladesh as obtained in the ultimate open disposal sites at six major cities of Bangladesh was reported earlier by WasteSafe (2005) and also Alamgir et al. (2006). The collection and treatment of leachate have become common practice in order to prevent environmental pollution (Rafizul et al. 2009). To this attempt, treatment that low cost, need less maintenance and environmental friendly are the target on how to treat the leachate. This study has been tried to treat leachate by locally available aquatic reactor of preconditioned samples that does not require any expensive cost. From the findings it was observed that the characteristics of lysimeter leachate influenced significantly for different cap liner systems and the presence of CCLs as well as by applying the different biological treatment system and conditioning of leachate, the parameters was significantly changed against the control system.

SANITARY LANDFILL LYSIMETERS AT KUET CAMPUS

Three cylindrical lysimeter as depicted in Figure 1, were designed and hence constructed having outer dia of 2.0m and inner dia of 1.48m, with a height of 3.35m, and a leachate collection tank (3.68x1.56x1.64m), accommodating four separate leachate discharge pipes in the temporary collection and storage containers, were constructed using 250mm thick brick wall resting on a 250mm thick of reinforced cement concrete mat foundation at a dept of 760mm below the existing ground surface. The lysimeter were plastered inside and outside with two coatings of waterproofing agent to avoid leakage and corrosion due to acidic environment. However, the detailed descriptions about the three lysimeters of A, B and C at KUET campus can be obtained in the companion paper of Rafizul et al. (2009a) and Rafizul et al. (2009b).

Figure 1 Pictorial view of lysimeter at KUET

LABORATORY ANALYSIS OF LEACHATE SAMPLES

After the deposition of MSW and the completion of the lysimeter test setup to examine three different situations of landfill, the leachate samples were collected in regular interval. Moreover, for laboratory investigations; various chemical tests were performed on the collected leachate samples as presented in Table 1 and hence discussed in the following sections. More investigations on leachate samples were also published earlier in Rafizul et al. (2009b).

Table 1 Characteristics of leachate generated from MSW in Lysimeter

Parameter	Lysimeter-A (leachate detection)	Lysimeter-A (leachate collection)	Lysimeter-B (leachate collection)	Lysimeter-C (leachate collection)
pH	6.18-8.47 (7.33)	6.03-8.75 (7.39)	6.40-8.61 (7.51)	6.33-8.73 (7.53)
Iron (mg/L)	0-12.20 (6.10)	0-52.10 (26.05)	0.5-16.10 (8.30)	0.0-72.0 (36.00)
TDS (mg/L)	210-10,000 (5,105)	3,830-29,980 (16,905)	8,210-26,000 (17,105)	4,990-35,810 (20,400)
Hardness (mg/L)	129.8-3,241 (1,685.4)	1064.9-10,000 (5,532.5)	1200-14,000 (7,600)	1,096-10,000 (5,548)
COD (mg/L)	160-20,800 (10,480)	320-60,000 (30,160)	800-60,000 (30,200)	1,280-60,000 (30,150)
Chloride (mg/L)	75.0-1015.0 (545.0)	50.0-2778 (1414.0)	770.0-2500 (1635.0)	350-3000 (1675.0)

Range is given for the maximum, minimum values, while the value of parenthesis indicates the mean values.

Variation of pH

The variation of pH in leachate with the increase of elapsed period of waste deposion for detection and collection systems of lysimeter-A as depicted in Figure 2. Based on the figure it can be noted that in case of detection system, the values of pH in leachate was higher of 8.47 than that of collection system of 7.86 up to the waste deposition period of 6weeks then in case of detection system the pH values gradually decreased, while, for collection system the value rised upto 13weeks of 8.75, then gradually decreased up to the waste deposition period of 60weeks. The figure also reveals that the after the waste deposition period of 13weeks, the decreasing trend of pH in case of collection system lies above the detection systyem of lysimeter-A. Diaz (1996) introduced that the values of pH varied from 2.7 to 8.75 of leachate generated from MSW deposited in landfill. In case of present study, the values of pH in leachate were varied from 6.18 to 8.75 and the maximum concentration was found for collection system of lysimete-A of 8.75. The variation of pH values for both the cases due to the applicability of CCL of 400mm thick as a barrier between detection and collection system of lysimeter-A. The pH basically the buffering capacity of CO_3-H-CO_3 system in water. The pH of leachate influences chemical and biological process of precipitation, sorption and methanogenesis. The pH rised when the microorganisms utilize the carbonates in the water, while the decompositon of organic pollutants causes pH to drop the acidic range.

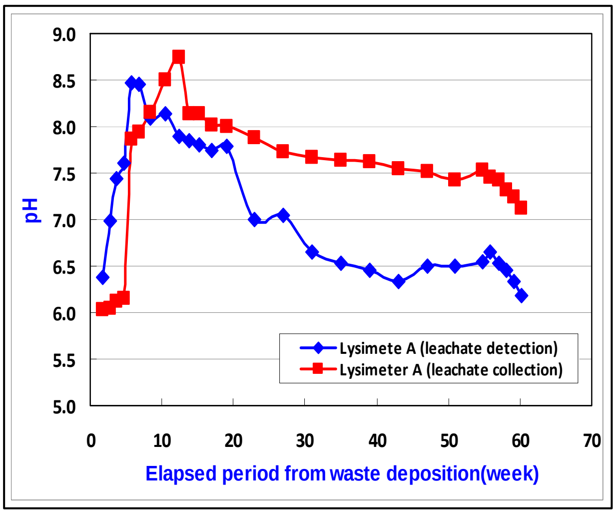

Figure 2 Variation of pH in leachate from detection and collection system of lysimeter-A

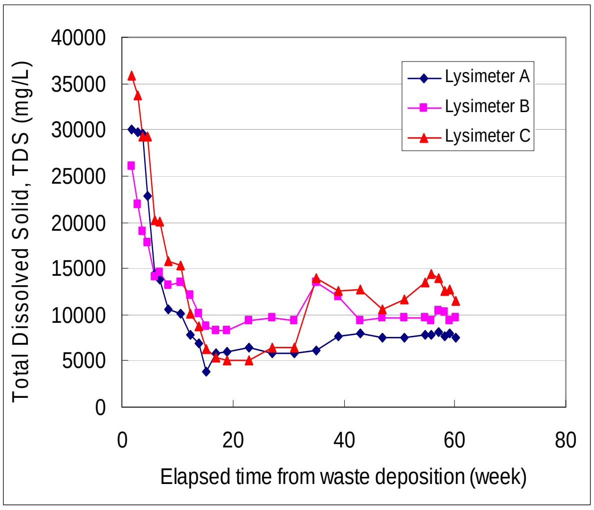

Figure 3 Variation of TDS in leachate from collection system of lysimeter-A, B and C

Variation of Total Dissolved Solid (TDS)

The relationship of TDS with the elapsed period of waste deposition in lysimeters as illustrates in Figure 3 for the collection system of lysimete-A, B and C. This figure reveals that the values of TDS decresed sharply with the increses of waste deposition period of 8weeks and showing the almost similar decreasing trend for both the cases. The figure also depicts that after the waste deposition period of 8weeks, the values of TDS increased with the increases of waste deposition period up to 60weeks for both the cases. Based on the figure, it was observed that in case of lysimeter-A, the values of TDS has changed significantly in the range of 3830 to 29980mg/L and for lysimeter-B of 8800 to 26,000mg/L and for the increase of waste deposition period from 2 to 15weeks. Here, it can be noted that for all the cases, the values of TDS decreased with the increases of elapsed period and the rate of decrease was found as steeper up to the elapsed period of 8weeks and then the rate of increase was flatter in between the elapsed period of 8 to 60weeks and the finding was in good conformity with the general performance of TDS versus elapsed period from waste deposition. The TDS in leachate depends not only on elapsed period from the waste deposition but also the types, applicability and compactness of base and cap liner. Due to the influence of the above factors, the magnitudes of TDS in case of lysimeter-C, was higher than that of lysimeter-B and C up to the waste deposition period of 60weeks although the trend is similar. In addition, although both the ysimeter-B and C were in anaerobic condition but the variation of TDS due to the difference of lysimeter-B and C in terms of thickness and compaction conditions of cap liner. Diaz (1996) introduced that the values of TDS varied from 0 to 42,276mg/L of leachate generated from MSW in landfill. In case of present study, the concentration of TDS varied from 3,830 to 35,810mg/L and the maximum concentration was found in lysimeter-C of 35,810mg/L. The variation of TDS due to the difference of three lysimeters in terms of base liner as well as cap liner and compaction condition. In general, the TDS values presents in the water less than 500 mg/L are the most pleasing for domestic use. The maximum allowable concentration of TDS for water supply is 1500 mg/L according to WHO standard. The TDS values are affected by the natural seasons especially during rainy seasons due to the dilution.

Variation of Iron Concentration

Figure 4 illustrates the variation of Iron concentration in leachate with the varying elapsed period of waste deposition in case of collection system of lysimeter-B and C. Here, it can be noted that the values of Iron in leachate in case of lysimeter-C was found as 72.0mg/L which was higher than that of lysimeter-B of 11.2mg/L at the deposition period of 2weeks, then sharply decreased up to the period of 9 weeks for both the cases. The figure also depicts that after the period of 9weeks, the concentration of Iron was increased up to the elapsed period of 10weeks then also decreased up to the period of 47weeks for both the cases and then also increases. From the figure, it can be observed that in case of lysimeter-C, the concentration of Iron has changed significantly in the range of 72.0 to 3.33mg/L and for lysimeter-B of 11.2 to 2.22mg/L for the increase of waste deposition period from 2 to 4weeks. Diaz (1996) introduced that the values of Iron varied from 0.20 to 5,500mg/L of leachate generated from MSW in landfill. In case of present study, the concentration of Iron varied from 0.0 to 72.0mg/L and the maximum concentration was found in lysimeter-C of 72.0mg/L. The variation Iron due to the difference of lysimeter-B and C in terms of thickness and compaction conditions of cap liner. The rate of Iron oxidation at the pH level below 6.0 is increased by the presence of certain inorganic catalysts of through the action of micro-organisms. Iron also imparts a test to water, which is detectable at very low concentrations.

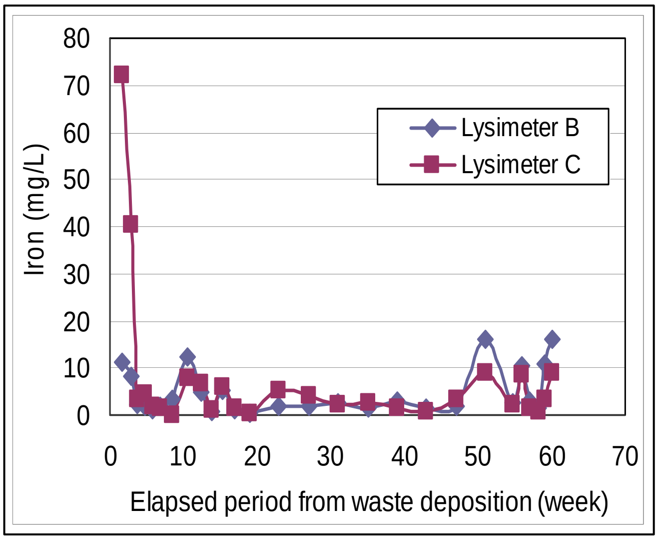

Figure 4 Variation of Iron in leachate from collection systems of lysimeter-B and C

Variation of Chemical Oxygen Demand (COD) concentration

Figure 5 illustrates the variation of COD concentration in leachate with the varying elapsed period of waste deposition from collection system of lysimeter-A and B. The figure reveals that up to the elapsed period of 60weeks, the concentration of COD in leachate was significantly decreased in the range of 60,000 to 320mg/L and 60,000 to 400mg/L for lysimeter-A and B, repectively. The figure also depicts that the concentration of COD was decreased sharply with the increases of elapsed period up to 6weeks. In addition, for both the cases almost similar non-linear decreasing trend of COD concentration with the increase of elapsed period was also observed. Diaz (1996) introduced that the concentration of COD varied from 0 to 89,520mg/L of leachate generated from MSW in landfill. In case of present study, the concentration of COD in leachate varied from 160 to 60,000mg/L for both the lysimeters. The COD is the measure of oxygen equivalent to the portion of organic matter that is susceptible to oxidation by Potassium Dichromate. COD is an important test and gives a quick measurement of pollution load of the leachate. According to Bangladesh standard the COD value in water must be less than 4 mg/L.

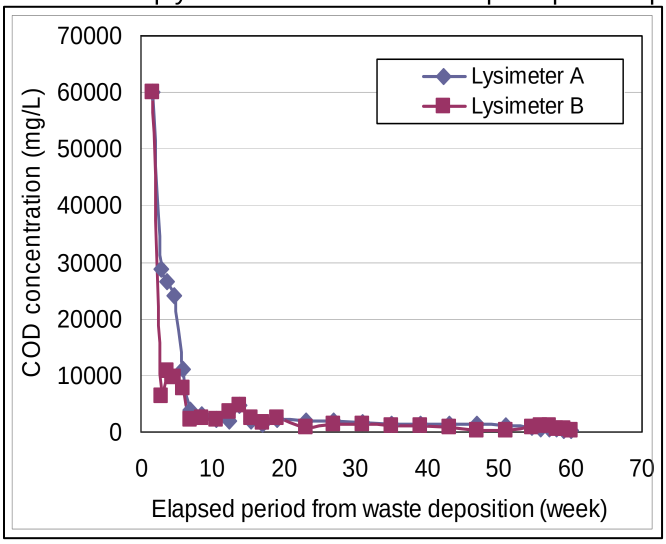

Figure 5 Variation of COD in leachate from collection system of Lysimeter-A and B

Variation of Hardness

The variation of Hardness in leachate with increase of elapsed period of waste deposition from collection system of lysimeter-A, B and C as depicted in Figure 6. This figure reveals that the values of Hardness in leachate was significantly decreased in the range of 10,000 to 2222mg/L, 14,000 to 2408mg/L and 10,000 to 2315mg/L for lysimeter-A, B and C, repectively, up to the deposition period of

9weeks and then it was increased upto the waste deposition period of 60weeks for both the cases. Diaz (1996) introduced that the values of Hardness varied from 0 to 22,800mg/L of leachate generated from MSW in landfill. In case of present study, Hardness varied from 1064.9 to 14,000mg/L. Hardness is defined as the concentration of multivalent metallic cations in solution. The multivalent metallic ions most abundant in waters are calcium and magnesium. Soap consumption by hard waters represents an economic loss to the water user. The precipitate formed by hardness and soap adheres to surfaces of tubs, skins, and dishwashers and may stain clothing, dishes, and other items.

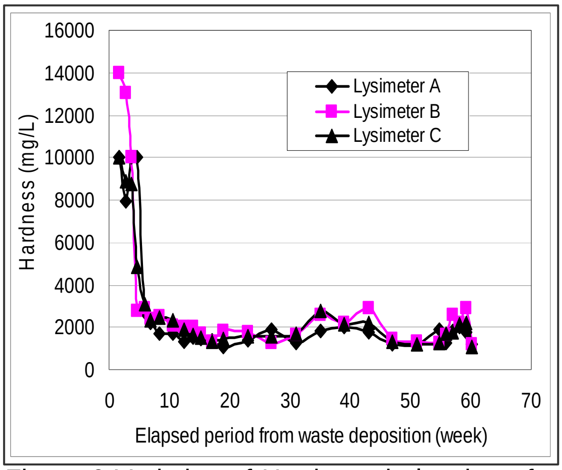

Figure 6 Variation of Hardness in leachate for collection system of lysimeter-A, B and C

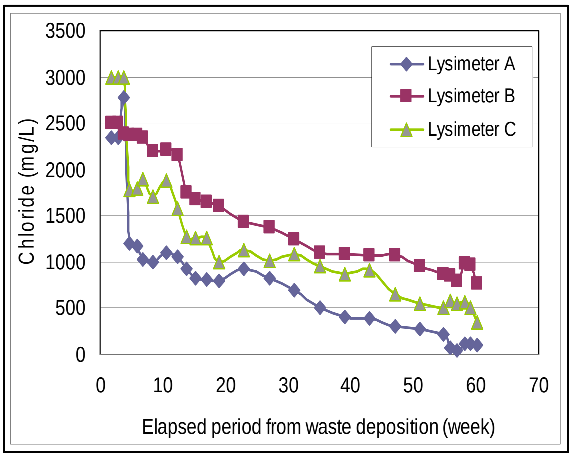

Figure 7 Variation of Chloride in leachate for collection system of lysimeter-A, B and C

Variation of Chloride

The variation of Chloride in leachate with increase of elapsed period of waste deposition from collection system of lysimeter-A, B and C as depicted in Figure 7. This figure reveals that the values of Chloride in leachate was significantly decreased in the range of 2778 to 50mg/L, 2500 to 770mg/L and 3000 to 350mg/L for lysimeter-A, B and C, repectively, up to the deposition period of 60weeks. Diaz (1996) introduced that the values of Chloride varied from 34 to 2,800mg/L of leachate generated from MSW in landfill. In case of present study, Chloride varied from 50 to 3,000mg/L and maximum values was found in case of lysimeter-C of 3000mg/L. Chloride in reasonable concentrations is not harmful to human. In many areas of the world where water supplies are scare, source containing as much as 2,000 mg/L are used for domestic purposes without the development of adverse effects. Before the development of bacteriological testing procedures, chemical test of chloride and its various forms serves as the basis or detecting contamination of groundwater through wastewater.

BIOLOGICAL TREATMENT SYSTEMS OF LEACHATE

In the pilot scale treatment scheme, the adopted biological treatment through aquatic reactors by Duckweed *(Lemna minor),* Snail (*Pila globasa*), Helencha (*Enhydra fluctuans*) and Topapana (*Pistia stratiotes*) was carried out as shown in Figure 8.

This study mainly focused on the ability of some of the natural biological treatment systems available in Bangladesh, in removing nutrients in leachate and also dealed about the control system. The volume of the bucket that was used for biological treatment of leachate of 32 liters. During the treatment period, the bucket was placed in the laboratory in room temperature. For laboratory investigations, leachate samples at varying concentrated were prepared through the dilution of raw leachate with tap water. At such stage, the prepared 100 concentrations of leachate means 100% of raw leachate was used and 50 concentration means 50% of tap water was mixed with 50% of raw leachate. Similarly 20 concentration of Leachate means 80% of tap water was mixed with 20% of raw leachate. In addition, the leachate samples subsequent to pre-treatment through different aquatic reactors were analyzed based on the elapsed period from the treatment, leachate concentration (conditioning system) and removal efficiency and hence discussed in the following sections.

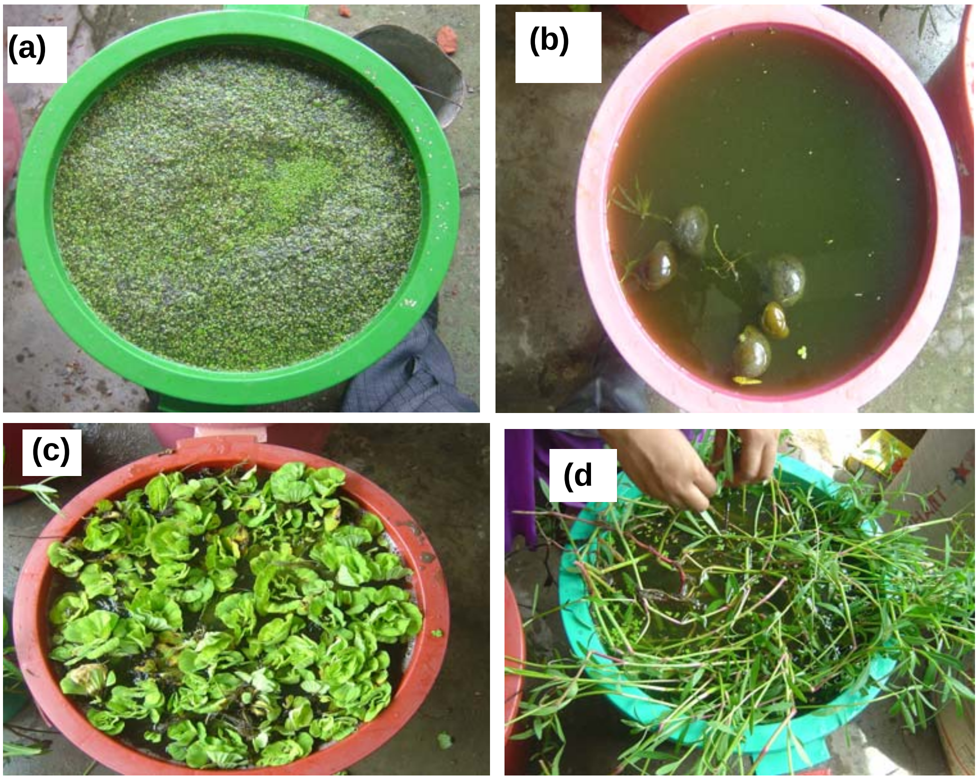

Figure 8 Different adopted biological treatment systems (a) Duckweed *(Lemna minor),* (b) Snail (*Pila globasa)*, (c) Topapana (*Pistia stratiotes*) and (d) Helencha (*Enhydra fluctuans*)

Effect on pH of the Leachate

The Figure 9 illustrates the variation of values of pH with the increase of elapsed period from the treatment; to investigate the consequence of the different adopted biological treatment systems by Duckweed, Snail, Topapana and Helencha. Based on figure, it can be noted that, the values of pH decreased with the increases of elapsed period from the treatment up to 10weeks for all the treatment systems. The figure also depicts that all the treatment systems provides the lower values of pH against of control system and the removal efficiency was found as positive for all the cases. Moreover, the removal efficiency of Snail was higher than that of other treatment systems. This figure also reveals that almost similar decreasing trend with increases of elapsed period was observed for both the treatment systems. Diaz (1996) introduced that pH is the logarithmic hydrogen concentration of any liquid. Generally the pH value depends on temperature, amount of hydrogen ion etc. and it increases with the increase of hydrogen ion and the liquid becomes acidic.

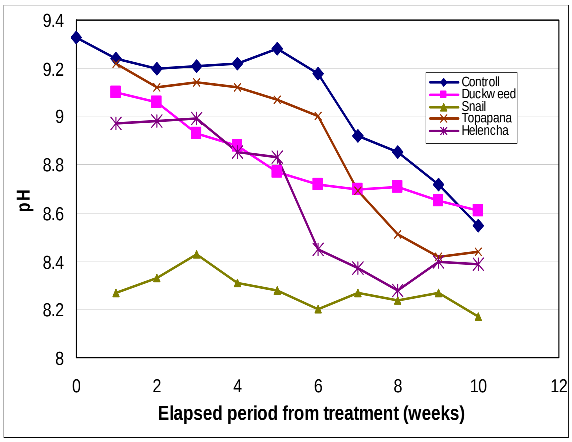

Figure 9 Variation of pH among the different treatment of 100 concentration of lecahate

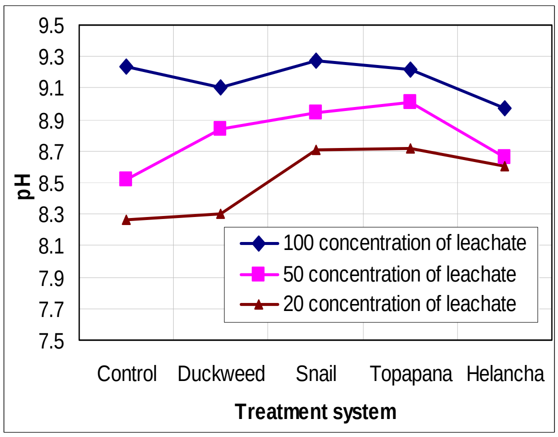

Figure 10 Comparison of pH among different treatment system after 1week

However, the variation of pH values at the different adopted biological treatment systems of 100, 50 and 20 concentration of leachate as depicted in Figure 10. From the figure it was observed that the values of pH fall down with the decreases of concentration of raw leachate by applying conditioning system. Moreover, the trend of 100 concentration of leachate sample having more values of pH than that of other two concentrated leachate samples. Here, it can be noted that the performance of remove of COD concentration for all the treatment systems was more in case of 100 concentration of leachate against other two concentrated samples. Diaz (1996) introduced that preparation of samples is thus of prerequisite, such as dilution factor becomes effective to enhance the further treatment to some extent. It is evident from that the more dilution condition of the leachate the more enhance to the treatment capability for biological components and having more pH concentrations. The findings of this study agree well with the postulation given by Diaz (1996).

Effect on Chemical Oxygen Demand (COD) of the Leachate

The variation of the concentration of COD of 100 concentration of leachate varies with the increase of the elapsed period from the treatment systems of Duckweed, Snail Topapana and Helencha up to the elapsed period of 10weeks as depicted in Figure 11. This figure reveals that the value of COD decreased up to the elapsed period of 10weeks for the entire treatment system and showing almost similar decreasing trend for all the treatment systems. In addition, the concentration of COD in case of control system was found as higher than that of the subjected treatment systems. Here, it can be noted that all the treatment systems showing positive and very efficient performance for the removal of COD concentration. COD is the measure of oxygen consumed during the oxidation of the oxidizable organic matter by a strong oxidizing agent. The determinations of COD are of great importance where BOD values can not be determined accurately due to the presence of toxins and unfavorable conditions for growth of microorganism. The COD test remains a very important parameter in management and design of treatment plants because of its rapidity in determination.

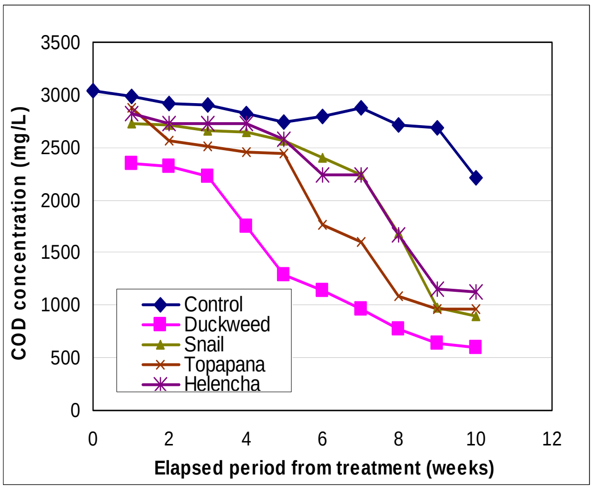

Figure 11 Variation of COD among the different treatment of 100 concentration of leachate

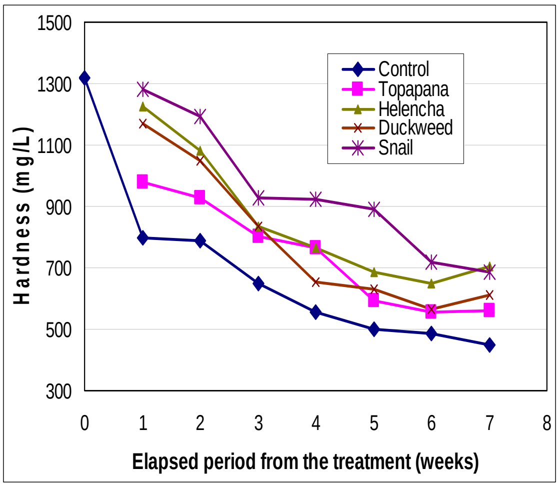

Figure 12 Variation of Hardness among different treatment for 20 concentration of leachate

Effect on Hardness of the Lecahate

The different biological treatment systems for 20 concentartion of leachate of the values of Hardness as depicted in Figure of 12. The Figure 12 depicts that the value of Hardness varies with the increases of the elapsed period for the treatment systems of Control, Topapana, Helencha, Duckweed and Snail up to the elapsed period of 7weeks. The figure also depicts that the value of Hardness decreased sharply up to the elapsed period of 7weeks for all the treatment system and showing the almost similar decreasing trend for both the treatment systems. The figure also shows that the values of Hardness for all the treatment system lies above the control system and also showing negative performance to reduce the values of Hardness with respect to control system.

COMPARISON OF ADOPTED BIOLOGICAL TREATMENT SYSTEMS

The percentage of removal efficiency of different biological treatment systems based on the elapsed period from the treatment was analyzed and hence discussed in the following sections.

Removal of Total Dissolved Solid (TDS)

The removal efficiency of the values of TDS was ranging from 13.19 to 66.35% for the different adopted biological treatment after the elapsed period of 7weeks from the treatment for 50 concentration of leachate as illustrates in Figure 13. The Figure 13 depicts that at 7weeks of treatment, effective removal were achieved for Topapana, Helencha, Duckweed and Snail of 13.19, 42.13, 49.13 and 66.35%, respectively. Based on the findings it can be concluded that Topapana does not significantly contribute in the removal of TDS, while, Snail shows the highest performance of removal, which was obtained as 66.35%. Here, it can be noted that some of the treatment systems was very effective to remove some particular parameter like snail was more effective for the removal of TDS values.

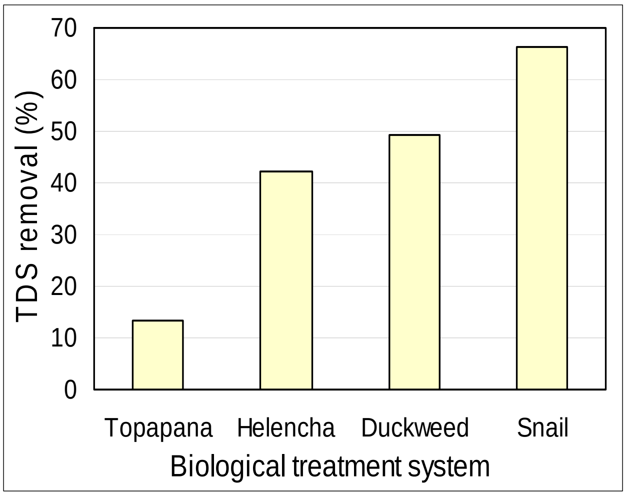

Figure 13 Removal efficiency of TDS of 50 concentration of leachate after 7weeks

Removal of COD

The figure 14 represents the removal efficiency of COD concentration with the different adopted biological treatment systems. This Figure depicts that the removal efficiency of COD ranging from 63.16% to 80.26% in leachate against different treatment system. Here, it can be noted that at the elapsed period of 7weeks, effective removal were achieved for Duckweed, Snail Topapana and Helencha of 80.26, 70.53, 68.42 and 63.16% respectively. From the figure it can also be concluded that all the treatment system performed better efficiency for the removal of COD concentration, however, among the adopted system Duckweed gives the highest removal efficiency, which was measured as 80.26%.

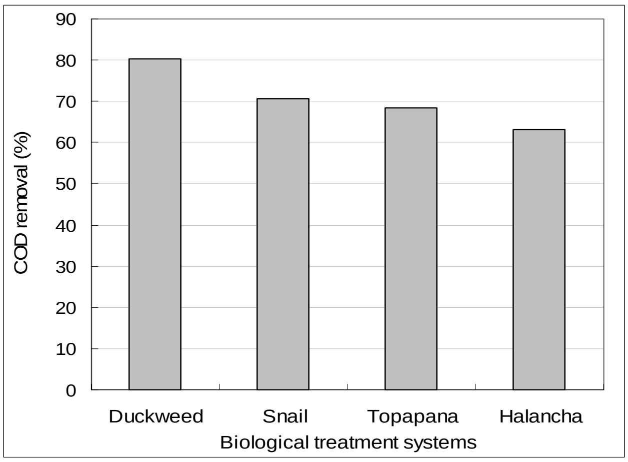

Figure 14 Removal efficiency of COD of 100 concentration of leachate after 7weeks

CONCLUSIONS

The experimental result reveals that the parameters of leachate were varied significantly for the different condition of construction materials used as cap and base liner in lysimeter. Here, it can be noted that the adopted biological treatment systems were more effective when the concentration was low and no single treatment system showing commonly the better performance for all the parameters in leachate. Based on the evaluated results, it can be concluded that some of the treatment systems were very effective to remove some particular parameter. Snail was found as more effective for the removal of pH, TDS and chloride, while, the performance of Duckweed was more effective for the removal of COD and the values of Alkalinity and Hardness can not remove by any of the biological treatment systems. This study has been tried to treat leachate by locally available aquatic reactor of preconditioned leachate that does not require any expensive cost. Finally it can be concluded that locally available aquatic reactors can be used satisfactory for biological treatment of leachate.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support provided by European Commission through the WasteSafe II project of EU- Asia Pro Eco II Programme (ASIE/2006/122-432).

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Field Experience on the Daily Operation of a Pilot Scale Sanitary Landfill in Bangladesh

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ABSTRACT

The problems associated with open dump are ground water, surface water and air contamination, acceptance of hazardous waste and inappropriate location in sensitive areas. There is no sanitary landfill in Bangladesh except the open dump in Matuail at Dhaka, which was recently converted to engineered landfill. A step has been taken in Khulna to establish appropriate landfill technology for Bangladesh based on the experimental findings on a Pilot Scale Sanitary Landfill (PSSL) construction and operation. This research reveals that special drainage system is required during monsoon and proper covering of sanitary landfill to prevent direct rain water infiltration into the landfill. From the field experience, it is also revealed that a sanitary landfill should be sufficiently equipped with necessary machineries and staff to run the system properly. During daily operation much attention should be given how to manage the huge amount of leachate generated during monsoon period. Higher percentage of water content and the biodegradable nature of incoming waste also need to take into consideration.

INTRODUCTION

In adequate and inefficient solid waste management systems have become important environmental issues for the residents of the urban areas of most of these developing countries. The adverse environmental impact of solid waste is a major public concern in the cities. Uncontrolled and unplanned landfill of solid waste, a general practice in the cities of the developing countries, is a pervasive problem that causes significant external costs, such as health hazards etc.

As one of the densely populated countries and the increase of population in the urban areas, the city authorities have been facing severe problems to get new sites for ultimate disposal of municipal solid waste (MSW). There is no sanitary landfill in Bangladesh except conversion of open dumping to landfill in Matuail, Dhaka (Ahmed et al. 2008). Due to non-engineered nature, the existing sites are also going to early closure. Peoples are also protested to close some existing sites because of their inherent hazards nature. The city authority might think about the upgrading of existing sites to improve the present situation and future disposal sites in accordance with local conditions and technological capabilities (Alamgir et al. 2005).

Environmental pollution at open dumping site includes air pollution, water and soil contamination due to propagation of generated leachate, emission of landfill gasses, odor, dust and potential fire hazards etc (Diaz et al. 1996). In ultimate disposal site (UDS), leachate percolates and contaminates surface and ground water. In some sites, the sources of ground water are very close to UDS. Peoples are uses this water in various purposes such as bathing, washing 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.

In developing countries like Bangladesh more than 90 % of solid waste is disposed of in open dumps. Considering this region’s specific climatic conditions, it is necessary to develop strategies to design and operate simple landfills, which are in-transition between dumpsite and engineered sanitary landfill. This approach demands comprehensive research on an environment safe waste deposition. To this endeavor, field research has been conducted through the construction of a Pilot Scale Sanitary Landfill (PSSL) at Khulna. The various aspects of daily operation at this landfill such as waste inspection, recording, deposition techniques, compaction, daily cover and leachate management are discussed in this pager.

OVERVIEW OF THE PILOT SCALE SANITARY LANDFILL

Figure 1 Location of the PSSL

The Pilot Scale Sanitary Landfill (PSSL) was designed by Wastesafe team of KUET and hence constructed in Rajbandh, Khulna, which is now in final covering stage. The site is located at the open dumping site of Khulna City Corporation (KCC), which is 8 Km far from the city center and situated along the north side of Khulna-Satkhira road. In this PSSL, the operational management has done in contest to the available facilities and safety. The PSSL consists of the main components of a standard landfill such as (i) Waste deposition cell, (ii) Compacted clay liner on a geological barrier with a drainage layer on top (iii) Top Cover with compacted clay liner, drainage layer, top soil as vegetation cover, surface run-off and percolated water collection system, (iv) Gas measurement and management facility, (v) Leachate detection and collection system with leachate holding tank, (vi) Leachate pond with leachate treatment facility, (vii) Vehicle inspection and washing facility, (viii) Access Road and Site office, (ix) On-going and post closure monitoring facilities. Details of design and construction of the PSSL can be obtained in Alamgir and Islam (2009) and Islam et al. (2009). The location of PSSL and the cross section is shown in Figures 1 and 2, respectively.

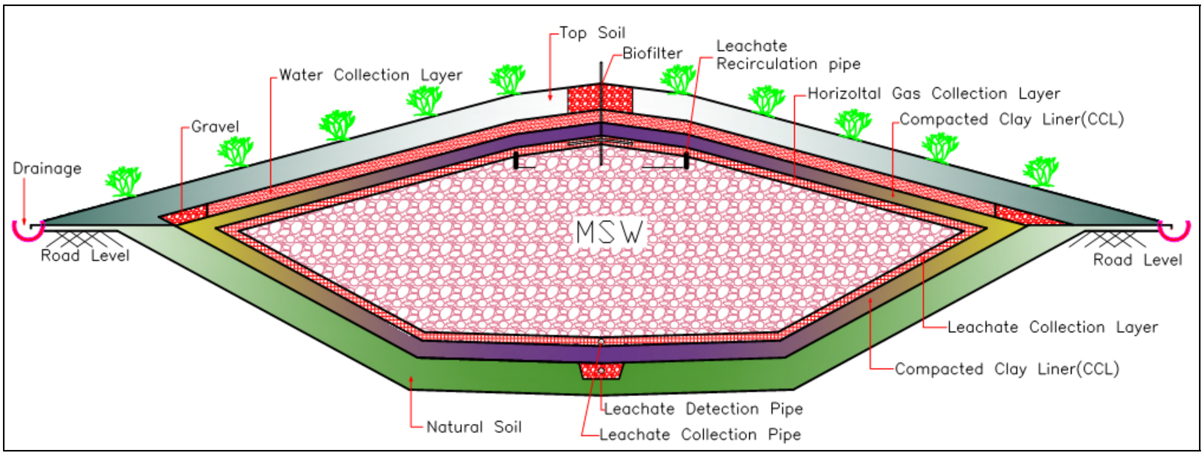


Figure 2 Cross-sectional view of the PSSL

METEROLOGICAL CONDITION OF THE SITE

Bangladesh is called the land of six seasons (*Sadartu*). It has a tropical climate because of its geological location. The Bangla calendar year is traditionally divided into six seasons. Each season on average two months lasting, some seasons merge into another seasons, while others are short. More broadly, Bangladesh has three distinct seasons such as the hot and dry pre-monsoon season, from March to May; the rainy season, from June to October, the cool and dry winter season, from November to February. The seasons of Bangladesh regulate its economy, communications, trade and commerce, art and culture and, in fact, the entire lifestyle of the people. The influence of the tropical monsoon climate is clearly evident in Bangladesh during the rainy season. April is usually the hottest month in the country. Wind direction changes from time to time in this season, especially during its early part. Rainfall which takes place during this time accounts for 10 to 25% of the annual total. This rainfall is caused by thunderstorms. This rainy season coincides with the summer monsoon. Rainfall of this season accounts for 70 to 85% of the annual total. This is caused by the tropical depression that enters the country from the Bay of Bengal. January is the coldest month in Bangladesh. However, the cold winter air that moves into the country from the northwestern part of India loses much of its intensity by the time it reaches the northwestern corner of the country. Average temperature in January varies from 17^0C in the northwest and northeast of the country, to 20^0C-21^0C in the coastal areas. The minimum temperature in the extreme northwest in late December and early January can be as low as 3^0C to 4^0C. As the winter season progresses into the pre-monsoon hot season, temperatures rise, reaching the maximum in April, which is the middle of the pre-monsoon hot season. Average temperatures in April vary from about 27^0C in the northeast to 30^0C in the extreme west of the country. After April, the temperature decreases slightly during the summer months, which coincides with the rainy season. Average temperatures in July vary from about 27^0C in the southeast to 29^0C in the northwest of the country (Banglapedia 2005).In regard to the meteorological condition of the PSSL site it has shown in Table 1 in for five years precipitation data. All data are collected from weather station, Gallamari, Khulna.

Table 1 Average monthly ppt data from 2004 to 2008 in Khulna

Month	Precipitation (mm) in Year					
	2004	2005	2006	2007	2008	2009
January	000	015	000	000	067	001
February	000	000	000	054	036	006
March	007	148	005	014	048	010
April	085	047	019	092	036	023
May	180	215	246	119	151	137
June	383	103	262	392	187	233
July	253	435	522	591	301	347
August	266	194	371	160	203	570
September	621	363	603	397	379	
October	182	420	105	198	187	
November	000	000	004	113	000	
December	000	000	000	000	000	
Total	1977	1940	2137	2130	1595	
Average	165	162	178	177.5	132.91	

WASTE CHARACTERISTICS

In Bangladesh the solid wastes mainly consists of food and vegetables waste (WasteSafe 2005). Other items are presents in negligible percentages. For a basic understanding of the nature of the wastes that are generally encountered, the type distribution of particle sizes must be known. The particle size distribution of waste was determined by sieve analysis of the sieve of openings are 400, 300, 200, 100, 75, 38.2, 19.1, 9.52, 4.76 and 2.38mm. The result shows that the average percent finer in Bangladesh are 100% in 200mm sieve openings whereas 83% in 100mm, 72% in 76.2mm, 53% in 38.2mm and 33% in 19.1mm and gradually decreases for smaller sieve openings. Physical properties of wastes are determined before the deposition in the pilot scale sanitary landfill. The average moisture content of the waste deposited in the sanitary landfill is 64.48%. The typical composition is shown in Figure 3, which represents the percentage of solid waste as food, vegetable & bio-wastes 88%, plastics 3%, demolitions 5% and others 4%.

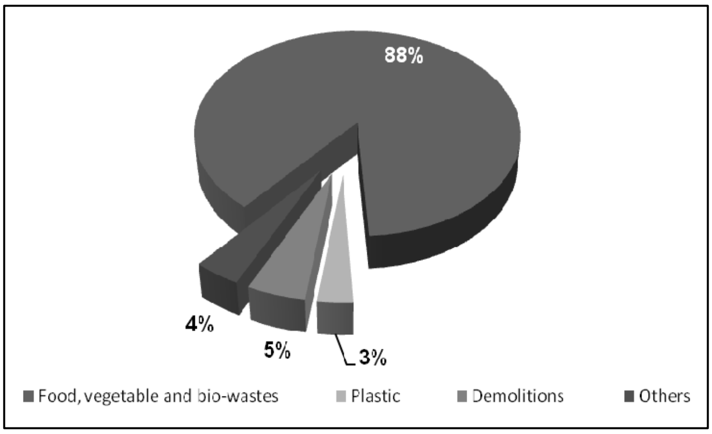


Figure 3 Compostion of the MSW deposited in the PSSL

OPERATION OF PSSL

Operation procedures of a sanitary landfill are determined by many factors, which vary from site to site. The plan of landfill operation is prepared as a part of the design procedures serve as the primary resource document, providing the technical details of the landfill and procedures for constructing the various engineered elements. While landfills may outwardly appear simple, they need to operate carefully and follow specific guidelines that include where to start filling, wind direction, the type of equipment used, method of filling, roadways to and within the landfill, the angle of slope of cell, controlling contact of the waste with ground water, and the handling of equipment at the landfill site. In the operation of PSSL, the local conditions are considered in every stages. However, it is also intended to follows the standard landfill operation aspects. The major components of landfill operation as followed in the PSSL are discussed in the following section.

Inspection of Incoming Waste and Recording

MSW generated in KCC areas has been deposited in the PSSL. The incoming waste carrying vehicles are being counted; volume of waste measured roughly and then weight measured indirectly unit weight method, and hence recorded properly in the site office of PSSL. The plan area of the site office is 54 m^2 as shown in Figure 4 constructed using locally available materials and located just beside of control gate. Waste carrying vehicle which is entered in the PSSL has inspected and a registered book is maintained for recording all the vehicles. There are different types of waste carrying vehicles entered into the PSSL. It can be divided three categories; small, medium and large by volume of waste carrying as 3.00 to 4.5, 6.44 to 6.80 and 7.94 m^3 respectively. Control gate of vehicle and inspection of waste in the PSSL has shown in Figure 5 which is maintained manually by using as colored bamboo stick placed transversely to the entrance road. After waste deposition in the landfill, the vehicle has gone over washing platform. Then it has washed manually. The size of the platform is 6mx7.5m constructed using very rich RCC pavement. It has done the out going vehicle to prevent any possible littering of waste while running out in the street. Approach road has maintained at the PSSL periodically. It is very important to maintain approach road for waste deposition. The vehicle washing during PSSL operation is shown in Figure 6.

Figure 4 Site office of the PSSL

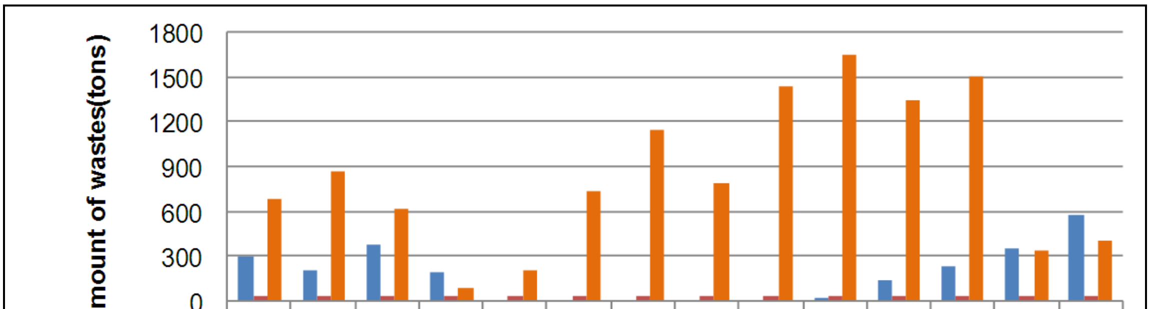
Figure 5 Control and inspection gate of incoming solid waste in the PSSL

Figure 6 Washing of solid waste carrying vehicle at the PSSL

Waste deposition

Waste deposition in the PSSL site is steeply dipping un-compacted layer. Later spreading of waste and compaction has done together. The deposition of waste in a landfill has a major influence on the chemical reaction and conditions in the landfill. It has high permeability, there is rapid infiltration and percolation of water, and prevails an aerobic condition. The first minute of MSW deposited in the PSSL has shown in Figure 7. During 14 months landfill operation, 11790 tons of waste has already been deposited in the landfill. The figure 8 shows that waste deposition in month wise at different climate condition. From Figure 8 it can be seen that in the beginning of waste deposition during monsoon, waste deposited 720ton (avg.) from July to September, 2008 and then it has dropped to 95ton (avg.) in next two months. This is because of huge amount of leachate generated during this monsoon and it has created an adverse condition to landfill. After disposal of these huge amounts of leachate, the environment has come in favor to waste deposition and the operation runs in full swing from December, 2008 to June, 2009. It has reached the record amount of landfill on average 1227 ton/months. After that the monsoon has come again and the situation is repeated. It was planned that the period of land filling was six month by 50ton/day but due to the climate condition only 28 ton/day of waste is possible to fill in the PSSL. Later, the operation period is extended to few more months to complete waste deposition and other associated works.

Figure 7 First minutes of MSW deposition in PSSL



	July,08	August,08	Sep.,08	Oct.,08	Nov.,08	Dec.,08	Jan.,09	Feb.,09	March,09	April,09	May,09	June,09	July,09	August,09
PPt(mm)	301	203	379	187	0	0	1	6	10	23	137	233	347	570
Max.Temp(0C)	31.5	32.5	32.8	31.8	29.6	26.1	26.2	29.8	33.2	36.6	35.6	34.8	32.3	32.6
Landfilling(ton)	680	867.	614.	87.9	205.	736.	1142	784.	1434	1644	1342	1507	343.	408.

Figure 8 Waste deposition into the PSSL month wise at different climate condition

Waste Spreading and Compaction

In the beginning of waste deposition in the PSSL, waste was spreading manually, latter KCC's vehicle such as Back-Wheel Compactor Cum Excavator and Chain-Dozer has employed. In some instances, for convenience, manual labor and compactor worked together for waste spreading and compaction. The spreading and compaction of waste in the PSSL has shown in Figure 9. It is observed that due the presence of high moisture content, bio-degradable nature of waste, waste volume decreased noticeably. It is also observed that waste spreading and subsequent compaction becomes very difficult due to the presence of high water content. The movement of mechanized vehicle is difficult due to smaller plan area and the presence of very soft soil beneath the adjacent approach road. Moreover, smooth spreading is not possible. Therefore, difficulties arrive during the waste spread and compaction process, which eventually developed the waste deposition activities.

Figure 9 Waste spreading and compaction operation at the PSSL

Daily Cover

Daily cover material has applied in the PSSL, as necessary to minimize fire hazards, odors, blowing litter, vector food and harborage; control gas venting and infiltration of precipitation; discourage scavenging; and has provide an aesthetic appearance. At the beginning of PSSL, Polythene sheet has used as temporary daily cover during monsoon and later, local sand is used as daily cover. Sand has also convenience for the movement of waste transport vehicles and compaction machinery. The practice of covering the waste is shown in Figure 10. However, the use of polythene does not work as expected.

Figure 10 Daily Cover: (a) Polythene sheet and (b) Sand layer.

LEACHATE MANAGEMENT AND THE MONSOON

Leachate is considered to be a contaminated liquid; it contains many dissolved and suspended materials. Good management techniques that can limit adverse impact of leachate on ground and surface waters include control of leachate production and discharge from a landfill, and collection of leachate with final treatment and/or disposal. The leachate which is generated in the PSSL is stored in the leachate holding tank (Figure 11) through the leachate collection pipe and then it has transferred to the leachate treatment pond (Figure 12). Leachate detection pipe is also connected in this tank attached with a large pipe through which lecahate samples are collected for required investigation. Leachate reaches to the tank through gravity flow from the cell. During heavy rain in monsoon, a huge

Figure 11 Leachate holding tank which collects leachate from the cell through gravity flow

amount of leachate is generated that is pumped out in the nearby reservoir ponds of PSSL because of the difficulties of the operation has shown in Figure 13. For that reason landfill operation is greatly hampered and delayed. Only a small scale treatment plant was made for partial treatment but it was not enough to treat that huge leachate. In this field experiences, it has revealed that adequate drainage system is required to control the heavy monsoon rain and to protect the direct rain infiltration in the PSSL. The experience reveals that in the landfill (constructed in Bangladesh) special cell should be considered to accommodate precipitation only in the rainy season just to avoid the enter of huge amount of rain water in the Landfill, otherwise it would be very difficult and hence expensive also to manage and treat the large volume of leachate. This can be a very interesting further research works.

Figure 12 Leachate treatment pond in the PSSL

Figure 13 Leachate reservoir pond in monsoon

CONTROL OF SCAVENGER AND VECTORS

In Bangladesh, scavenging are generally carried out in most of the open dumping sites by the poor street children, which is also found very difficult to control even in the PSSL in spite of strong inspection and protection. However, attempts have been taken to discourage people for such kind of unhygienic works providing information of the consequences of such unhygienic acts. Another difficult task is to prevent the birds, dogs and other vectors to enter into the site. A local traditional system, known as *Kaktadua* is used in addition with noise for controlling birds. As these attempts do not work perfectly, there remains the possibility of spreading germs and different types of disease, which is growing concern. Fencing of the PSSL site is also constructed to prevent entry of general people inside the PSSL.

CONCLUSIONS

This research reveals that proper site selection and design alone are insufficient to result in a sanitary landfill which provides for the protection of public health and the environment. To achieve such protection, operation of a landfill in Bangladesh should depend on the socio-economical and technological capabilities. In this context the field experience plays a very vital role to decide the guidelines based on which the sanitary landfill in Bangladesh to be constructed and hence being operated successfully. From this study it is observed that the staff involved in the management of landfill including the drivers of the waste carrying vehicles should be trained up with ABC knowledge of wastes and the sanitary landfill. It is also realized that the management of the landfill should be done professionally by ensuring the requirement of environmental sustainability. The leachate management reveals that the special attention should be taken to tackle heavy monsoon precipitation against entering into the cell, which eventually increase the amount and make the task difficult. However, in future, the field experience will help while constructing and operating a full scale sanitary landfill in Bangladesh as well as in LDACs.

ACKNOWLEDGEMENT

The authors gratefully acknowledged the financial support provided by European Commission through WasteSafe II project under EU-Asia Pro Eco II Programme (ASIE/2006/122-432).

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ISBN: 978-984-33-0761-3, Vol. 2, pp.503-511

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Geoenvironmental Properties of Clays for Landfill Construction in Bangladesh

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ABSTRACT

Municipal solid waste has become a major environmental issue in the urban areas of least developed Asian countries (LDACs) due to often inadequate and inefficient waste management. Most of the LDACs do not have any engineered landfills, and crude open dumping for ultimate disposal of solid waste is common practice. An important part of sustainable waste management is the construction of safe landfills for those wastes that cannot be reused or recycled. The paper describes the characteristics of local natural clays to be used as waste containment barriers at potential landfill sites in Bangladesh. It is shown that the mineralogical and geotechnical properties of the studied clays are favorable for their use as geological and technical barriers for engineered landfills.

INTRODUCTION

In the rapidly growing cities of the developing countries, municipal solid waste (MSW) management is regarded as one of the most immediate and serious problems faced by the city authorities. Due to often inefficient waste management, solid waste – generated at an increasing rate – has become an important environmental issue especially for residents of the major cities of the least developed Asian countries (LDACs). Many LDACs share similar problems in the waste management sector, especially in urban areas. Inadequate or unavailable solid waste collection and disposal services result in indiscriminate dumping of waste on streets and in public areas, clogging of urban drainage systems, contamination of water resources, and proliferation of insects and rodents (Alamgir et al. 2005). Clinical and industrial wastes are also in part mixed with the general flow of MSW, increasing the health risks due to direct human contact with the waste (e.g., through scavenging).

Most of the LDACs do not have any engineered landfill for the ultimate disposal of MSW. Crude open dumping of solid wastes in low-lying lands is common practice. At such dumping sites the risk of contamination of groundwater by leachate propagation is a major concern. Heavy rainfall during the monsoon is very conducive to the generation of leachate at the dumping sites. Leachate has the potential of slowly moving downwards and eventually reaching the aquifer used for the city water supply, contaminating this precious resource. Other problems related to unorganized waste dumping are the spread of waste by wind, run-off and floodwaters, and the easy accessibility by persons to potentially hazardous or infectious materials. Despite efforts in waste reduction and – often unmanaged – reuse, recycling and composting activities, large amounts of the MSW still need to be placed in landfills. Safe and reliable long-term disposal of municipal waste is therefore an important component of integrated solid waste management. Properly planned engineered landfilling is the only affordable option for the safe disposal of the majority of MSW in the LDACs for the foreseeable future. Safe disposal involves the placement of the waste in landfill cells which are lined and capped and which also contain the decomposition products of the waste.

In the frame of two European Union-funded cooperation projects on integrated waste management in LDACs (WasteSafe I and II) carried out by partner institutions from Bangladesh, Germany, Nepal, Poland, Thailand and United Kingdom, the feasibility of safe and sustainable disposal of MSW in engineered landfills was studied (WasteSafe 2007). Natural clays play an important role as constituents of geological or technical barriers in the design of waste disposal facilities because of their content of surface-active clay minerals, implicating a low hydraulic permeability and high contaminant retention capacity (Rowe et al. 1995; Czurda 2006). This paper reports on the mineralogical and geomechanical properties of clayey soils from potential sites for engineered landfills in Bangladesh.

LANDFILL OF WASTE

In the European Union, the final disposal of waste is regulated by Landfill Directive 99/31/EC (Roehl et al. 2005). Its main objective is to prevent or reduce as far as possible negative effects on the environment from the landfilling of waste, by introducing stringent technical requirements for waste and landfills. It would require all wastes to be treated before being landfilled (i.e. no waste to be landfilled with more then 5% of ignition loss). It defines the different categories of waste (municipal waste, hazardous waste, non-hazardous waste and inert waste) and applies to all landfills, defined as waste disposal sites for the deposit of waste onto or into land.

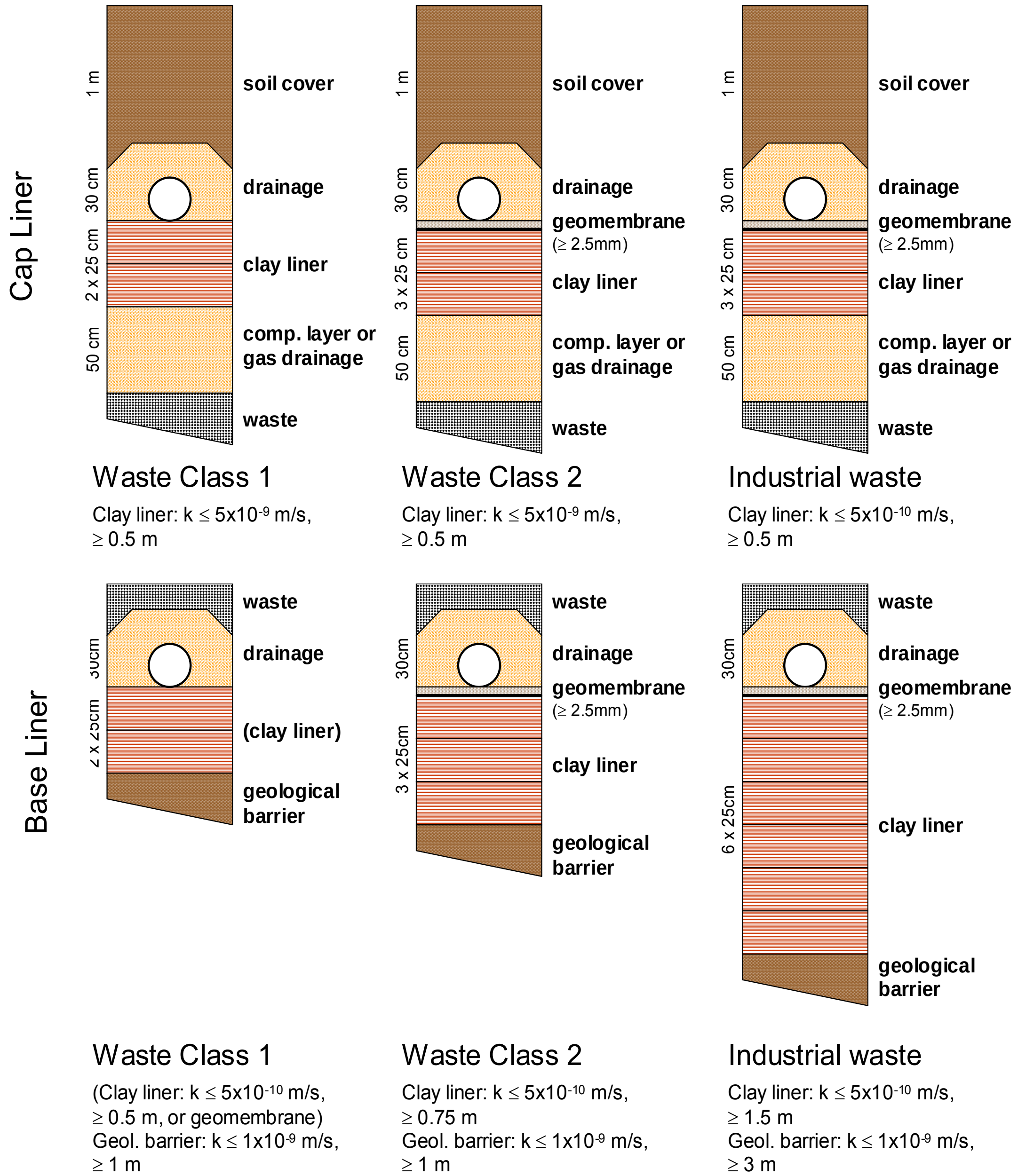

Figure 1 Requirements for landfill base and cap liner systems in Germany.

A central part of any landfill liner system is the mineral sealing layer (Fig. 1), typically in the form of a compacted clay liner (CCL). While many provisions of the directive cannot be transferred easily to the conditions prevailing in LDACs, especially due to the different composition of municipal wastes, the European practice offers a technical and regulatory background for the planning construction of municipal solid waste landfills in LDACs. Fig. 1 shows the requirements for landfill base and cap liner systems in Germany, including the location of the CCL within the barrier systems.

MATERIAL AND METHODS

Inhibiting the propagation of leachate in the underlying subsoil of a landfill is a major concern in designing or constructing a landfill for safe encapsulation of disposed of solid waste. It is desirable to take advantage of the local geology of the landfill site. In particular, the types of soil and rock underlying the disposal site and the thickness of each soil layer are important factors in controlling the migration of the leachate towards groundwater and reducing the concentration of contaminants by retardation processes. Subsoil investigations were carried out at eight ultimate disposal sites located in six major cities of Bangladesh to identify the soil strata and properties of sub-soil concerning mineralogical composition, strength, and hydraulic conductivity. The sites studied are Matuail and Gabtali Beeri Bandh in Dhaka, Raufabadh and Halishahar in Chittagong, Rajbandh in Khulna, Shishu Park in Rajshahi, North Kawnia in Barisal, and Lalmati in Sylhet (Wastesafe 2005). In addition, the subsoil characteristics at the site of a then planned experimental landfill cell near the city of Khulna (further on called New Rajbandh site) have also been investigated.

At all case study sites, drillings down to the depth of 18 m were conducted using the wash boring method. Disturbed and undisturbed soil samples were collected at around 1.5 m regular intervals for the required field and laboratory investigations. Standard penetration tests were conducted at regular intervals during drilling to identify the subsoil strength. In general, three boreholes were drilled at each site except Dhaka and Chittagong, where two boreholes were drilled at Matuail and Halishahar, each, and one in Gabtali Beeri Bandh and Raufabadh, respectively. The soil samples collected from each site were investigated both in the field and laboratory to identify the sub-soil strata and to analyze their mineralogical and geotechnical properties.

The samples were analyzed for their mineralogical composition with special emphasis on their clay mineralogy. Methods used for the mineralogical sample characterization included powder X-ray diffraction on textured and non-textured samples, the determination of carbonate content, and methylene blue adsorption. The X-ray analyses were performed in an X-ray diffractometer SIEMENS D-500 with a Cu-Kα tube (at a wavelength of λ = 1.5406 Å) at 40 KV and 30 mA. Textured samples were prepared on glass plates and analyzed after three different treatment steps: Untreated ("normal") air-dried samples, samples saturated with ethylene glycol ("EG") to identify swelling clay minerals, and samples heated to 550°C to differentiate between kaolinite/chlorite and other clay minerals. The cation exchange capacity was estimated using the methylene blue adsorption method.

Soil characterization parameters such as moisture content, grain size distribution, plastic/liquid limit, loss on ignition, and hydraulic conductivity were determined using standard soil mechanical procedures.

MINERALOGICAL COMPOSITION

In most of the soil samples taken at different sites in Bangladesh, clay minerals account for around one-half to two-thirds of the overall mineralogical composition. The results are compiled in Tables 1 and 2 and in Figures 2 and 3.

Table 1 Average mineralogical composition of the top 10 meters of soils at MSW dumping sites in Bangladesh (in weight-%; 0-10 m depth)

Location	Quartz	Feld-spars	Carbo-nates	Illite / Musc.	Kaoli-nite	Chlorite	Swelling clay min.	Other
Matuai, Dhaka	25-30	5-10	n.d.	30-35	15-20	5	5-10	2.5
Gabtali Dhaka	25	3-4	n.d.	35	15-20	n.d.	20	n.d.
Halishahar, Chittagong	35-40	5-10	n.d.	35	10	3-4	5-8	2.5
Roufabad Chittagong	60-70	3-5	n.d.	10	15-20	n.d.	1-2	n.d.
Rajbandh, Khulna	20	5-8	0-4	45-50	10-15	2-3	10-12	n.d.
Shishu Park, Rajshahi	20-25	5-10	0-10	35-40	10-15	n.d.	15-20	n.d.
N. Kawnia, Barisal	30	5	n.d.	30-35	20-25	3	4-6	2.5
Lalmati, Sylhet	30	4-7	n.d.	35	10-15	3	10-15	n.d.

n.d. = not detected

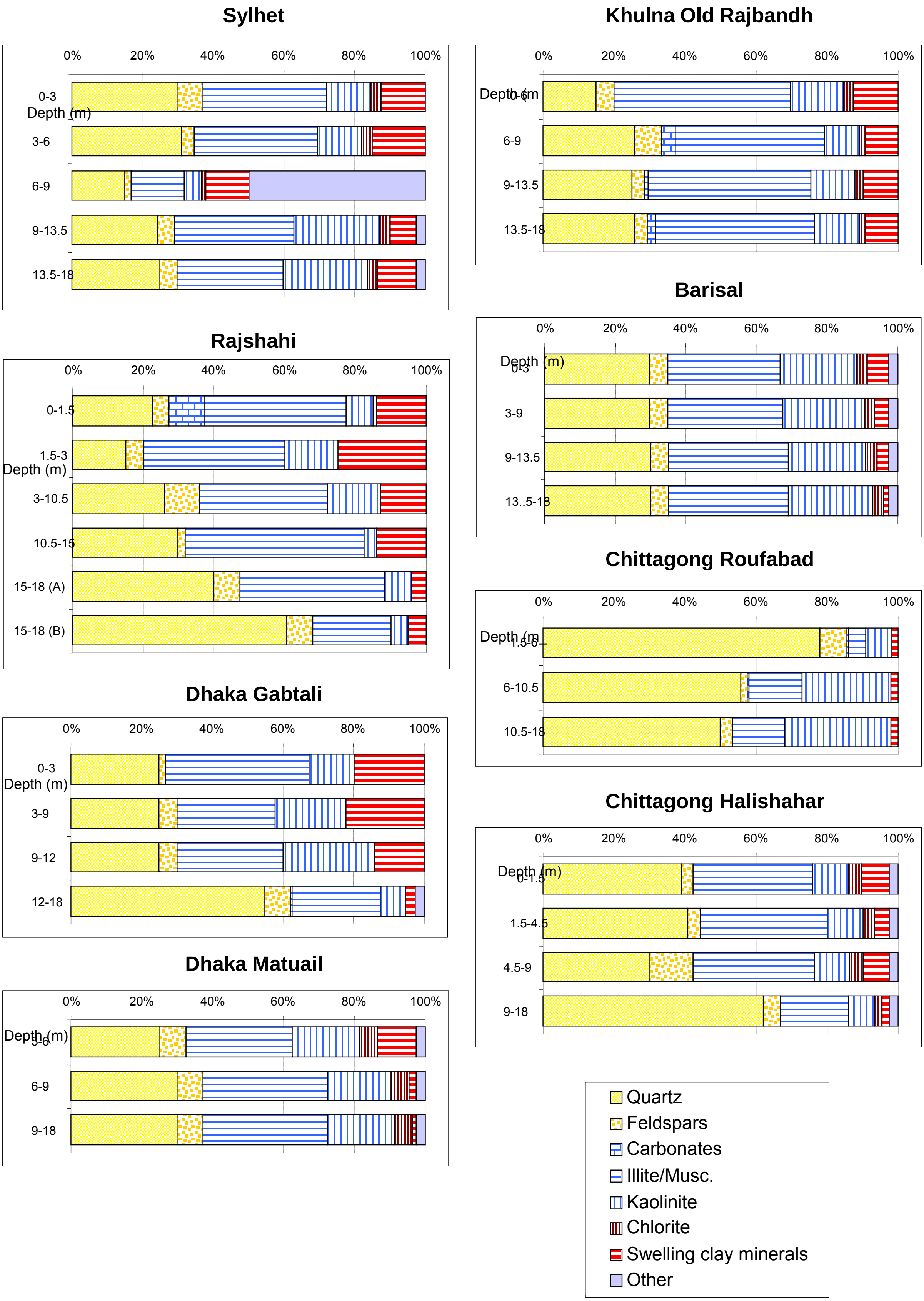

Figure 2 Summary of the mineralogical composition of soils at different MSW dumping sites in Bangladesh (in weight-%; after WasteSafe 2005)

Swelling clay minerals, which are mainly responsible for positive barrier features of soils, are present in varying amounts. Favorable cation exchange capacities in the range from 10-25 meq/100g are estimated for many of the sampled soils. Especially the soils sampled in Sylhet, Rajshahi, Dhaka Gabtali and Khulna appear to be of suitable composition for their use as a natural barrier material for landfill sites. The Chittagong samples are more coarse-grained than the samples from the other locations. This is also reflected by their mineralogical composition which contains all in all less clay minerals than samples from other locations (Figure 2), and their lower cation exchange capacity (~ 1-10 meq/100g). The Barisal samples, although containing overall high clay mineral content, also exhibit low CEC values (5-7 meq/100g) due to their low amount of swelling clay minerals.

Figure 3 shows typical X-ray diffractograms of textured clay samples from the New Rajbandh site in Khulna, for the three treatment steps performed. Kaolinite, a non-swelling 1:1 clay mineral, shows a 7 Å peak in the normal, air-dried sample and in the EG (ethylene glycol) sample, which vanishes in the heated (550°C) sample. Illite, a mostly non-swelling 2:1 clay mineral, shows a 10 Å peak in all treatment steps. As swelling 2:1 clay minerals, minerals of the smectite group are present in both samples. They can be identified by the large and broad diffraction peak moving from around 14 Å in the normal sample to around 17 Å in the EG-treated sample (due to migration of EG molecules into the inter layers) and breaking down to 10 Å in the heated sample (the latter effect due to evaporation of interlayer water and EG molecules). Chlorite, a non-swelling 2:1:1 clay mineral, shows a 14 Å peak in all treatment steps, but this peak is blanketed by the broad smectite peak in the normal sample. In the EG sample, with the smectite peak moving to lower diffraction angles, the chlorite peak can be resolved on the right shoulder of the smectite peak.

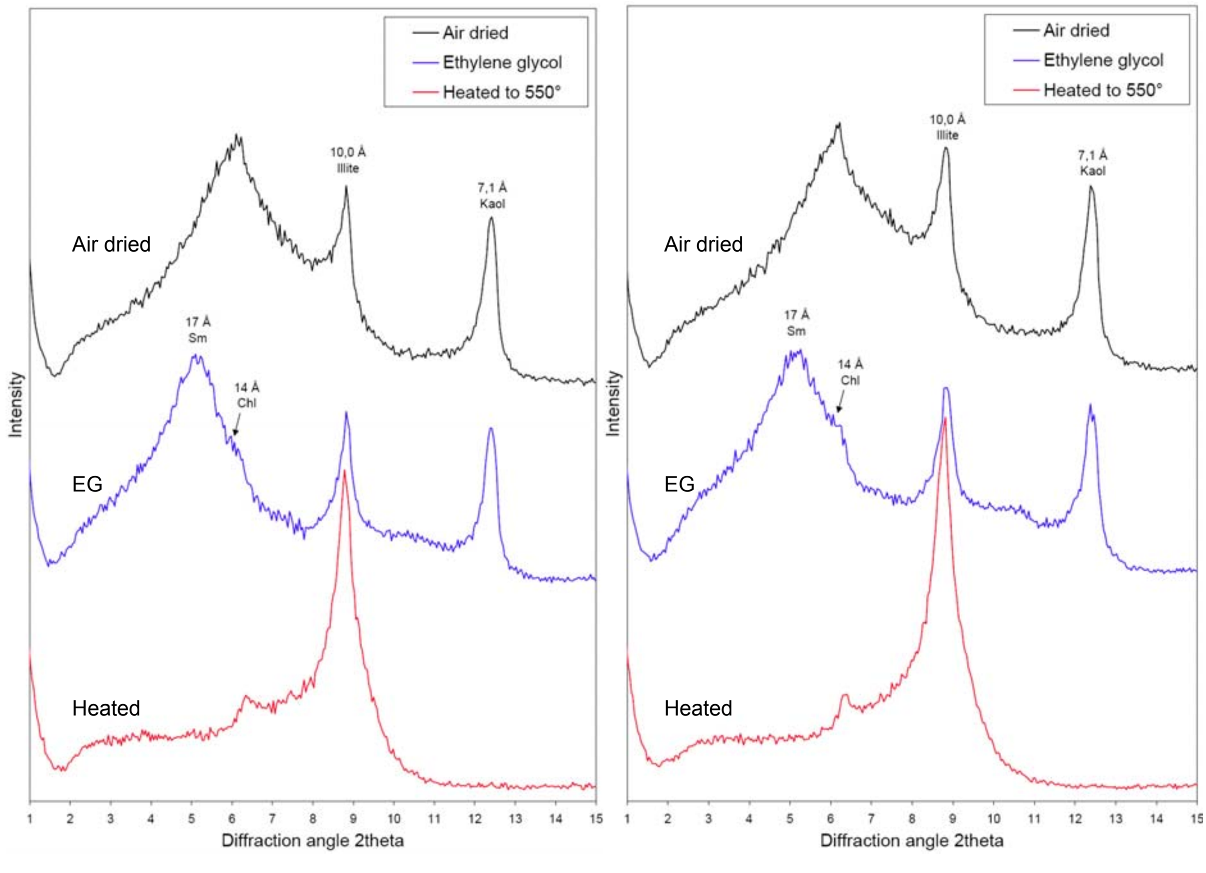

Figure 3 X-ray diffractograms of textured sample 0-0.6 m (left) and 1.2-2.1 m (right) from New Rajbandh in Khulna with different treatment steps (Sm = smectite; Chl = chlorite; Kaol = kaolinite)

The results of the semi-quantitative mineralogical analysis on two soil samples of the New Rajbandh site are shown in Table 2. Clay minerals account for more than two-thirds of the mineralogical composition of these samples. The clay mineral composition is dominated by illite, with some amount of kaolinite and trace amounts of chlorite. The amount of swelling clay minerals (around 20%) is very high, dominated by highly-swelling smectites. Non-clay minerals are around or less than 20%. The results correspond well with analyses conducted on soil samples from the Old Rajbandh site (Table 1).

Table 2 Average mineralogical composition of two soil samples taken at the New Rajbandh site, Khulna, at different depths (in weight-%)

Location	Quartz	Feldspars	Carbonates	Illite / Musc.	Kaolinite	Chlorite	Swelling clay min.	Other
0 – 0.6 m	19	< 1	n.d.	~ 50	~ 10	< 1	20	n.d.
1.2 – 2.1 m	17	< 1	n.d.	~ 50	~ 10	1-2	19	n.d.

n.d. = not detected

GEOTECHANICAL PROPERTIES

Soil Strata and Index Properties

Figure 4 shows that the subsoil at the case study sites mainly consist of sedimentary deposits (cf. Khan 1991), however, the soil types vary from each other. Liquid limit, plasticity index and percentage of clay at different depths are presented in Table 3.

A thick fine-grained soil, i.e. clay layer, is encountered at all sites except Raufabadh, Chittagong, where the subsoil consist mainly of fine sand down to the final drilling depth of 18 m. However, at Halishahar clay deposits are available to the depth of 9 m. In Dhaka, the clay deposits extend down to the final drilling depth at Matuail and to a depth of 10.50 m at Gabtali; after that sand is encountered.

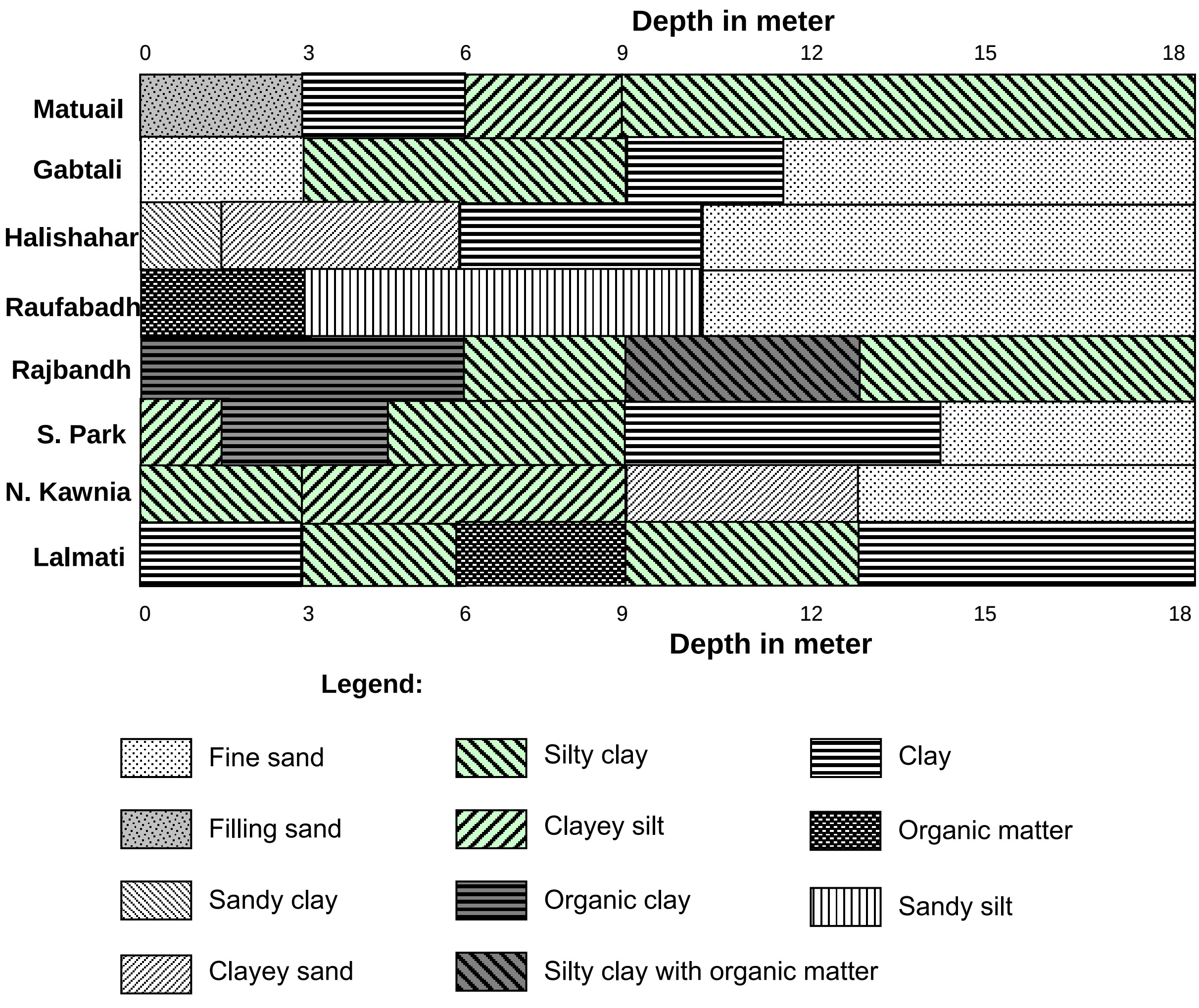

Figure 4 Sub-soil strata at eight different MSW dumping sites in Bangladesh

Table 3 Geotechnical properties of subsoils at eight MSW dumping sites in Bangladesh

Depth below the ground surface (m)	Liquid limit w_L (%)	Plasticity index PI	Clay (%)	Coefficient of permeability k (10^{-9} m/s)	N-value
Matuail					
0 to 3	-	-	-	-	-
3 to 6	47	23	40	2.40	9
6 to 9	33	5	31	22.2	19
9 to 12	40	12	22	1.35	28
12 to 15	45	9	17	8.50	35
15 to 18	38	10	15	1.05	42
Gabtali					
0 to 3	-	-	-	988	13
3 to 6	46	18	35	1.30	21
6 to 9	38	13	28	9.25	25
9 to 12	44	22	48	1.75	36
12 to 15	-	-	-	2150	63
15 to 18	-	-	-	1350	80
Halishahar					
0 to 3	42	18	18	3.60	2
3 to 6	-	-	12	22.0	2
6 to 9	44	12	35	5.40	3
9 to 12	-	-	-	1875	7
12 to 15	-	-	-	872	16
15 to 18	-	-	-	2570	30
Raufabadh					
0 to 3	-	-	-	2486	12
3 to 6	-	-	4	10.50	22
6 to 9	-	-	6	823	36
9 to 12	-	-	-	5120	56
12 to 15	-	-	-	2865	64
15 to 18	-	-	-	3412	70
Rajbandh					
0 to 3	85	27	28	1.90	2
3 to 6	79	20	23	2.35	3
6 to 9	38	8	20	20.40	4
9 to 12	46	9	26	26.75	5
12 to 15	42	10	26	2.75	6
15 to 18	49	12	28	3.20	5
Shishu Park					
0 to 3	32	5	27	1.51	4
3 to 6	65	18	30	7.50	7
6 to 9	42	13	28	11.20	9
9 to 12	48	20	33	11.50	16
12 to 15	-	-	12	7.10	35
15 to 18	-	-	-	2.35	56
North Kawnia					
0 to 3	33	3	12	4.75	5
3 to 6	35	8	15	228.0	7
6 to 9	28	12	10	324.0	8
9 to 12	30	5	7	1645	22
12 to 15	-	-	5	1285	27
15 to 18	-	-	-	1378	53
Lalmati					
0 to 3	43	14	25	3.85	5
3 to 6	37	8	28	3.08	4
6 to 9	-	-	-	15.70	8
9 to 12	35	6	18	23.50	10
12 to 15	40	12	16	2.55	9
15 to 18	45	10	27	4.20	12

In Rajbandh, Khulna, cohesive soil, i.e. mainly clay with silt and high organic matter content, exists throughout the covered drilling depth. In Shishu Park, Rajshahi, clay exists down to the depth of 12 m including some organic-rich soil, followed by sand deposits. In North Kawnia, Barisal, the subsoil strata consists of cohesive soil layer, mainly silty clay, clayey silt and clayey sand, down to a depth of 10.50 m, with sand at lower depths. At the Lalmati of Sylhet, clay exists throughout the covered depth, with organic-rich soils in some locations. The site investigation showed that the subsoils of the current waste dumping sites contain a considerable amount of clay, which can be considered a potentially suitable material for the construction of base liner systems.

Strength Properties

A waste containment system should retain its structural integrity during its design life. The settlement of foundation soils might damage the bottom liner, leachate collection system top and cover and allow the leachate to exit the system freely. Similarly, the slope failures of the structures, either local or systematic, would lead to catastrophic consequences (Reddi and Inyang, 2000). Therefore, knowledge about the strength of the subsoils at the studied MSW dumping sites is very important to apply required counter measures against any possible slope stability failure. The strength of the subsoil is measured in the field through standard penetration test (SPT). Its results are included in Table 3 as penetration resistance, i.e. the N-value (blows per foot). From the field results as illustrated in the table it is observed that subsoil conditions at both of the study sites of Dhaka and one site (Raufabadh) in Chittagong are reasonably good. But at other locations, subsoil conditions are not good. At Halishahr (the second site in Chittagong), Rajbandh site in Khulna, and Lalmati site in Syjhet, the subsoil conditions are very poor even till the final depth of boring. However, at the North Kawnia in Barisal and Shishu Park in Rajshahi, the subsoil conditions are weak down to a depth of 7.5 m, but beyond this depth the soil strength increases significantly. Therefore, the situation of subsoil conditions must be kept in mind while designing a sanitary landfill at these sites or for the upgrading of the sites. At sites where subsoil conditions are poor, required counter measures – such as soil improvement – can be an option to be employed for the safe installation of solid waste containment facilities.

Hydraulic Properties

Solid wastes can be buried above or within a natural occurring formation of low hydraulic conductivity, e.g. a clay-rich soil. Natural liners normally contain significant amounts of clay minerals and have a hydraulic conductivity of around $k < 10^{-8}$ to 10^{-9} m/s. Recommended soil properties to achieve such low hydraulic conductivities by compaction, if they not exist naturally, are: percentage of fines (< 0.075 mm) ≥ 30%, 20 ≤ PI ≤ 30, and percentage of gravel (5 to 50 mm) ≤ 20%. Natural liners typically serve as a back-up to engineered liners, but occasionally a natural liner may represent the only liner at a waste disposal site facility (Daniel 1993, Rowe et al. 1995). It is worth to note that in LDACs, as most of the existing sites are crude open dumping, a massive uniform natural soil liner is often the only means for protecting the groundwater from contamination resulting from the percolation of leachate. As all the existing MSW dumping sites in Bangladesh are of the open crude disposal type, and the sites typically have subsoils rich in clays, the continuity and hydraulic conductivity of these natural clay liner materials are crucial issues. Considering these crucial aspects for a possible future construction of sanitary landfills in Bangladesh, and for the assessment of the present situation of the existing dumping sites, the subsoils of all eight sites studied were sampled down to a depth of 18 m and the hydraulic conductivity of selected samples was examined in the laboratory. The test results averaged for different designated depth are included in Table 3. The results indicate that most of the studied subsoils contain low-conductivity layers that make these soils suitable as natural clay liners for the containment of MSW.

CONCLUSIONS

When considering the construction of landfills in LDACs, the use of locally available materials is indispensable. Natural clays should be used – where available – as geological and/or technical barriers for municipal waste disposal sites. The type of clay and its usage should be selected and supervised by experts. In Bangladesh, field and laboratory analyses showed that local clay deposits constitute a valuable material for geological and technical barriers for waste containment facilities. They should be investigated further on a case-by-case basis to define areas suitable for the construction of engineered landfills for municipal solid waste.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of the European Commission through the two grants projects of Asia Pro Eco Programme, WasteSafe (Contract No ASI/B7/16-2004/79010) and EU-Asia Pro Eco II Programme, WasteSafe II (Contract No ASIE/2006/122-432).

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ISBN: 978-984-33-0761-3, Vol. 2, pp.513-516

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Erosion of Municipal Solid Waste Landfill Cell Capping–A Model Study

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ABSTRACT

Erosion of soil covers of municipal landfill capping may become a serious problem in regions of high precipitations and extreme rainfall events. The erosion threat is especially serious when the top of the landfill capping consists of a silt or clay soil. The proper management of rainfall and run-off water, supported by vegetation cover and erosion rate prediction may reduce the risk of capping failure.

This paper presents results of prediction of soil erosion from landfill capping calculated by WEPP model. Two different trapezoidal shapes of the landfill capping and three different types of soil cover (bare soil, 50% and 100% grass cover) were taken into consideration. Numerical prediction of soil erosion was based on weather, soil, slope and vegetation data. The results of calculations for bare soil showed that the highest value of predicted average annual sediments leaving the soil profile reached the level of 113.7 Mg/ha. The introduction of grass cover decreases the soil water erosion rate by about 15-21%. The presented results of soil erosion prediction require empirical verification by field measurements of annual sediments leaving the top layer of the landfill capping.

INTRODUCTION

The known literature studies focused on soil erosion indicate that hilly watersheds of Bangladesh (e.g. Chittagong Hills) are endangered by water erosion as well as the southern part of the country being highly prone to riverbank erosion (Gafur et al. 2003, Misbahuzzaman 2007, Rasul and Thapa 2007). Soil erosion is being observed at, at least, 25% of the whole country area. The maximum reported value of soil loss caused by soil erosion in mountain regions of Bangladesh reached the level of 120 Mg ha^{-1} $year^{-1}$ (Gafur et al. 2003). The factors triggering soil erosion include: rainfall events, slope inclination, soil erodibility and soil management manners (Li at al. 2001, Govers et al. 2004, Valentin at al. 2005, Zheng 2006).

The region of the experimental landfill cell (Alamgir at al. 2005) localization in Khulna is characterized by a very high precipitation reaching 2600 mm maximum, 1609 mm minimum and 1992 mm average value per year, concentrated mainly within the rainy season. According to the literature reports (e.g. Govers et al. 2004, Valentin et al. 2005) the soil cover of the Khulna landfill consisting in 99% of silt and clay (Alamgir at al. 2005) is highly erodible. The low hydraulic conductivity of topsoil increases generation of runoff and limits infiltration of surface water (Govers et al. 2004). Thus, soil erosion: sheet, rill and inter- rill erosion are likely to be expected on the top cover of the landfill cell. Extensive rainfall events during the rainy season may even create danger of destroying the whole covering layer. In this case the water drainage layer as well as liner, gas drainage and even the waste body would be exposed to the atmospheric conditions. The damages caused by water erosion can be also dangerous to gas and water management of landfill cell. Detailed studies of surface run-off generation and its intensity as well as erodibility of local soils are necessary to obtain the required knowledge allowing predicting the water erosion rate and to develop the proper soil erosion control and landfill cover soil conservation strategy.

MATERIALS AND METHODS

Numerical prediction of landfill cell soil cover were conducted with use of the Water Erosion Prediction Project (WEPP) model developed by United Stated Department of Agriculture, National Soil Erosion

Research Laboratory (Flanagan and Nearing 1995, Bhuyan et al. 2002, Grønsten et al. 2006). The WEPP model enables the prediction of soil erosion rate understood as soil loss – sediments leaving the soil profile for perennial period or for the selected single rainfall event. The soil erosion prediction is based on four groups of input data: slope geometrical data, soil data, climatic conditions and cropping management data.

Two variants of geometrical landfill cell developed during Waste Safe II project meetings during the period of 2007-2008 were considered. The applied variants of trapezoid shape differs in length and inclination of the slope – see Figure 1.

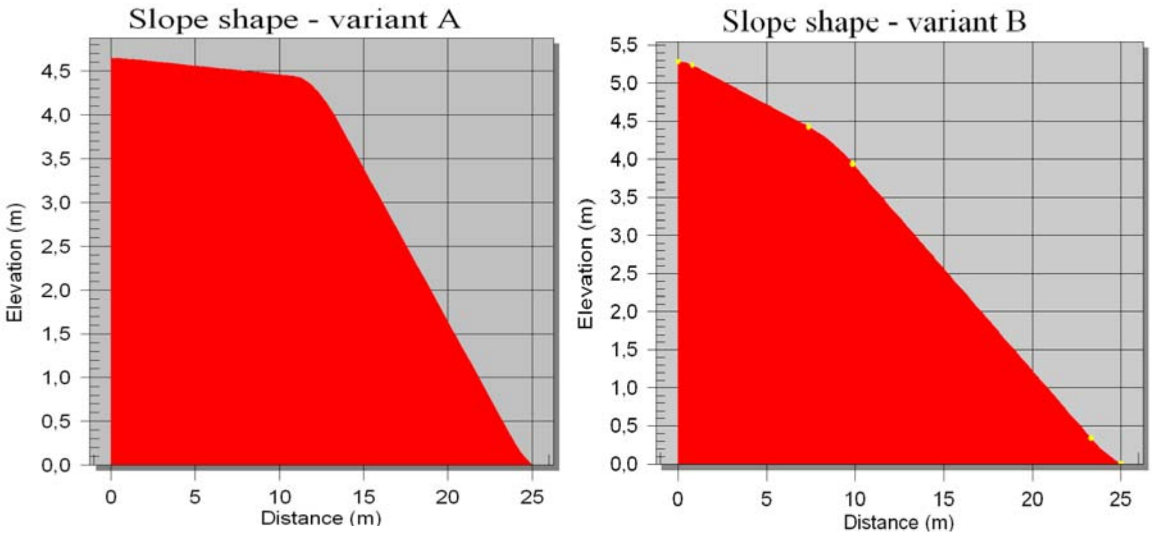

Figure 1 Two studied shapes of landfill cell cover slope

The considered, required by WEPP model soil data covered particle size distribution, soil saturated hydraulic conductivity, rill and inter-rill erodibility, as well as soil critical shear. The soil data applied to the numerical prediction of soil erosion rate were presented in Table 1.

Table 1 The basic soil parameters used in water erosion prediction (Alamgir et al. 2005)

Layer thickness (mm)	Sand (%)	Clay (%)	Silt (%)	Organic Matter (%)	K_{sat} (mm h^{-1})
600	0.5	44.3	55.2	3.0	0.007812

The other earlier described parameters were calculated by the WEPP model (Flanagan and Nearing, 1995).

Climatic conditions applied to this prediction studies were based on meteorological measurements conducted in Kulhna, Bangladesh covering daily precipitation, minimal and maximum temperature for the period 1994-98. Then, input file was created by Cligen Weather Generator (http://www.ars.usda.gov, Zhang 2004, 2005) enabling the 5 year simulation.

Three types of surface vegetation management were considered for all studied slopes: bare soil, 50 % and 100% grass cover. Grass cover means permanent grass of 50% or 100% slope area coverage, with no killing or planting.

The presented above input data enabled running the soil erosion prediction for the duration of 5 years. The simulation results covered on and off site effects of water erosion i.e.: soil loss/deposition along slope profile, maximum soil loss, average annual sediment leaving profile.

RESULTS

The results of soil erosion rate calculation conducted by WEPP model for two different shapes of municipal landfill cell in conditions of Khulna, Bangladesh are presented in Table 2. Three different types of soil surface management were considered. The presented results covered average annual sediment leaving profile, soil loss and maximum soil loss value and its on slope location for all studied variants.

Table 2 Results of soil erosion rate prediction by WEPP model

Type of top cover	Average Annual Sediment Leaving Profile Mg ha-1		Annual Soil Loss kg m^{-2}		Maximum Soil Loss kg m^{-2}	
	A shape	B shape	A shape	B shape	A shape	B shape
Bare soil	113.715	107.570	11.372	10.757	23.599 at 23.75 meters	18.976 at 23.25 meters
50 % grass	102.191	88.947	10.219	8.895	22.529 at 23.75 meters	16.869 at 23.25 meters
100% grass	96.760	84.878	9.676	8.488	21.222 at 23.75 meters	16.030 at 23.25 meters

The highest calculated value of soil loss caused by soil erosion was equal to 113.715 Mg ha^{-1} $year^{-1}$ for the A slope shape and bare soil (bare soil B shape was characterized by 107.570 Mg ha^{-1} $year^{-1}$) . The lowest predicted values of sediment yield were observed for 100 % grass vegetational cover - 96.760 Mg ha^{-1} $year^{-1}$ for a shape and 84.878 Mg ha^{-1} $year^{-1}$ B shape.

The results of numerical prediction of landfill capping soil erosion rate shows that the predicted values of mean yearly erosional soil loss is comparable to the maximum values of soil loss reported for Bangladesh i.e. 120 Mg ha^{-1} $year^{-1}$ on deforested hill slopes (Gafur et al. 2003) and 109.45 Mg ha^{-1} $year^{-1}$ for conventional tillage: hoeing without mulch at Chittagong Hill Tracts (Rasul and Thapa 2007). This observation means that landfill cell capping constructed in Khulna, Bangladesh, with use of local erodible soils may be clearly endangered by water erosion at high degree. Landfill capping surface should be strengthen by vegetation cover – according to the results of our calculations 50 % of grass cover reduces rate of soil erosion by 10%, thus 100% grass cover limits soil loss by more than 20%.

Calculations of maximum soil loss show that shape B of landfill cross section causes lower local soil loss, thus reducing the risk of destroying the capping continuity and increasing the surface water infiltration to deposited waste body. The maximum local soil loss for B shape is lower by approx. 25% then the predicted value for a shape.

CONCLUSIONS

The predicted by WEPP model values of soil erosion for different shapes and variable types of soil surface management showed that capping of municipal landfill cell constructed in Khulna, Bangladesh local climatic and soil conditions may be severely endangered by soil erosion. Soil erosion rate may be limited by vegetation cover introduction, for example grass cover, our calculations showed that even 50% of grass cover enables noticeable reduction of soil loss. The presented studies showed also that choice of municipal landfill cell cross section shape should be chosen advisedly. The shorter and steeper slopes generate higher rates of annual soil loss and local maximum soil loss.

However, despite the fact that required countermeasures of limiting the soil erosion by water are applied, the surface of landfill cell should be carefully, regularly observed after each extreme rainfall event and all damages caused by run-off water should be repaired.

Our calculations should be empirically verified by comparison with the results of soil erosion rate measured at newly constructed municipal solid waste landfill cell at Khulna, Bangladesh.

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ISBN: 978-984-33-0761-3, Vol. 2, pp.517-524

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Construction and Operation of Landfill: Experience of Dhaka City Corporation

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ABSTRACT

Upgrading a crude dump site into sanitary landfill is a very challenging task. Matuail landfill site at Dhaka city posed such a challenge. From the very beginning, the existing disposal site had been used as crude dumping of solid wastes. All types of solid wastes were haphazardly disposed of all over the site. The existing drainage channels of the dumping ground were not operational due to blockage by indiscriminate waste dumping. A large amount of leachate emission out from wastes mixed up with storm water made the site aesthetically very displeasing, and environmentally unsound. This adverse situation sometimes caused disruption of the waste vehicular movement. Step-by-step improvement measures have been taken in the open dump to make it controlled and sanitary by adopting simple and locally available materials, technical guidelines and construction techniques. Dhaka City Corporation (DCC) *has been operating the landfill site since October '2007. This paper is mainly sharing the construction and operational challenges and learning of the landfill for its potential replication in other cities.*

INTRODUCTION

DCC inaugurated the first ever sanitary landfill in Bangladesh at Matuail in October 2007. A dump site was transformed into a sanitary landfill. This was a very tough job and DCC succeeded very nicely. Now DCC is doing the tougher and the challenging task; operating the landfill as a sanitary landfill.

Matuail Landfill never sleeps! It is operated 24 hours a day in 3 shifts. It receives around 1,200 tons per day, arriving at both daytime and nighttime. Over 350 truck trips arrive to the landfill in one day. The truck enters through the LF gate and proceeds to the weighbridge. A weighbridge operator inputs the truck weight and arrival times into the PC. The truck then proceeds to the waste dumping areas using access roads built on the waste disposal areas. A waste instructor instructs the truck where to unload its waste. Three types of heavy equipments are used in Matuail Landfill; excavator to unload the trucks, tyre dozer to push the waste away from the platform & feed the bull dozers and bull dozers to spread & compact the dumped wastes which are operated 24 hours as required. Now the empty truck descends from the waste disposal area, and goes to the vehicle washing bays where the tires and body are sprayed by water. The truck then leaves the site.

Leachate is generated as rain falls on the disposed wastes and rain water percolates through the waste. Also the moisture in the waste trickles down forming the leachate. Perforated pipes have been laid below the waste layers to collect the leachate into two large ponds. There the leachate pond operator operates blowers and the leachate is aerated and then re-circulated back into the waste layers. No leachate is allowed to leave the site. The landfill is designed as semi-aerobic and perforated gas vent pipes are installed at 50m interval. With the increasing height of the waste piles; the gas vent pipes are vertically extended.

For sanitary landfill operation two types of soil covers are used; daily soil cover and final soil cover. Daily soil cover has to be applied after each day dumping operation and final soil cover to be applied on the places where dumping operation will not be carried further. Environmental monitoring of ground water, surface water, leachate and gases are done at regular interval.

WHAT WAS THE SITUATION BEFORE THE INITIATIVE?

Upgrading a crude dump site into sanitary landfill was a very challenging task. Matuail landfill site at Dhaka posed such a challenge. From the very beginning the existing disposal site had been used as crude dumping of solid wastes. All types of solid wastes were haphazardly disposed of all over the site. The existing drainage channels of the dumping ground were not operational due to blockage by indiscriminate waste dumping. A large amount of leachate oozing out from wastes mixed up with storm water made the site aesthetically very displeasing, and environmentally unsound. This adverse situation sometimes caused internal flooding of the roads and disrupted the movement of the waste transporting trucks. As a result, the operation of solid waste disposal at Matuail used to become extremely difficult during and immediately after rainfalls. As the waste was dumped in an unplanned way and sometimes over the embankment; during the rainy season, the leachate was draining out to the nearby lands polluting the fishery and agriculture fields. The bad smell from the site caused an obnoxious situation in and around two to three km areas.

WHAT WERE THE KEY BENEFITS RESULTING FROM THE INITIATIVE?

Matuail Sanitary Landfill is the first sanitary landfill in Bangladesh. It was a 15 years old dump site, surrounded by agriculture field, fishery & housing. Due to crude dumping, the common scenario of the dumpsite was confined with huge vectors, bad smell, water pollution due to uncontrolled leachate discharge, air pollution etc. After the intervention, a tremendous improvement has been observed. Now smell is less, vectors are reduced, leachate is controlled, and surrounding environment is improved significantly due to controlled and scientific disposal of waste. After rehabilitation of the old dumpsite, the land filling capacity of the almost closed existing landfill has been increased for five years and the extended part of the landfill has secured capacity for another 30 years. From the environmental and socio-economic point of view, the project has contributed significantly for the inhabitants of the surrounding area. Due to scarcity of land for waste disposal and the high price of land in and around the city, the rehabilitation of the existing landfill has added positive value in terms of its cost-benefit proposition and environmental benefits.

During the design and implementation stages many innovative aspects were considered which were suitable to the local context and achieved the required results. Some of these aspects are:

- Much old waste was excavated in order to reform the slopes, make space for administrative area construction, and develop internal road network. The excavated old waste was used for cover material. This aided DCC very much because of the high purchase and transport costs associated with the import of cover materials to the site.
- The haphazard waste dumping was transformed to planned waste disposal through the preparation of the waste disposal platforms, monitoring of amounts of arriving wastes and increasing the skills of the DCC officials. This planned waste disposal ensured the smooth operation at the site, better working conditions and less impact to surrounding environment.
- Working conditions at the landfill is very difficult and risky. The Project greatly improved the working conditions at the landfill through preparation of the operation and management manual, provision of safety gears, holding of training workshops to the staff, provision of first aid equipment at the site and arrangement of medical checkups for the landfill staffs.
- The socioeconomic conditions in Bangladesh attract many people to engage in waste picking activities. There are around 200 waste pickers engaged at the landfill. The waste pickers' working conditions have significantly improved with the introduction of planned operations, stationing of trained waste instructors to control the operation of heavy equipments and waste trucks un-loading, and planned implementation of a registration system for waste pickers.
- DCC is not different from other developing cities where financial constraints affect the quality of services. Bearing this in mind, the costs incurred in the introduced system were kept at a level that would not create an excessive burden for DCC, both during development and operation. Local materials were used in the development, and easy to operate treatment systems were adopted.

WHO PROPOSED THE SOLUTION, WHO IMPLEMENTED IT AND WHO WERE THE STAKEHOLDERS?

The project was one of the priority programmes of the Clean Dhaka Master Plan prepared for the improvement of solid waste management situation of Dhaka City.

Dhaka City Corporation implemented the project through its Project Implementation Unit (PIU) with the technical guidance of the experts of Bangladesh University of Engineering and Technology. Japan International Cooperation Agency (JICA) dispatched Experts during the planning and design stage.

The major stakeholders of the project were:

The People's Republic of Bangladesh

The Project is the first Sanitary Landfill of its kind in Bangladesh. It is therefore become a model project for the whole country, and holds a good prospect for multiplying the model to other big cities of Bangladesh through transferring of knowledge, technology and practice.

Dhaka City Corporation (DCC)

DCC is responsible for the solid waste management of Dhaka City. This landfill site is 15 years old open dump which has been converted into sanitary landfill thus control the environmental pollution of the surrounding areas from the solid wastes.

The Dhaka Citizens

Dhaka City has a population of over 12 million, generating about 3500 tons waste daily. The people of Dhaka city are enjoying clean and healthy environment due to the implementation of the project.

The Villages Surrounding the Landfill

There are four villages within 1 km distance from the Matuail landfill, namely Kazla, Kazla South, Sharifpara and Mridharbari, with a total population of around 20,000. These residents are engaged in agriculture and fishery activities. The Project has stopped the pollution of the surrounding surface water bodies by the leachate generated from the landfill, and thereby support the residents' economic activities. Moreover, the aesthetic of the landfill site has been improved dramatically and air pollution has been reduced significantly. The overall environmental condition has been improved to a greater extent and the villagers are now relieved of the obnoxious odour.

WHAT WERE THE OBJECTIVES AND STRATEGIES USED TO IMPLEMENT THE INITIATIVE?

The major objective of the project is:
Reversing the worst aesthetic environmental and operational conditions to a sustainable and environmental friendly waste disposal system in the most densely populated city with acute shortage of land area.
The specific objectives are as follows:

- to transform the existing dump site into a sanitary landfill and to reduce the environmental pollution generated from the disposal activities.
- to develop a new sanitary landfill for future use in the extended part
- to improve the control and operational practice of landfilling through provision of sufficient facilities and equipments
- improve the working conditions at the site including safety
- improve the aesthetics of the landfill site through pleasant landscaping including plantation and turfing.

Prior to the development activities of the project, Matuail was an open dump site, receiving about 1,800 tons of municipal wastes daily. The crude waste disposal practice at that time resulted in environmental pollution of the surrounding area including water pollution, air pollution, obnoxious odour problem and drainage congestion. Also the DCC staff worked at the site in very poor and unhealthy working conditions. And this condition also affected the health of the waste pickers' active in the site.The Project has addressed all these issues and taken the following strategies:

- monitoring of waste load arrivals at the site and landfilling in a planned way.
- improvement of generated leachate quality, and its proper collection and treatment.
- establishment of proper storm water drainage system
- decrease in the amount of generated methane in the landfill.
- provision for soil cover on waste in order to combat vectors, waste scattering and odour

- putting in place the necessary facilities and equipments to implement environmental monitoring during the landfill operations
- preparing the plan to register waste pickers at the landfill and improve their working conditions

WHAT WERE THE KEY DEVELOPMENT AND IMPLEMENTATION STEPS AND THE CHRONOLOGY?

The total area of the landfill is about 40 hectares, half of which is a 15-year old dumping site. The project called for (1) conversion of the existing 20 hectares old dumping site into a sanitary landfill and (2) development of a new sanitary landfill at the newly acquired 20 hectares land. The design for the rehabilitation and new extension followed the semi-aerobic landfill system developed by Fukuoka University of Japan. This system permits the rapid degradation and stabilization of solid wastes, decrease in methane gas generation, improvement of leachate quality and reduction in fire hazard. The main activities are briefly summarized as follows:

Conversion of Existing Dump Site into a Multi-Stage Sanitary Landfill

- layout planning of landfill facilities (control building, weighbridge, heavy equipment sheds, monitoring and recording facilities etc.)
- land development for internal access roads
- design and construction/installation of administrative/operational facilities
- establishment of side slope of waste dump
- installation of leachate collection and landfill gas vent system
- construction of boundary storm water drainage system
- establishment of semi-aerobic system of solid waste stabilization
- construction of waste disposal platforms
- excavation of old wastes for use as cover materials
- construction of electrical sub-station and flood lights
- installation of monitoring wells
- installation of water supply and sanitation system

Construction of a New Sanitary Landfill in The Extended Area

- development of four blocks for waste disposal (including natural bottom impermeable layers and embankment)
- construction of road pavement and permanent platform for waste disposal
- construction of bed level leachate collection network including leachate pumping pits.
- construction of aerated lagoons for leachate treatment

The Chronological Development of the Project

2005: The Clean Dhaka Master Plan was prepared by DCC and JICA. The M/P prepared the preliminary plan for this Project.

2006: The planning and design of the Matuail landfill were done.

2006-2007: Construction was undertaken to (1) convert the existing crude dumping site into a sanitary landfill and (2) develop a new sanitary landfill at the extension area.

2007 October: Construction works of most of the landfill facilities were completed and inauguration of the systematic landfill operation started.

Since October 2007, the landfill has been operating as a sanitary landfill with semi-aerobic system of waste stabilization including the provision of landfill gas venting system, leachate collection system with perforated pipes, storm water drainage and disposal system, waste delivery monitoring and application of cover materials.

June 2008: Leachate treatment facilities completed.

From June 2008: The leachate treatment started with recirculation.

WHAT WERE THE MAIN OBSTACLES ENCOUNTERED? HOW WERE THEY OVERCOME?

Problems and Challenges

The project faced the following problems and challenges during its planning and implementation:

- Total landfill area was filled up with waste, no suitable space was available for administrative and control area.
- All the drains were filled up with solid wastes causing severe drainage congestion. The dumped waste was vertically placed in an unstable condition and most of the places. the dumped waste occupied part of the road causing interference with the vehicular movement. During monsoon, the site was almost inundated and inaccessible. No working road was there, excavator was used to lift the waste for piling on top in an inefficient and costly manner. Fire hazard was very common in the dump site.
- The installation of leachate pipes at 20 feet depth by excavating the dumped waste was very challenging because sometimes the waste pile was broken down into the excavated trench and the trench was filled up with leachate and rain water.
- Construction of temporary road on waste was a difficult job because of the underlying soft and wet waste layer.

All the problems and challenges were carefully handled by expert guidance of the consultants and close supervision of DCC engineers. The Landfill Management Unit of DCC now operates the site properly as a sanitary landfill. DCC ensures the necessary human and financial resources, short term as well as long term planning and preparations and routine environmental monitoring to ensure that the landfill disposal is proceeding well.

WHAT RESOURCES WERE USED FOR THE INITIATIVE? SPECIFY WHAT WERE THE FINANCIAL, TECHNICAL AND HUMAN RESOURCES

The total Project cost is about 7 million US$ which has been allocated through Japan Bank for International Cooperation (JBIC) as the Japan Debt Cancellation Fund (JDCF) as shown in Table 1.

Table 1 The activities undertaken and respective fund allocations

Activity	Allocated Funds (in US$)
1. Transforming the existing dump site into sanitary landfill	
(1) - Preparation of administrative area (Old waste removal and base preparation)	907142
- Control Building	142857
- Weighbridge	75714
- Heavy equipments shed	187142
- Small laboratory	4285
- Others (Toilet, guard room)	10000
(2) Internal roads	300000
(3) Waste slopes formation	28571
(4) Leachate and landfill gas pipe networks	
- Leachate system	785713
- Landfill gas system	728571
(5) Waste disposal platform	80000
(6) Old waste excavation, storage and soil cover	285714
(7) Substation and Flood lights	571428
(8) Establish monitor wells	714
(9) Site fencing and gates	17142
(10) Others (office furniture, landscaping etc.)	10000
2. Extension of the new landfill area	
(1) Development of four waste disposal blocks with peripheral leachate pipes	2000000
(2) Development of two leachate ponds	114285

(3) Provision of aeration for the leachate treatment	214285
(4) Develop access roads	71428
(5) Others	7142
3. Other Costs	
(1) Engineering cost	21428
(2) Management cost	21428
Total	6584988

IS THE INITIATIVE SUSTAINABLE AND TRANSFERABLE? HOW THE INITIATIVE IS BEING REPLICATED OR DISSEMINATED THROUGHOUT THE PUBLIC SERVICE AT THE NATIONAL AND/OR INTERNATIONAL LEVELS AND/OR HOW IT COULD BE REPLICATED?

Sustainability of the Project

The project was inaugurated on October 2007 for full scale operation. Since then the landfill has been operating as a sanitary landfill with semi-aerobic system of waste stabilization including the provision of landfill gas venting system, leachate collection system with perforated pipes, storm water drainage and disposal system, waste delivery monitoring and application of soil cover materials.

DCC is realizing the operation and maintenance of the project from its annual revenue budget. Landfill Management Unit (LMU) of Waste Management Department (WMD) of DCC is in charge of the operation & maintenance.

The capacity building through the project, the establishment of LMU & the allocation of required operational budget by DCC ensures the sustainability of the project.

The Matuail Sanitary Landfill is the first of its kind in all of Bangladesh. Bearing this in mind DCC has made efforts to make known to other municipal authorities in the country about the activities of the landfill. These efforts have taken various forms of arranging site visits for officials of other municipalities and central government, holding seminars and workshops, and maintaining documented records of the development and operation, including DVDs.

Already 2-3 other city corporations in Bangladesh have indicated plans to develop their own sanitary landfills in the model of Matuail LF and DCC has been requested to provide technical and other advices to them.

The transfer of technology and institutional building is achieved through the project:

Technology

This is the first sanitary landfill in Bangladesh. The JICA landfill expert and the BUET consultant was involved in planning, design and implementation phase. The Semi-aerobic system of waste stabilization of Fukuoka University of Japan was adopted. Gravity drainage of leachate and storm water was introduced for separate management of leachate and rainwater. Aerated lagoons with recirculation facilities were introduced for leachate treatment. Simple and low cost technologies, local materials and local expertise were involved in landfill construction which ensures easy transfer of technology and sustainability.

Design, Planning and Management

The planning was carried out with the assistance of JICA experts. The design was done by BUET Consultants and the construction was carried out by local contractors under the supervision of DCC engineers. The LMU is responsible for the management of the operation and maintenance of all the landfill facilities. JICA experts assisted to develop the capacity of the LMU staff.

Capacity Development

DCC lacked the knowledge to operate the landfill site at the beginning. Training was held for the LMU staff, Operational Manual was prepared and regular briefings are given at the site which develops an institutional structure for regular operation and monitoring activities.

Organizational Arrangement

To operate and maintain the constructed landfill facilities properly, a Landfill Management Unit (LMU) has been formed under the Waste Management Division of the DCC. LMU has been staffed with the needed manpower and the required heavy equipment is being provided.

The project is well appraised and appreciated by the policy makers. It has opened up a window as a research field for the academic and research institutions. The dissemination of information of the landfill through organizing visits, seminars and technical workshops has gained attention of the officials of other municipalities and the central government. The visits of the donor agencies and professionals of neighboring countries have created opportunity for its replication to other countries.

WHAT ARE THE IMPACTS OF THE INITIATIVE?

Impact on Socio-Economic Activity

The socio-economic condition attracts many people to engage in waste picking activities. There are around 200 waste pickers working at the landfill site. The waste pickers' working conditions have significantly improved. Planning for introduction of a registration system for the waste pickers and providing them safety gears will bring positive impact in their socio-economic condition and thus contributes to poverty alleviation for the targeted groups.

Impact on Environment

The fundamental target of the project is to improve the old dump site into sanitary landfill with protection and preservation of environment. Significant reduction of environmental pollution has again created opportunity for diversified and better use of the surrounding area by the local people. The direct outcome and impacts of the project are as follows:

- waste management system and operational conditions of the landfill have tremendously improved due to the construction of control building, weighbridges, car wash pool, water supply and sanitation facilities, working road and platform, lighting facilities for night time operation and installation of monitoring and recording facilities.
- environmental conditions have been greatly improved due to the construction of leachate collection, gas venting system and surface drainage.
- leachate accumulation and drainage congestion have been eliminated.
- odour, fire hazard and fly breeding have been reduced.
- quality of surface water around the landfill site has significantly improved.
- aesthetic condition of the site has been drastically improved due to the waste slope reformation (1:3), landscaping, grass turfing and plantation.
- the service life of the existing dump site has been greatly extended by the proposed multi-stage landfill system (total height 20 m). This type of land-saving project is very much needed as land is extremely scare and costly in and around Dhaka City.

The Indirect impacts/secondary effects of the Project can be stated as follows:

- the project has raised the awareness of central government officials on the need for sanitary landfill of the wastes
- the media coverage that accompanied the implementation and inauguration of this Project raised the awareness of the general public on solid waste management in general
- the DCC personnel especially the landfill instructors and heavy equipment operators are encouraged to carry out their duties spontaneously due to having improved aesthetic, environmental and operational conditions of the landfill site.
- significant reduction of environmental pollution has created opportunity for diversified and better use of the surrounding land area.
- the workers at the landfill site are provided safety gears such as hand gloves, long boots and gas masks for their personal safety resulting in reduction of occupational and health hazards.
- since this is the first landfill in Bangladesh, national companies and research institutes gained practical experience in planning, design and construction of sanitary landfill. It is expected that this practical experience will be employed in other cities of Bangladesh to construct landfills
- it will create an excellent opportunity for the over-crowded city dwellers of Dhaka Metropolitan area to develop a recreational facility at the landfill site after its closure.

WHAT ARE THE LESSONS LEARNED FROM THE CONSTRUCTION AND OPERATION OF LANDFILL?

During the implementation of the project, many valuable lessons were learned:

- optimum utilization of existing landfill site in order to avoid difficulties in finding new site for landfill.

- low cost technologies and locally available materials are to be used for development of the landfill facilities for ensuring sustainability of the development works.
- consultation with the field level officials and workers to include their reasonable ideas and suggestions in planning, design and operation of landfill facilities.
- expert guidance by local consultants and close supervision by engineers are essential to solve the peculiar local problems and challenges confronted during implementation of project.
- consultation with the local people to accommodate their pragmatic views into the project.
- regular training of the landfill staff to enhance their skill is essential for proper management of the landfill site.
- regular flow of fund is a must to procure and timely maintenance of heavy landfill equipment and operates the landfill satisfactorily.
- time to time appraisal of the project activities to higher officials and related central government agencies is required for building confidence and getting continuous cooperation.

The Matuail landfill has been operating in an improved condition since October 2007. The experiences during the operation of landfill are:

- a dedicated Landfill Management Unit is essential for smooth operation of the landfill.
- availability of the heavy equipments is required for daily operation.
- operation in the rainy season is very challenging. Special preparation need to be taken for the waste dumping during rainy season. Placement of steel plate in the dumping platform in the rainy season as practiced in Matuail may be a good practice.
- coordination between the landfill instructor and the drivers is needed.
- daily cover with matured waste can be an economic option for landfill.
- operational budget need to be ensured.
- weekly coordination meeting among the staff can identify and resolve problems in the landfill.
- wearing of safety gears (Boots, gas mask etc.), health check-up of the staffs are ensured.
- daily operational records/reporting and monitoring system is maintained.
- routine monitoring of environmental parameters (leachate, gas, surface and ground water) is key to maintain the landfill standard.

CONCLUSIONS

This is the first sanitary landfill of its kind in Bangladesh. The shift from the conventional practice to the improved and controlled system is a very challenging. The systematic dumping, staff motivation, budget, regular monitoring and coordination are important for effective management of landfill. The landfill site must be managed efficiently to minimize the adverse impacts on the surrounding environment. Environmental parameters monitoring and compliance are essential part of the landfill operation. A separate landfill management unit has to be set up to monitor the daily operation such as developing disposal plan, maintaining the daily operation records, and managing the heavy equipment operation and daily cover application. Moreover, good coordination with the transport and mechanical department is needed for effective operation.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.525-531

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Construction and Monitoring of Landfill Test Cells under Tropical Climatic Condition

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ABSTRACT

Two test cells (open cell and closed cell) were constructed by using the locally available construction materials. The cells were filled with the municipal solid waste and monitored for the first period of rainy and dry seasons under tropical climatic condition. The results indicate that the open cell simulation showed higher leachate generation during the rainy season and a halt during the dry season. No groundwater contamination has been found and shows the efficiency of the liner system.

INTRODUCTION

The problem of municipal solid waste (MSW) management has acquired an alarming dimension in the developing countries during the last few decades (Visvanathan et al. 2004). The development of urban and rural areas and the changes of consumption patterns have resulted in a quantum jump in solid waste generation. In developed countries, landfill design and construction technology has advanced rapidly in response to more stringent regulatory requirements and demands. The modern landfills are required the systems, such as the leachate collection and removal system, liner design, final cover system, gas generation and management, and groundwater monitoring system.

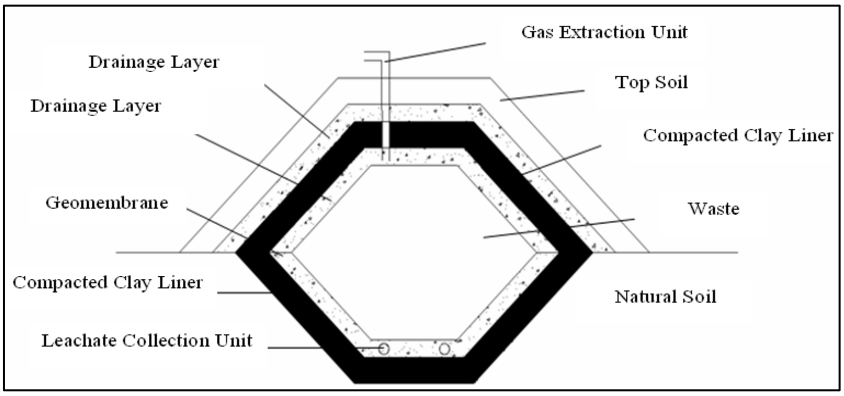
In south and Southeast Asian countries, however open dumping is a prevalent MSW disposal (Visvanathan et al. 2004). Even in large metropolitan areas such as Bangkok, open dumping was the standard of practice of solid waste disposal until recently. Almost of the solid waste in Bangkok has been disposed in sanitary landfill since 2000 (Bangkok State of the Environment 2005). Ashford et al. (2000) surveyed the distribution of landfill styles in Thailand and showed 52% open dumps, 37% non-engineered landfills, and 11% engineered landfills. The non-engineered landfill means that the disposal site must be operated with at least a daily cover, the waste be compacted and a final soil cover applied.

While the open dumps are not acceptable landfill practice in developed countries, the approach of open dumping has been suggested as one of the suitable options for developing countries (Visvanathan et al. 2007). In this approach, the amount of leachate generated from open cell is stored during rainy season, and recirculated during dry season to provide moisture in waste, accelerate biodegradation and lead to rapid waste stabilization. While the previous studies focused on the leachate management, the landfill design and construction need to consider the leachate collection and removal systems, liner design, final cover systems, gas generation and management, and groundwater monitoring system. In addition, both heavy rainfall and flooding are major difficulties that must be dealt with in the design, construction and operation of landfills because the quantity and quality of leachate from landfill are influenced by tropical seasonal variations (Tränkler et al. 2005).

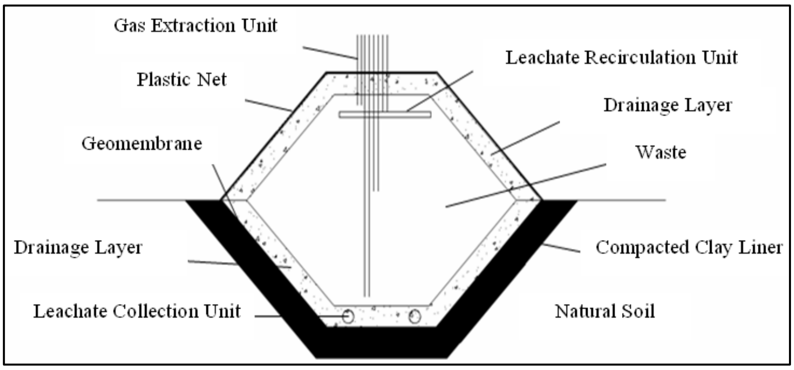
In order to examine the operation of landfill in the open and closed cover systems and identify the general behavior in both of systems, two small-scale test cells (closed cell and open cell) were constructed by using the locally available construction materials and filling the municipal solid waste. Then the first period of rainy and dry season was monitored and the operation of two cells is compared.

CONSTRUCTION OF TEST CELLS

Two test cells were constructed at Latlumkaeo, Pathumthani, Thailand. Fig. 1 shows the details of constructed test cells.



(a) Closed cell



(b) Open cell

Figure 1 Test cells

Each test cell was constructed with four elements: bottom liner system, leachate collection and removal system, gas collection system and top cover system. As the bottom liner system, the composite liner was constructed by using the compacted clay liner (300 mm thick) and HDPE geomembrane (1mm thick). As the leachate collection system, the drainage layer (200 mm thick gravel) and perforated PVC were used. The gas collection system and landfill cover design were different in open and closed cells. Although the PVC pipes were used in both cells to detect the gas, the gas emission has been monitored at four different points (0.45 m, 1.05 m, 1.75 m and 2.0 m below the top level) in the open cell and two different points (top and bottom of the cell) in the closed cell (Fig. 1). The top cover of closed cell was composed of two gravel layers (200 mm thick each), the compacted clay layer (300 mm thick) and top soil (300 mm thick). In a cover system of open cell, gravel drainage layer (200 mm thick) and plastic net were used for the rainfall percolation and the control of birds, flies and insects.

For the compacted clay liner, laboratory tests were carried out to identify physical and engineering properties of soils near the test cells site. The clay, classified as inorganic clay with high plasticity (CH), was considered to be suitable for the compacted clay liner (Suweero 2009, Zin 2009). The clays were compacted at water content of 30% less than optimum to obtain high hydraulic conductivity. The sand cone test was conducted to check the effectiveness of compaction during liner construction and the achievement of the required density.

Municipal solid wastes were collected from Bang Luang, Pathumthani province, and mainly consist of organic fraction (55 %) with an average moisture content of 50%. The composition of the wastes is shown in Table 1, and compared with typical MSW composition from Thailand. The compaction density of 352 kg/m^3 was used in open cell, while 618 kg/m^3 was used in closed cell. Total 3.4 ton and 5.8 ton of MSW was disposed in the open and closed cells, respectively.

Three ground water monitoring wells were constructed around test cells to estimate the groundwater quality and the effectiveness of test cell performance. The quality of groundwater was checked using the parameters, such as pH, conductivity, alkalinity, turbidity, COD, TKN, and heavy metals.The monitoring and sample collections were performed on a weekly basis during the first rainy season.

Table 1 Composition of MSW

MSW	Test cells	Pathumthani	Thailand
Food & vegetables	52.3	49.6	38.6~67.2
Plastic	29.02	24	4.06~20.89
Paper	4.86	4.5	1.69~23.86
Cloth, yard waste	7.58	12	1.6~11.96
Rubber, leather	2.74	3.9	0.37~4.72
Glass, stone	2.32	2.7	1.05~30
Metals	0.6	2.9	0.8~6.6
Others	0.5	0.4	0.4~21.3

MONITORING RESULTS AND DISCUSSIONS

Leachate Generation

The relationship between weekly rainfall and cumulative leachate generation of the open cell (OC) and the closed cell (CC) is shown in Fig. 2. These data show the first period of cell operation from September 2008 to March 2009. During the first rainy season (September to mid-November 2008), high amount of leachate was generated from the open cell. The leachate generation from the open cell is about 2.5 times more than that of the closed cell. Considering about 46% of the moisture content and about 55% of organic waste composition, the amount of leachate generation is found to be strongly related to rainfall and cover system.

During the first dry season, little leachate was pumped out from the closed cell while the open cell had no leachate.

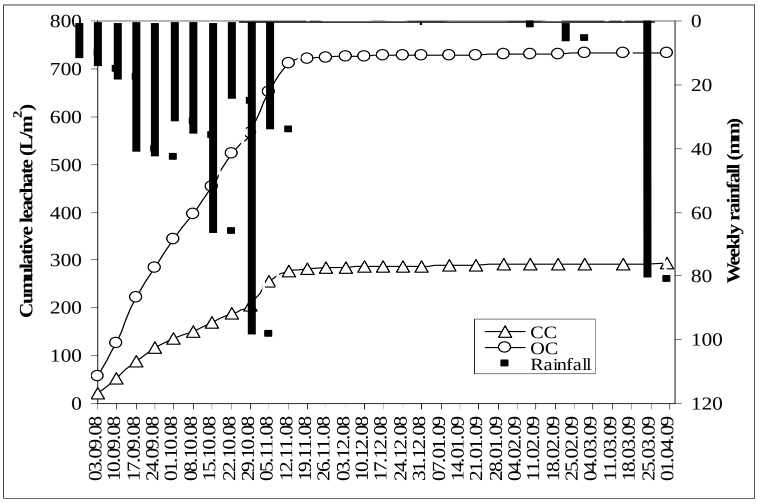


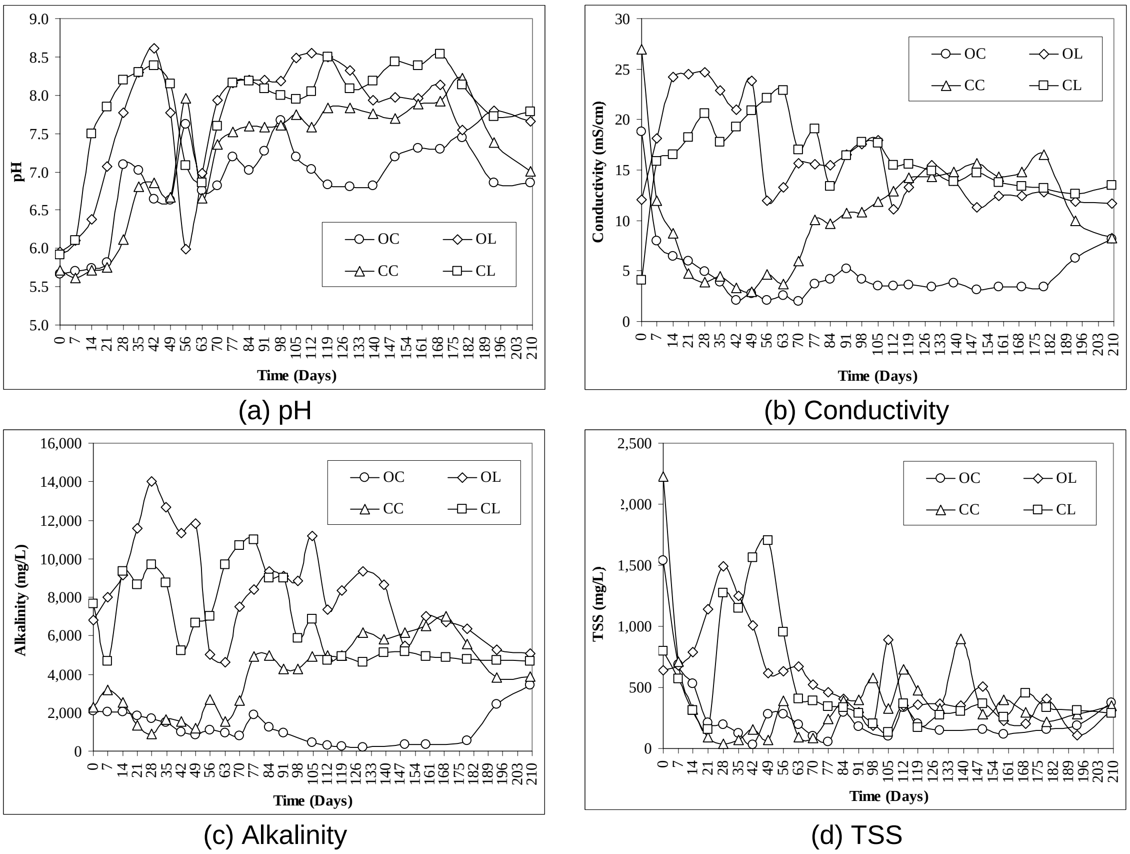
Figure 2 Cumulative leachate generation from open and closed cells

Leachate Characteristics

In order to identify the leachate characteristics, some parameters were monitored. The change of leachate concentration can be used as biodegradation indicator (Yuen et al. 2001).

Figure 3 shows the temporal variation of the physical properties, such as pH, conductivity, alkalinity and TSS (Total Suspended Solid) for two cells, together with the results of previous open lysimeter (OL) and closed lysimeter (CL). The pH was initially acidic and gradually increased to basic. Considering that the rainfall in this site area is acidic, this change may indicate the decomposition of organic biodegradable component in waste.

The conductivity and TSS were initially high values, but decreased during the rainy season. The conductivity and alkalinity in the closed cell were increased up to the same level of the previous open and closed lysimeters during the dry season. However, the conductivity and alkalinity in the open cell remained low values.



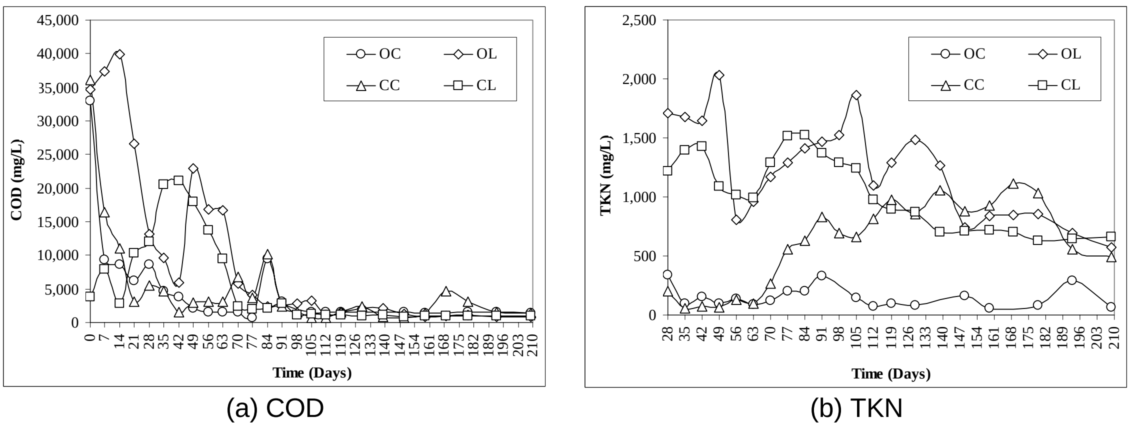
(a) pH (b) Conductivity

(c) Alkalinity (d) TSS

Figure 3 Temporal variation of pH, conductivity, Alkalinity and TSS

Fig. 4 shows the temporal variation of COD and TKN. The COD concentration was initially about 35 g/L, but dropped markedly with the rainfall. The COD concentration seemed to be diluted due to the rainfall events (Tränkler et al. 2005, Monteiro et al. 2002). The specific cumulative load of the COD is calculated as

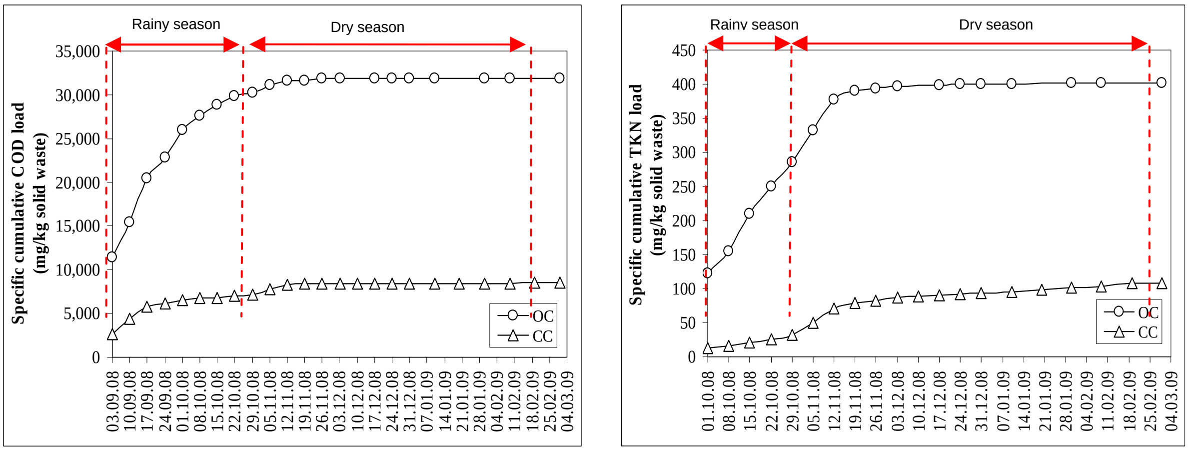
$$COD\ load\ (g/kg) = \frac{COD(g/L) \times leachate\ generation\ (L)}{Initial\ weight\ (wet\ basis)\ of\ \ waste\ (kg)} \qquad (1)$$



(a) COD (b) TKN

Figure 4 Temporal variations of COD and TKN

The values of the specific cumulative COD of open cell is higher than those of closed cell (Fig.5). The loading gradually increased during the rainy season, but did not change during the dry season due to low degradation and leachate generation.



(a) COD load (b) TKN load

Figure 5 Cumulative COD load and TKN load

The specific cumulative TKN load values of open cell are higher than closed cell. The loading of TKN gradually increased during rainy season.

Settlement Monitoring

Figure 6 shows the settlement variation of test cells. The settlement of the open cell is more than that of the closed cell. This may be expected because the compaction density of the waste in the closed cell is higher than that of the open cell. The primary settlement occurred rapidly within 1~2 months during the rainy season. The settlement was steadily increased for both cells during the dry season.

Groundwater Monitoring

Figure 7 shows some of the groundwater monitoring results. The results show that, for the first period of rainy and dry seasons, test cells are containing the waste effectively and not affecting the site groundwater.

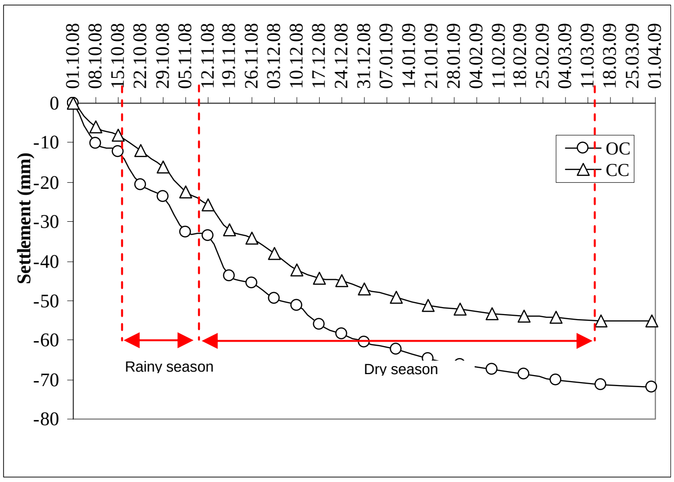
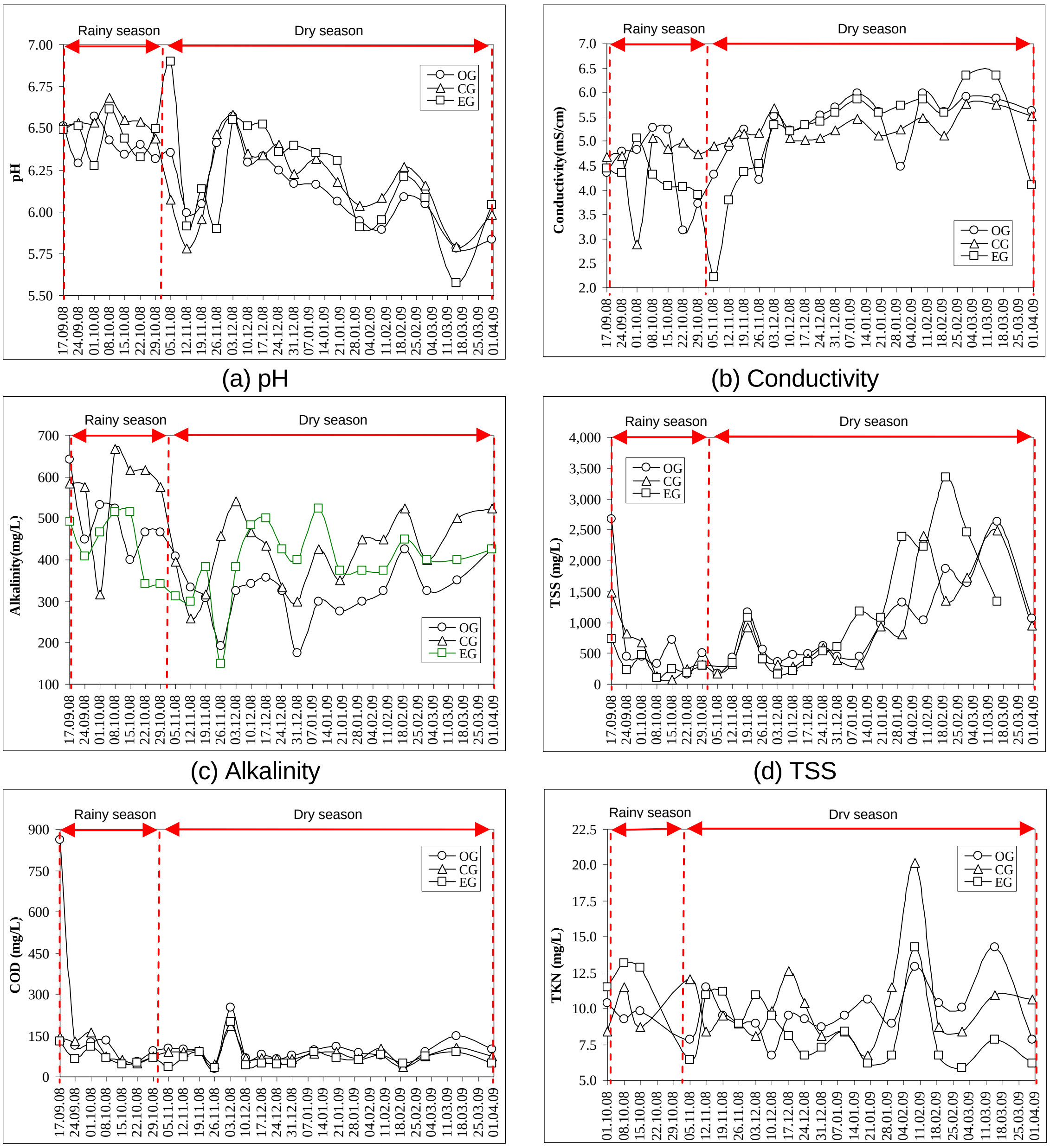


Figure 6 Variation of settlement in open and closed cells



(a) pH (b) Conductivity

(c) Alkalinity (d) TSS

(e) COD (f) TKN

Figure 7 Variation of physical properties in groundwater

CONCLUSIONS

In order to investigate landfill operation under the tropical climate condition, two test cells were constructed by using the locally available construction materials and filling the domestic waste. The first period of rainy and dry season was monitored. The following conclusions can be drawn:

(1) The rainfall is very sensitive in the open cell. The open cell simulation shows much leachate generation during the rainy season than that of the closed cell. The leachate generation was very little during the dry season in both test cells.
(2) The pH was increased, but conductivity, alkalinity, TSS were decreased during the rainy season. The COD was initially high concentration, but rapidly decreased with the rainfall events.
(3) The primary settlement occurred rapidly within 1~2 months during the rainy season. The settlement gradually increased during the dry season.
(4) The groundwater monitoring results showed that, for the first period of rainy and dry seasons, test cells are containing the waste effectively and not affecting the site groundwater.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support of EU-Asia Pro Eco II Programme of EC (ASIE/2006/122-432, 'Safe and Sustainable Management of Municipal Solid Waste in Bangladesh through the Practical Application of WasteSafe Proposal – WasteSafe II').

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.533-540

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Lignocellulolitic Enzymes Production: An Important Phenomenon for the Production of Citric Acid from Lignocellulosic Substrate through Solid State Bioconversion

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ABSTRACT

An investigation was carried out to determine the production of lignocellulitic enzymes: ligninase and cellulases (exo-cellulase and edo-cellulase) and their effects during the bioconvertion of empty fruit bunches (EFB) for the production of citric acid. The result shows that the maximum production of citric acid was 181.25 g/kg of dry EFB from A. niger IBO-114MNB after 8 days of bioconversion, 152.4 g/kg of dry EFB from A. niger IBO-103MNB after 6 days of bioconversion and 103.8 g/kg of dry EFB from A. niger IBO-109MNB after 6 days of bioconversion with the exo-cellulase production of 4.9 FPU/g EFB, 4.5 EFU/g EFB and 2.3 FPU/ g EFB as well as endo-cellulase was produced 8.6 CMC/g EFB, 8.3 CMC/g EFB and 3.8 CMC/g EFB, respectively. At the same time ligninase production was 6707.9 U/g EFB, 5020 U/g EFB and 3333 U/g EFB from IBO-103MNB, IBO-114MNB and IBO-109MNB, respectively. The degradation of cellulose and hemicelluloses content were 15.5-23.3% of initial contents that contribute 115-173 g sugar from 1 kg of dry EFB.

INTRODUCTION

Malaysia is the largest oil palm (*Elaeis guianeensis*) plantation country in the world and annually produced 17.08 million tons empty fruit bunches (EFB) as lignocellulosic solid waste (Chew and Bhatia 2008). The lignocellulosic material like oil palm empty fruit bunches (EFB), which is abundant in Malaysia contains high percentage of lignin, cellulose and hemicelluloses (Aziz et al. 2007). The cellulose and hemicelluloses (about 70%) are the source of sugar that might be main source of carbon for the production of citric acid through the solid state bioconversion by using fungal strain *Aspergillus niger*. The potentiality of any lignocellulosic substrate depends on its contribution as a source of carbon and nutrient as well as carrier for microbial growth. The role of empty fruit bunches as a carbon source dependent on the production of lignocellulitic enzymes and its hydrolysis during the bioconversion.

Citric acid is an organic acid that has been observed to be a commercially valuable microbial metabolite which is produced mainly through submerged (liquid state) fermentation of starch or sucrose based media, using the filamentous fungus *Aspergillus niger* (Haq et al. 2003; Lofty et al. 2007a,b; Barrington and Kim 2008). Because of its manifest use, citric acid is considered one of the most important fermentation products. Among the industrially produced organic acids, it has the highest amount in quantitative terms with an annual global production of about 1.4 million tons (Soccol et al. 2006).

As the global demand for citric acid is growing faster than its production while the cost of existing raw materials is increasing thus requiring an alternative economical process with new substrates to be an attractive over the SmF process. Solid-state fermentation (SSF) is an alternative method to submerged fermentation for citric acid production using agro-industrial residues as reported by several researchers (Imandi et al. 2008; Narayanamurthy et al. 2008). In recent years, a considerable interest has been shown in using agricultural products and their residues as alternative sources of carbon for citric acid production by using *Aspergillus niger* (Lofty et al. 2007a,b; Barrington and Kim 2008; Imandi et al. 2008). Having similar lignocellulosic characteristics of EFB like sugarcane bagasse, carob pod, cassava bagasse, corn husk which have been investigated by other researchers, it might be a potential alternative substrate for citric acid production (Kumar et al. 2003a,b; Prado et al. 2005a,b; Tran et al. 1998) . Therefore, the aim of this study was to determine the influence of lignocellulitic enzymes production on the production of citric acid from empty fruit bunches through solid state bioconversion.

MATERIALS AND METHODS

Major Substrate and Microorganisms

The major substrate, the oil palm empty fruit bunches (EFB), was collected from the Seri Ulu Langat Palm Oil Mill in Dengkil, Selangor, Malaysia and stored in a cold room at $4^{o}C$ to avoid the unwanted bio-degradation by the microorganisms. The EFB sample was milled to 0.5 mm down grade particle size by grinding after washing vigorously with tap water and drying at $105^{o}C$ for 24 hours (Bari et al. 2009). The ground EFB was dried at $60^{o}C$ for 48 hours to obtain constant dry weight for the experimental study. The characterization of EFB was carried out as 518 g/kg-EFB of cellulose, 224 g/kg-EFB of hemi-cellulose and 219 g/kg-EFB of lignin. On the other hand, report shows that it contains 4.4 g/kg-EFB of nitrogen, 1.44 g/kg-EFB of phosphorous, 22.4 g/kg-EFB of potassium, 3.6 g/kg-EFB of magnesium and 3.6 g/kg-EFB of calcium (Menon et al. 2003)

The fungal strains *Aspergillus niger* IBO-103MNB (IMI396649), IBO-109MNB (IMI396650) and IBO-114MNB (IMI396651) were selected for this study through a series of experiments such as isolation, purification and screening based on citric acid production by using EFB as a substrate. The fungal strains were maintained on 3.9% w/v of potato dextrose agar (PDA, Mark) slants, sub-cultured once in a month and stored at $4^{o}C$.

Preparation of Inoculum

The cultures of *A. niger* were grown on PDA plates at $32^{o}C$ for 4 days and washed with 15 ml sterilized distilled water to prepare the inoculum. Spore suspension was collected in a 100 ml Erlenmeyer flask by filtering with Whatman No. 1 filter paper. The spores were counted with the haemocytometer to maintain the density of 1×10^{8} spores/ml.

Experimental Procedure for Solid State Bioconversion

Twenty grams (20g) of total fermentation media of EFB (particle size ≤0.5 mm) on wet basis was prepared with 2% (w/w) sucrose and 1 ml (5% v/w) mineral solution adopted from slight modification of Erikson et al. (1980) containing $NH_4H_2PO_4$, (2 g/l); KH_2PO_4, (0.6 g/l); K_2HPO_4, (0.4 g/l); $MgSO_4.7H_2O$, (0.5 g/l); $CaCl_2.2H_2O$, (74 mg/l); Ferric acid citrate, (12 mg/l); $ZnSO_4.7H_2O$, (6.6 mg/l); $MnSO_4$, (5 mg/l); $CuSO_4.5H_2O$, (1 mg/l); and thiamine hydrochloride, (0.1 mg/l) (Alam et al., 2009). The moisture content of 70% (v/w) was adjusted with mineral solution, inoculum and distilled water. Inoculum was added after sterilization of media by autoclaving at $121^{0}C$ for 15 minutes. The bioconversion experiment was carried out in 250 ml Erlenmeyer flask. The culture media was incubated at $32^{0}C$ for 1 to 10 days. The initial pH of the substrate recorded varied from 5.5 to 5.8 but was not adjusted during the bioconversion process.

Harvesting and Extraction of Citric Acid

Harvesting and extraction of citric acid were carried out after 1, 2, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 9 and 10 days of bioconversion. Fifty milliliters (50 ml) of distilled water was added to the fermented substrate and mixed with a spatula thoroughly for homogeneity in the dilute. Fermented media was shaken at 150 rpm for 1 hour at room temperature ($28\pm1^{0}C$) in a rotary shaker (Tran et al. 1998). The supernatant was collected by filtering with Whatman no. 1 filter paper and allowed to pass through a 0.2 μm filter and immediately analyzed by the HPLC to determine the content of citric acid.

Determination of Citric Acid

The concentration of citric acid in extract was determined by the Waters HPLC instrument equipped with a refractive index detector (RID) and Shodex RSpak KC 811 column (inner dia. 8×300 mm, Shodex, Japan). The eluent used for the analysis was 0.1% phosphoric acid solution. The HPLC analysis was carried out under the following operation conditions: pump flow, 1 ml/min; column temperature, 40^0C; sample volume 5 μl; integration method and peak area. Concentrations were automatically calculated by Breeze software (version 3.3), Waters corporation, U.S.A. The production of citric acid was expressed as g/kg-EFB.

Determination of Consumption of Sugar

The consumption of total sugar during the bioconversion was estimated by subtracting the existing total sugar after bioconversion from the initial total sugar and sugar added during the bioconversion. The existing total sugar was determined by the phenol sulfuric acid method of Dubois et al. (1956) with spectrophotometer at 490 nm.

Determination of Lignocellulitic Enzymes

There are three main types of enzyme found in cellulase systems that can degrade crystalline cellulose: exo-1, 4-β-D-glucanases, endo-1, 4-β-D-glucanase and cellobiase. The activity of exo-1, 4-β-D-glucanases (exo-cellulase) was determined using Filter Paper (Ghose, 1987). This assay is recommended by the Commission on Biotechnology (IUPAC) for the measurement of activity of total cellulose or true cellulose activity. The assay is based on estimating a fixed amount (2 mg) of glucose from a 50 mg sample of filter paper. The soluble derivative of cellulose, carboxymethyl cellulose (CMC), is widely used for the assay of endo-1, 4-β-D-glucanase (endo-cellulase) activity. Activity on carboxymethyl-cellulose was determined by measuring the increase in redusing power of the solution or the fall in viscosity (Ghose 1987).

Lignin Peroxidase (LiP) assay was carried out by the method suggested by Tien and Kirk (1984). The standard activity of LiP was measured on the basis of the oxidation reaction of Veratryl alcohol in the presence of hydrogen peroxidase. A 600 μl of Veratryl alcohol solution (10 mM) was mixed with 1.5 ml of distilled water, 50 μl of LiP sample solution and 600 μl of pH 2.5 tartrate buffer (0.25 M). The absorbance of the product, veratraldehyde, at 310 nm was measured for 1 minute after the addition of 240 μl of 5 mM H_2O_2. The activity was estimated by the following equation:

$$Enzyme\ activity = \frac{\Delta A}{\min} \times \frac{1}{\varepsilon} \times \frac{TV}{SV} \times 10^6 \qquad (1)$$

Where, ΔA is difference of absorbance, ε is molar absorptivity, TV is total volume of sample and reagents and SV is total volume of sample taken.

Determination of Degradation of Lignin, Cellulose and Hemicellulose

The degradation of lignin, cellulose and hemicellulose were estimated by determining the differences of lignin, cellulose and hemicellulose contents at before and after bioconversionin of EFB for citric acid production. Acid insoluble lignin was determined according to TAPPI T222 om-88 test method and acid soluble lignin was determined according to TAPPI Useful Method UM-250. The total lignin content was estimated with the sum of acid insoluble and acid soluble lignin contents. Alphacellulose (true cellulose) content was determined according to TAPPI T203os-61 test method. The quantity of hemicellulose was estimated by subtracting the quantity of alphacellulose from the quantity of holocellulose. Holocellulose content was determined according to method developed by Wise et al. (1946).

RESULT AND DISCUSSION

The variation of production of citric acid with bioconversion time and the production of lignocellulitic enzymes as well as corresponding degradation of lignocellulosic materials were observed through this study. The release of sugar from substrate due to their degradation and consumption of sugar were examined during the bioconversion of EFB for citric acid production.

Production of Ligninase Enzyme and Corresponding Degradation of Lignin Content

The lignin is a complex phenolic polymer like other cell wall components of biomass that covers the inner material (cellulose and hemicellulose) which is mainly the source of sugar. The breakdown of lignin from cell wall is important for the exposure as well as degradation of cellulose and hemicellulose. The ligninase (lignin peroxidase) enzyme is capable to hydrolyze the lignin content. The Figure 1 shows the production of ligninase enzyme in terms of activity and corresponding degradation of lignin content of EFB. It was observed that the highest activity of ligninase obtained after 2 days of bioconversion for all strains. The highest production of ligninase enzyme of 6708 unit/g-EFB was found for strain IBO-103MNB followed by IBO-114MNB and IBO-109MNB. The ligninase activity gradually decreased after 2 days of bioconversion. This decrement is might be due to stoppage of enzyme production or higher rate of utilization compare to production rate.

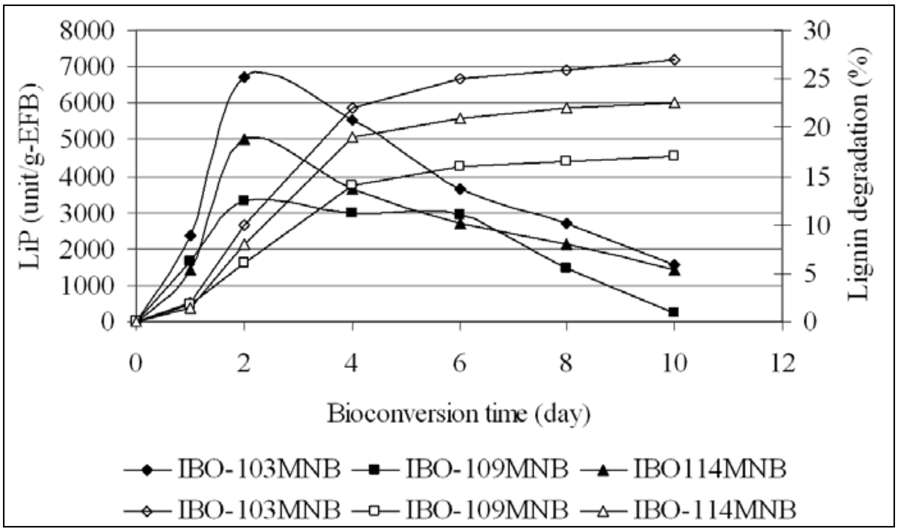

Figure 1 Production of ligninase and degradation of lignin content

The degradation of lignin fraction of EFB by the attack of ligninase enzyme occurred corresponding to the production of enzyme. About 17-27% of lignin fraction was degraded after 10 days of bioconversion and 14-22% of lignin was degraded within 4 days of bioconversion by strain IBO-103MNB, IBO-109MNB and IBO-114MNB. From the above results, it can be said that the strain of *Aspergillus niger* IBO-103MNB, IBO-109MNB and IBO-114MNB were able to liberate ligninase enzyme to degrade lignin content presents in the cell wall of EFB for the easy access of cellulose and hemicellulose from the beginning of bioconversion. In addition to that, maximum produced enzyme was utilized within the first phase of bioconversion and degradation was become slower corresponding to the availability of enzyme. Furthermore, the rate and amount of degradation varied for the different strains according to the enzyme production ability.

Production of Cellulolitic Enzymes and Degradation of Cellulose and Hemicellulose

There are three main types of enzyme found in cellulase systems that can degrade crystalline cellulose: exo-cellulase (exocellobiohydrolase: 1,4-*β*-D-glucan cellobiohydrolase), endo-cellulase (endo-1,4-*β*-D-glucanase: 1,4-*β*-D-glucan glucanohydrolase) and *β*-glucosidase (*β*-D-glucoside, glucohydrolase), or cellobiase. Exocellobiohydrolases are found as major components in some cellulase systems. Endo-cellulases hydrolyze cellulose chain at random to produce a rapid change in degree in polymerization. Hydrolysis of amorphous cellulose yields a mixture of glucose, cellobiose, and other soluble cellooligosaccharides. The rate of hydrolysis of the longer chain cellooligosaccharides is high, and the rate increases with degree of polymerization: glucose and cellobiose are the principal products of the reaction. Some endo-cellulases act in synergism with the cellobiohydrolase isolated from fungal cellulases to solubilize crystalline cellulose.

The results of exo-cellulase and endo-cellulase as well as degradation of cellulose and hemicellulose are presented in Figure 2. The highest production of exo-cellulase and endo-cellulase were obtained after 2 days of bioconversion all strains. The highest activity of exo-cellulase and end-cellulase were obtained of 4.9 FPU/g-EFB where substrate was Whatman no. 1 filter paper and 8.6 CMC/g-EFB where CMC was used as substrate, respectively for strain IBO-114MNB followed by IBO-103MNB and IBO-109MNB. The enzyme production decreased gradually after second day of bioconversion which is advantageous for the degradation of cellulose at the first stage of bioconversion.

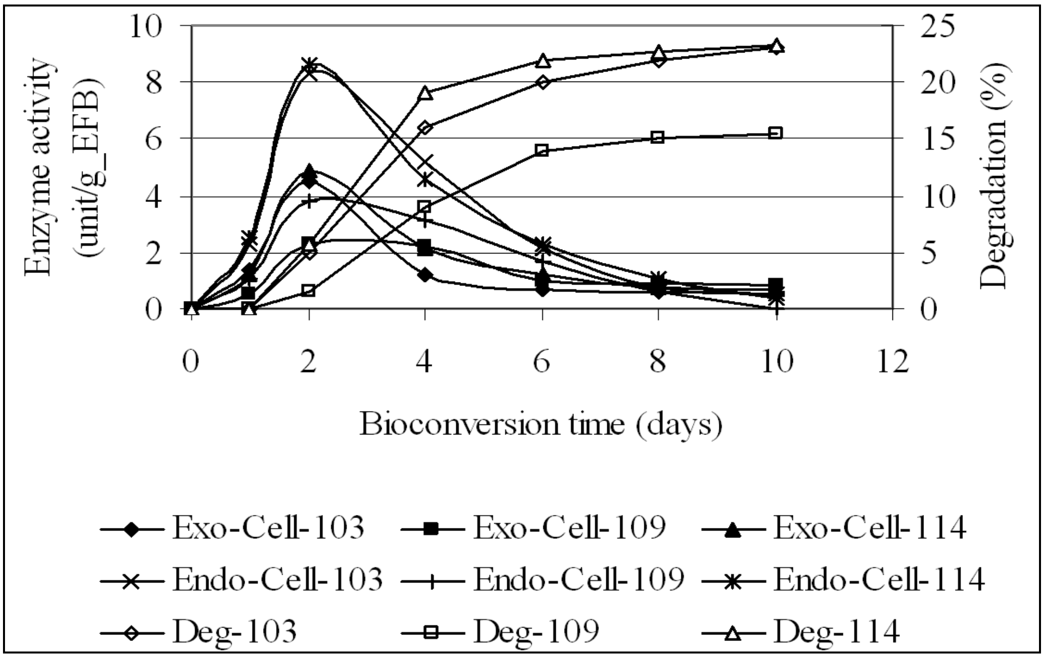

Figure 2 Production of cellulase enzymes and degradation of cellulose and hemicellulose

The degradation of cellulose and hemicellulose was started after 1 day of bioconversion and 19% degradation was obtained after 4 days of bioconversion while 23.3% was found at the end of bioconversion for strain IBO-114MNB. More than 13% degradation was obtained between 2 and 4 (48 h) days of bioconversion. The degradation of cellulose and hemicellulose continued after 4 days to the end of bioconversion at slow rate. The sharp decrease of cellulase activities within 2 to 4 days of bioconversion was might be due the maximum utilization of enzymes for the degradation of cellulose at the same time (Figure 2). From Figure 2 it is evident that degradation of cellulose is proportional to the availability of cellulase enzyme activities. The trend of degradation of cellulose and hemicellulose was same for all three strains and quantity of degradation varied depending on the variation of production of enzyme activity. Therefore, the degradation after 4 days of bioconversion was not increased reasonably. This might be due to shortage of enzyme activity for long term degradation.

Release of Sugar from the EFB to the Bioconversion System

The release of total sugar by the degradation of cellulose and hemicellulose content of the EFB due to the application of cellulase enzyme system that produced during the bioconversion of EFB for citric acid production by the same strain Aspergillus niger IBO-103MNB, IBO-109MNB and IBO-114MNB is shown in Figure 3. The highest released of sugar at the end of bioconversion was to be 173 g/kg-EFB which is 17.3% of the total EFB for strain IBO-114MNB followed by IBO-103MNB and IBO-109MNB. It is also observed from the characteristics of EFB that cellulose and hemicellulose contents are 74.28% of total EFB (Bari et al. 2009). From these two results it is observed that more than 23% of available sugar in EFB was obtained by the degradation of cellulose and hemicellulose through the bioconversion that contributes the higher production of citric acid.

Figure 3 shows that the release of sugar was started after 1 day of bioconversion as degradation started (Figure 2) and sharply increased within 2 to 4 days of bioconversion. The rate of sugar release was slower within 4-6 days and at the end it became flat. Since the release of sugar from EFB was by the degradation of cellulose and hemicellulose, the trend of sugar release was similar to the trend of degradation.

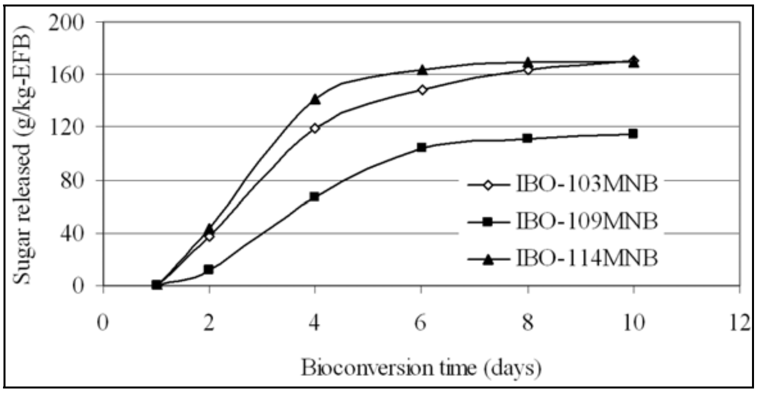

Figure 3 Released sugar from EFB during the bioconversion

Consumption of Sugar and Production of Citric Acid

The consumption of sugar was very high after 1 day to 4 days for strain IBO-103MNB and IBO-114MNB and after 1 day to 2 days for strain IBO-109MNB (Figure 4). Before and after this the consumption of sugar was less. These phenomena can be related with the fungal growth (data not shown) and citric acid production. The reason of less sugar consumption at the beginning (during the lag phase) might be due to the starting of germination of fungal spores. After germination, the demand and consumption of sugar was high for their growth (biomass formation), enzyme production and citric acid production simultaneously. This happened from lag phase to logarithmic growth phase. During the stationary growth phase, sugar consumed only for citric acid production where growth already stopped. The small consumption of sugar at the last stage can be explained with no formation of biomass, no production of enzyme and less production of citric acid.

The citric acid production trend with respect to bioconversion time is shown in Figure 4. It was observed that the production was very small after 1 day of bioconversion and then increased sharply within 1 and 2 days of bioconversion. The highest production of citric acid of 181.25 g/kg-EFB was obtained after 8 days of bioconversion for strain IBO-114MNB while total released sugar was 169.3g/kg-EFB and consumption of sugar was 240.8 g/kg-EFB. However, the highest production of citric acid from strain IBO-103MNB and IBO-109MNB were of 152.4 g/kg-EFB and 103.8 g/kg-EFB, respectively after 6 days of bioconversion. The decreasing trend of production was observed after reaching at the highest production to the end of bioconversion. This can be caused by depletion of substrate availability (Alam et al., 2008). The productivity for the highest citric acid production was estimated to be 22.7 g/kg-EFB/day for IBO-114MNB.

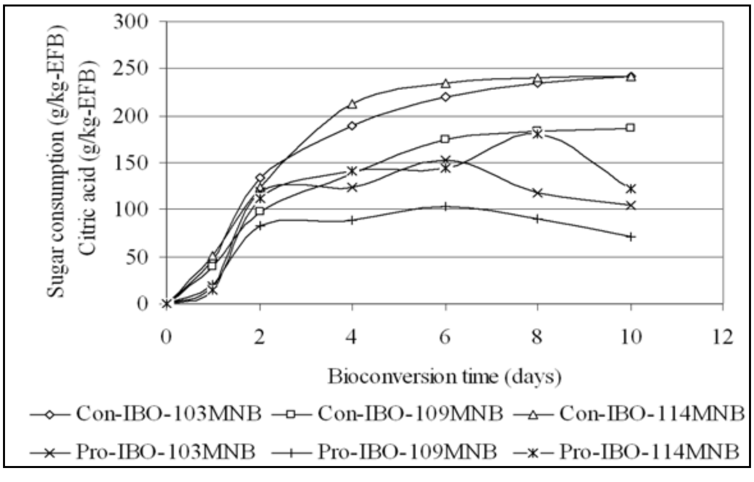

Figure 4 Production of citric acid and consumption of sugar

Yield of Citric Acid Production

The yield is important quantitative parameters for the description of bioconversion process. It can be estimated from Figure 4 that the yields of citric acid for highest production based on sugar consumption ($Y_{p/s}$) were 0.70, 0.60 and 0.75 for IBO-103MNB, IBO-109MNB and IBO-114MNB, respectively. The yield of citric acid production varied during the bioconversion of EFB might be due to simultaneous production of fungal biomass (growth), enzyme production and degradation of EFB and citric acid production.

The yield of citric acid production based on sugar consumption from the different lignocellulosic substrate that gave the highest production of citric acid through solid state fermentation can be discussed to evaluate the production of the present study. Prado et al (2005a) achieved 69% yield based on starch consumption for the production of 269 g/kg citric acid from cassava bagasse. Almost same (69.6%) yield based on sugar consumption has been achieved for citric acid production of 206 g/kg sugarcane bagasse by Kumar et al. (2003b). Roukas (1999) obtained 55% yield of citric acid production based on sugar consumption to produce citric acid of 264 g/kg from carob pod. Now it is evident that the yield of citric acid production (77.4%) based on sugar consumption from EFB is a good achievement.

The literature showed that Hang and Woodams (2001) used high activity of commercial enzyme, Rapidase Pomaliq (Gist-Brocades) containing activity of 2600 unit/ml carboximethyl cellulose and 490 units/ml xylanase for the enzymatic hydrolysis of corn cobs which is also a lignocellulosic material. In that study highest production of citric acid of 603.5±30.9 g/kg of dry corn cobs was achieved through liquid state fermentation. However, the production of citric acid was 326.5±7.4 g/kg of dry corn cobs in the same study without using commercial enzyme. Therefore, it is observed from the above discussion that the cellulase enzyme played a significant role to increase the production of citric acid.

In the present study 3% (w/w) sugar which is 111 g/kg-EFB was added initially to the substrate for bioconversion. However, total sugar of 240.75 g/kg-EFB was consumed to produce 181.25 g/kg-EFB citric acid after 8 days of bioconversion while total released sugar was 169.3 g/kg-EFB. From these results it is found that additional 129.75 g/kg sugar was consumed from total released sugar of 169.3 g/kg-EFB.

CONCLUSIONS

The simultaneous production of lignocellulitic enzymes during the bioconversion of EFB by same strain played an influential role to enhance the production of citric acid. This study also can claim that it is a single step process for the production of citric acid from EFB by using single strain through the production of lignocellulolitic enzymes and subsequent release of sugar by the degradation of EFB due to the application of produced enzyme in the system. It could be expected that the production of citric acid can be improved through the improvement of production of lignocellulolitic enzymes activity.

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ISBN: 978-984-33-0761-3, Vol. 2, pp.541-550

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Application of Forced and Passive Aeration in Bin Composting

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ABSTRACT

Paying attention to the effective use of kitchen and garden waste after converting as compost, this study was conducted to investigate the effect of forced and passive aeration on bin composting process. A total of six runs of bin composting were performed using 50 liters capacity plastic container for both of the forced and passive aeration process. Suitable organic wastes were collected from student's hall of Khulna University of Engineering & Technology, KUET and saw dust from local sawmills and paper from offices of KUET. The solid wastes from individuals were mixed with the selected proportions. Physical parameters like moisture content, volatile solids and fixed solid were tested before and after the conducted experiments. Inside temperatures of the bins were measured regularly. Degree and extent of degradation of waste mixture were identified through different composting process. Simple mass balance analyses were done for both the bin composting process. The analyses also help to characterize the compost. Considering the similar range of degradation and area under temperature curve, the passively aerated bin composting is suggested for batch purpose.

INTRODUCTION

Huge quantity of organic solid wastes is generating everyday from different cities and towns of Bangladesh. Municipalities and local government are under heavy pressure to find a sustainable and cost effective solution of solid waste management. Biological treatment offers a cost effective sustainable solution for the urban organic waste. In practice, the main biological process applied for solid waste is composting (Bari, et al. 2000). Composting is the biological degradation (in presence of oxygen) of highly concentrated biodegradable organic waste to carbon dioxide and water, where the biologically generated waste heat is sufficient to raise the temperature of the composting mass. The final product of composting is a stable humus-like material known as compost.

Each person is likely to produce 0.45 kg of solid waste per day with an organic content of 50 to 70 percent and moisture content between 60 to 70 percent (Ahmed & Rahman 2000 and WasteSafe 2005). These wastes either can be dumped directly into the land fill or can be converted to compost. If the wastes dumped directly into the landfill, it may create different problems due to the long term (more than several years) anaerobic reactions. The anaerobic reactions usually generate methane and other air pollutants. The leachate of this anaerobic decomposition can also pollute under ground water. On the other hand composting process offers a very short-term (few duration) treatment of solid waste. The final product after aerobic degradation is known as compost that can be beneficially used as soil conditioner, fertilizer or other purposes.

Some times larger scale composting process is difficult due to big investment and other management problems. However, there is an option that, the individuals can easily convert their kitchen and garden waste to compost using different bins. Kitchen waste is rich in nitrogen while garden waste is in poor. The compost produced from kitchen garbage in different seasons in Bangladesh has very good Nutrient values and also very good microbial quality and can effectively be used as soil conditioner (Moqsud and Rahman 2004).

Prodipan an NGO has already started composting project at Khulna City (Alamgir 2003). Small scale to family size bin composting processes has already been started at different places (Ahmed and Rahman 2000, WasteSafe 2005) in Bangladesh. However, very few scientific results are available so far. Presently, the research has greater importance in the field of solid waste management. The purpose of this study was to determine the effect of forced and passive aeration on the degree and extent of degradation of biodegradable organic solid waste generated from different house holds.

OUTLINE OF THE PASSIVE & FORCED AERATED BIN

The passive composting pile method involves forming the mix of raw material into a pile. The pile may be turned periodically primarily to rebuild the porosity. Aeration is accomplished through the passive movement of air through the pile. The pile should be small enough to allow the passive air movement. If it is too large, anaerobic zones form. Special attention should be given to the mixing of raw material. The mix must be capable of maintaining the necessary porosity and structure for adequate aeration throughout the entire composting period. The passive composting method requires minimal labor and equipment.

In forced aerated method the air is forced into the pile. The main difference between a passively aerated and forced aerated pile is that the forced aerated pile uses blowers that either suction air from the pile or blow air into the pile using positive pressure. The blowers used for aeration serve not only to provide oxygen, but also to provide cooling. Blowers can be run continuously or at intervals. Blower aeration with temperature control allows for greater process control than windrow turning. It should have a base layer and top layer much like the passively aerated windrow. The purpose of the base layer for the aerated static pile is to distribute air evenly either as it enters or leaves the aeration pipes. This requires porous material, such as wood chips or straw. The top layer is generally composed of finished compost or sawdust to absorb odors, deter flies, and retain moisture, ammonia, and heat. The initial mix and pile formation must have proper porosity and structure for adequate air distribution and even composting.

Figure 1 Forced aerated composting bin connected with air pump

Figure 2 Passively aerated composting bin fitted on a M.S. frame

In this study two plastic bins made of PVC drum with 50 liters capacity were used for both of the forced and passive aeration process. Some kind of low cost insulator made of cotton was provided around the bin to protect the generated heat due to the biological reaction of the organic waste. The inside temperature of the bins were increases up to about 50^0C to 60^0C. The insulator was 25 mm thick as like as quilt. An aquarium aerator was connected with forced aerated bin for supplying adequate aeration throughout the entire composting period. A wire net was provided at 10 cm from the bottom, for supporting the waste. The net also allowed the distribution of air inside the bin. Figure 1 show the forced aerated bin connected with air pump.

Figure 2 shows the passively aerated bin, which was fitted on a M.S. frame in order to facilitate the turning/rotation operation thereby allowing passive air movement into the waste.

The bin was over turned twice a day. A perforated PVC pipe with 50 mm diameter was inserted along the centerline (from top to bottom) inside the bin. Following the perforated pipe air was entered inside the bin.

METHODOLOGY

The study was performed by means of different mixing proportions for both of the passively and forced aerated bin. Suitable organic wastes were collected from student's hall of KUET and saw dust from local sawmills and papers from offices of KUET. Saw dust was used as bulking agent in composting process. The individual's solid wastes are mixed with such proportion to get a homogenous mixture and to put into the bins. Before and after experiments the physical tests like moisture content, volatile solid and fixed solid were performed. Two digital thermometers were inserted into the center of the bins for taking the inside temperature regularly. Two air pumps were connected with forced aerated bin for providing oxygen into the bin. The maturity period of compost was varying from 3 to 5 weeks.

Food waste was mixed with sawdust and waste paper (after cutting into small pieces). Generally Carbon-Nitrogen (C/N) ratio is very near to ideal value of plant life (BRAC 1997). The waste namely food, paper and sawdust were mixed with selected proportion to have a suitable C/N ratio ranged from 25 to 30 as suggested by Bari & Koening (2001). The experiments were performed in 6 different conditions. Table 1 shows the mixing condition of Exp-1, Exp-3, Exp-4 and Exp-6. Exp-2 and Exp-5 was a kind of 2^{nd} stage composting in which the mixed compost

Table 1 Initial waste mixture for different set of experiment

Type of Organic solid waste	% of weight						
	Exp -1		Exp- 3	Exp- 4		Exp-6	
	PAB	FAB	PAB	PAB	FAB	PAB	FAB
Food	60 (12)	60 (12)	55 (9.08)	48 (6.0)	48 (6.0)	33 (6.10)	33 (3.99)
Vegetable	18 (3.6)	18 (3.6)	20 (3.30)	20 (2.5)	20 (2.5)	27 (4.91)	27 (3.27)
Paper	10 (1.8)	10 (1.8)	7.5 (1.24)	7.5 (0.94)	7.5 (0.94)	20 (3.6)	20 (3.6)
Sawdust	12 (2.4)	12 (2.4)	12.5 (2.06)	12.5 (1.56)	12.5 (1.56)	20 (3.6)	20 (3.6)
Saw waste	-	-	5 (0.83)	5 (0.63)	5 (0.63)		
Total (kg)	20	20	16.5	12.5	12.5	18.4	12.1

PAB: Passively aerated bin, FAB: Forced aerated bin, Values in ( ) is in kg, Compost released from Exp-1 and Exp-4 were used as feedstock i.e. 2^{nd} stage in Exp- 2 and Exp-5, respectively

From the Exp-1 and Exp-4 was used as feedstock. In Exp-01, the percentage ratio of the waste mixture, food: vegetable: paper: sawdust was 60: 18: 10: 12, respectively.

EXPERIMENTAL RESULTS AND DISCUSSIONS

A variety of analyses were conducted by means of forced and passively aerated bin. It is generally accepted that maintaining temperatures between 45 ^oC and 65 ^oC (thermophilic temp.) allows for effective composting (Comp. 1). Time variations of temperature in bin composting process have been carried out through forced and passive aeration. Degree and extent of degradation up to the maturity of compost were identified through different stages of composting process. Simple mass balance analyses were also developed for both of the process.

Time Variations of Temperature in Different Experiments

In Exp-1 both the bins were run for 30 days. In passively aerated bin temperature was raised up to 50.2 °C. However, the inside temperature became fell down a few degrees after rotation of the system (Figure 3). In forced aerated bin the temperature was raised up to 50.4 °C (Figure 4), which is very close to each other. In passively aerated bin 50 °C temperature was stand for 10 days while in forced aerated bin it was for 3 days. The rate of temperature fall was sharp in case of forced aerated bin. Area under temperature curve before and after rotation was 8174 °Ch and 6819 °Ch, respectively. In forced aerated bin area under temperature curve was 9541 °Ch. The area under temperature curve, °Ch, is calculated by multiplying the biological heat generated in °C to the running time of the experiments in hours.

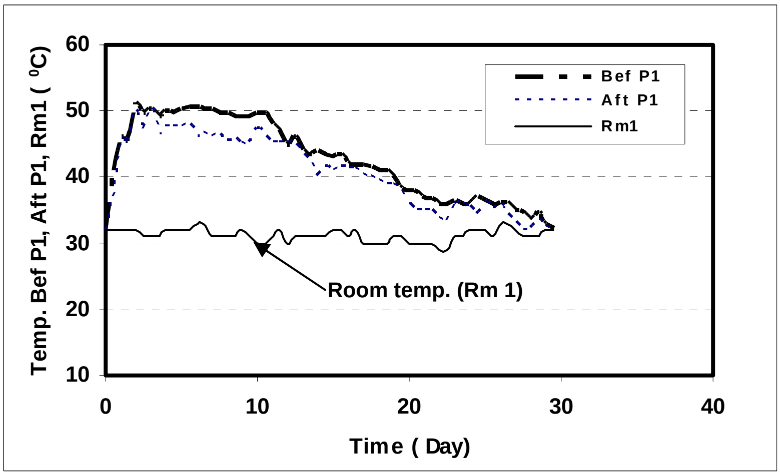


Figure 3 Time variations of temperature in passively aerated bin (Exp-1)

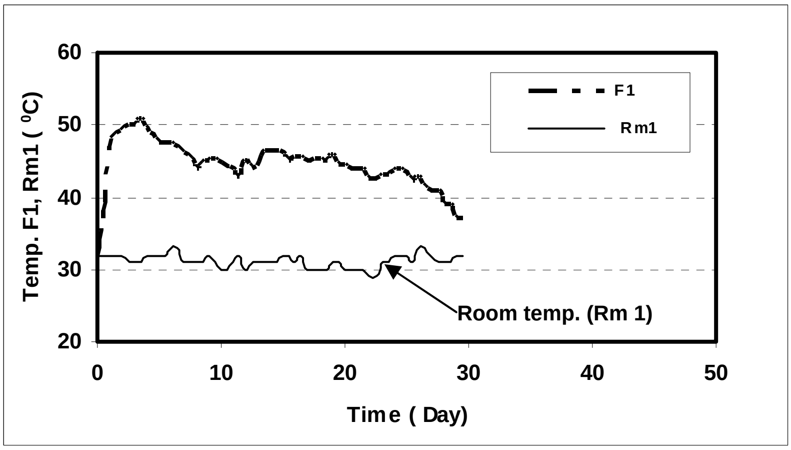


Figure 4 Time variations of temperature in forced aerated bin (Exp-1)

In Exp-3 only passively aerated bin was used to know the ideal condition of waste degradation. The duration of experiment was 30 days. The temperature inside the bin was raised up to 50.4 °C as shown in Figure 5. The area under temperature curve shows the satisfactory degradation. Area under temperature curve before and after rotation was 9150 °Ch 8197 °Ch, respectively.

In Exp-4 both the bins were run for 36 days. Inside temperature of passively aerated bin was raised up to 48.5 °C. However, it became fell down a few degrees after rotation of the system (Figure 6). In forced aerated bin the temperature was raised up to 51 °C (Figure 7), which is very close to passively aerated bin. In passively aerated bin area under curve with respect to ambient temperature was more than forced aerated bin. Area under temperature curve before and after rotation was 10584 °Ch and 10065 °Ch, respectively. In forced aerated bin area under temperature curve was 10350°Ch.

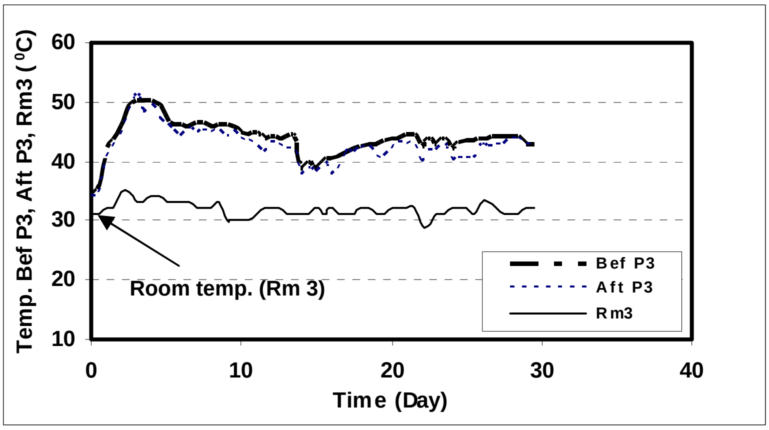


Figure 5 Time variations of temperature in passively aerated turned bin (Exp-3)

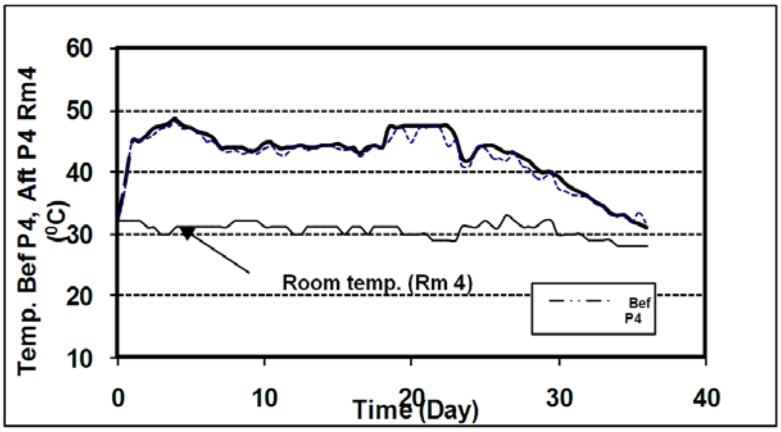


Figure 6 Time variations of temperature in passively aerated turned bin (Exp-4)

Compost released from the Exp-4 was mixed properly and used as feedstock in Exp-5. This feedstock was placed only in forced aerated bin for degradation. Then the system was run for 22 days and temperature was raised up to 47^{0}C (Figure 8). This could be the indication of more heat generation. Area under temperature curve was 6208^{0}Ch.

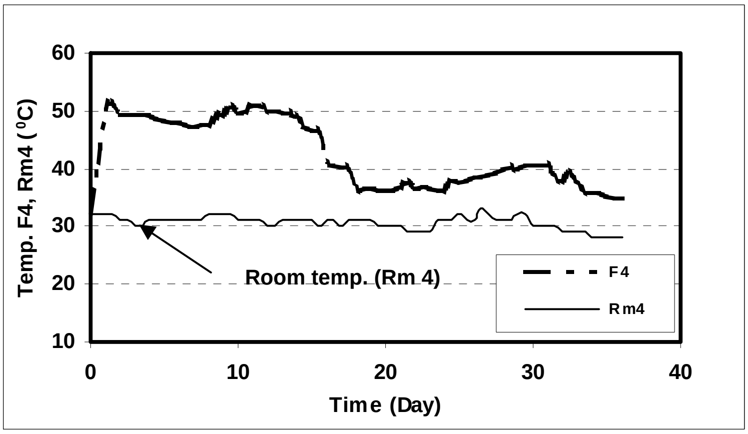


Figure 7 Time variations of temperature in forced aerated bin (Exp-4)

Figure 9 shows the time variations of temperature in passively aerated turned bin with intermittent waste feeding. In Exp-6 both the bins were run for 42 days. At a certain intervals specified wastes were feeded in the bins to know the optimum frequency of waste feeding specially for household purposes. At first day 25% of the total estimated waste was feeded in both the bins. In passively aerated bin the temperature raised up to 42.2^{0}C at 2nd day. The temperature was then fell down until the next feeding. Temperature rise and fall was continued up to 27th i.e. the day of last feeding. Final degradation was obtained between 27 th and 42 nd day. Area under temperature curve before and after rotation was 12640 °Ch and 12284 °Ch, respectively.

In case of forced aerated bin the area under temperature curve with respect to ambient temperature, Rm, was much more (23702 °Ch) than passively aerated bin (Figure 10).

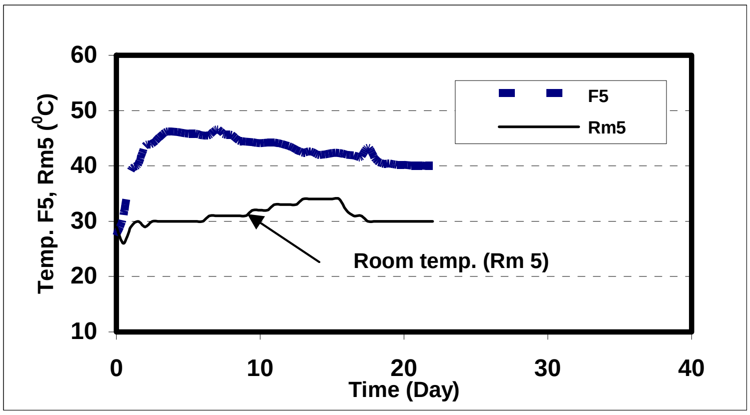


Figure 8 Time variations of temperature in forced aerated bin with feedstock (Exp-5)

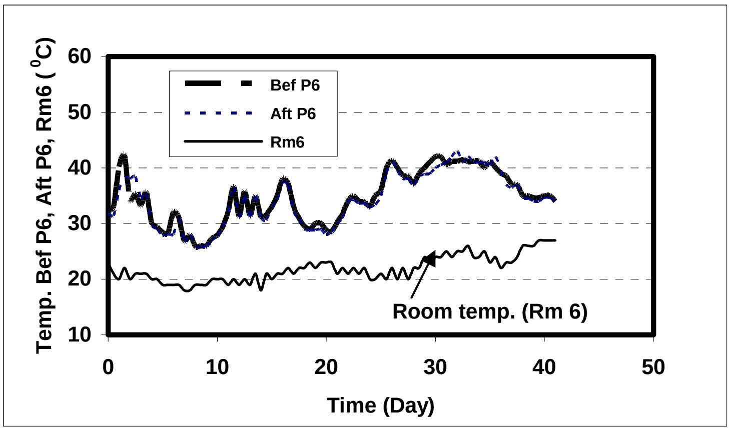


Figure 9 Time variations of temperature in passively aerated turned bin with intermittent waste feeding (Exp-6)

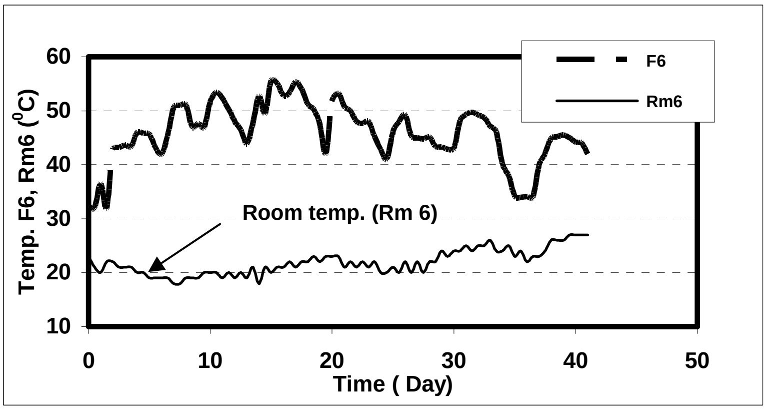


Figure 10 Time variations of temperature in forced aerated bin with intermittent waste feeding (Exp-6)

Simple Mass Balances for Different Experiment

During the experiments, mainly two types of wastes namely food waste (rice and vegetable) and waste paper were used. In addition, saw dust was used as a bulking agent. Generally moisture content between 40% and 65% should be maintained. The moisture content below ideal levels is the best approach (Becker and Köter 1995). Table 2 shows the moisture content and volatile solid of individual sample used in different experiment. Moisture content of the food waste was ranged from 55% to 79 %.

The water holding or water absorbing capacity of the compost material is also pertinent because the ideal moisture at which a material will compost is related to the water holding capacity of the material. Optimal biological activity occurs at 60 to 80 percent of the water holding capacity (Brinton 1993). Table 3 shows the changes in total mass, moisture content, volatile solids and fixed solids for the different set of experiment. Initial moisture content of the waste mixtures varied between 58 to 82 %. The ranges of initial and final weight of wastes poured into the passive and forced aerated bins were 12 to 20 kg and 7 to 17 kg, respectively.

The variations of weight as well as change of volatile solid were also calculated for all the experiment. The Figure 11 and 12 show the variation of volatile solid for Exp-1 and Exp-4, respectively.

Table 2 Moisture content and volatile solid of individual samples in different experiment

Experiment No.	MC/ VS	Food waste (%)	Vegetable waste (%)	Saw dust / Saw wood (%)	Waste paper (%)
Exp -1	MC	75.8	94.90	45.72	8.14
	VS	98.02	96.20	98.55	90.49
Exp-3	MC	72.5	85	45.38 / 10.41	9.81
	VS	99.2	86.89	96.09 / 99.26	92.60
Exp-4	MC	55.76	90.63	31	3.47
	VS	90.63	85.96	96.25	87.15
Exp-6	MC	79	88	40	14
	VS	92	92	97	95

In Exp-2 and Exp-5, the mixed compost released from Exp-1 and Exp-4 was used as feedstock

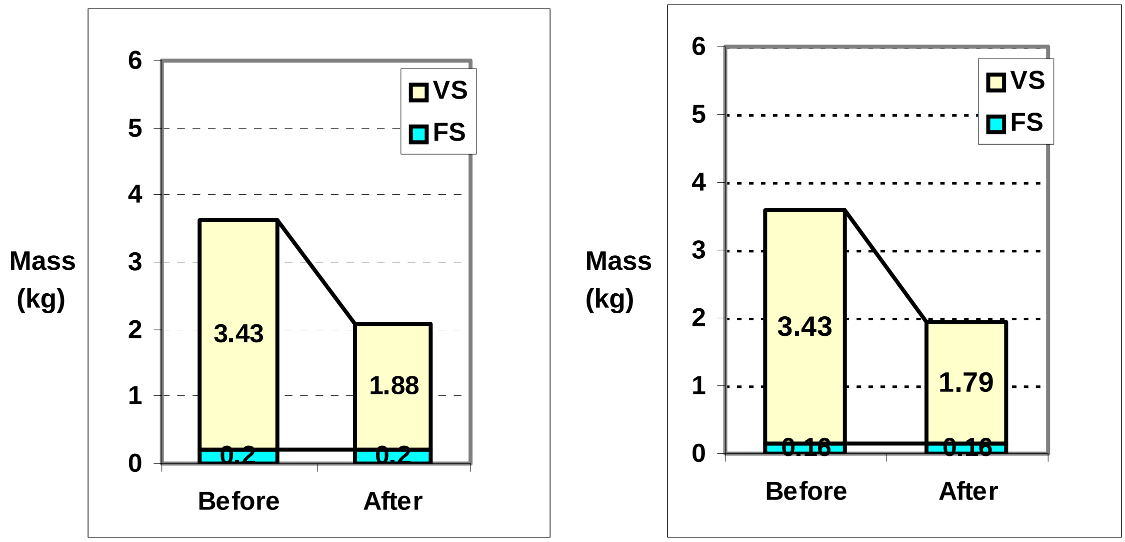
Table 3 Change in total mass, moisture content, volatile solid and fixed solid

Experiment No./Type		Mass (kg)		Moisture content (kg / %)		Volatile solid (kg / %)		Fixed solid (kg)	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final
Exp-1	P	20	11	16.40 / 82 %	8.91 / 81 %	3.43 / 95 %	1.88 / 90 %	0.20	0.20
	F	20	9.5	16.40 / 82 %	7.55 / 80 %	3.43 / 95 %	1.79 / 92 %	0.16	0.16
Exp-2	F	16	14	12.80 / 80 %	10.92 / 78 %	2.88 / 90 %	2.80 / 91 %	0.32	0.28
Exp -3	P	16.5	7	11.35 / 68.8 %	5.25 / 75 %	4.96 / 96.4 %	1.58 / 90.3 %	0.19	0.17
Exp-4	P	12.5	9	7.23 / 58 %	6.68 / 74 %	5.03 / 95.45 %	2.08 / 89.65 %	0.24	0.24
	F	12.5	7	7.23 / 58 %	4.70 / 67 %	5.03 / 95.45 %	2.03/ 88.26 %	0.24	0.24
Exp-5	F	14	10.5	10.5 / 75 %	8.09 / 77 %	3.08 / 88.11 %	2.0 / 83 %	0.41	0.41
Exp-6	P	18.4	17.4	11.4 / 62 %	10.78 / 62 %	6.44 / 92 %	6.02 / 91 %	0.56	0.56
	F	12.1	11.1	7.26 / 60 %	6.66 / 60 %	4.54 / 94 %	4.04/ 91 %	0.35	0.35

P: Passively aerated bin, F: Forced aerated bin

Table 4 shows the total and percentage change in moisture content and volatile solid of the conducted experiments. A general trend of volatile solid reductions was obtained for both the cases.

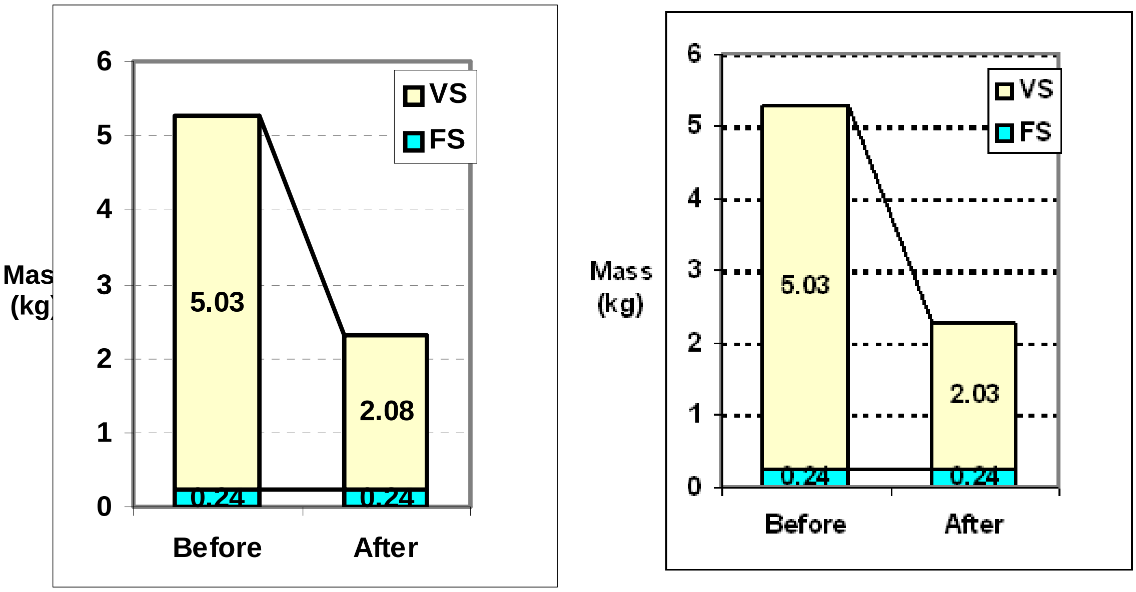
Table 5 shows the extent and degree of degradation of different experiments. The highest percentage of degradation (68%) was obtained in case of passively aerated bin with 30 days period of composting (Exp-3). This condition could support the suitability of passively aerated bin rather than forced aerated bin irrespective to other condition. In Exp-4, the percentage degradations for both of the bin were found to be very similar.



(a) Passively aerated bin

(b) Forced aerated bin

Figure 11 Mass variations in forced and passively aerated bins (Exp-1)



(a) Passively aerated bin

(b) Forced aerated bin

Figure 12 Mass variations in forced and passively aerated bins (Exp-4)

Table 4 Total and percentage change in moisture content and volatile solid

Experiment No./Type		Dur. of Exp (days)	Moisture content				Volatile solid			
			Initial (kg)	Final (kg)	Diff (kg)	Diff (%)	Initi. (kg)	Final (kg)	Diff (kg)	Diff (%)
Exp-1	P	30	16.40	8.91	7.49	45	3.43	1.88	1.55	45
	F	30	16.40	7.55	8.85	54	3.43	1.79	1.64	48
Exp-2 (2nd stage)	F	40	12.8	10.92	1.88	15	2.88	2.80	0.08	2
Exp -3	P	30	11.35	5.25	6.10	53	4.96	1.58	3.38	68
Exp-4	P	36	7.23	6.68	0.55	7.6	5.03	2.08	2.95	58
	F	36	7.23	4.70	2.53	35	5.03	2.03	3.00	59
Exp-5 (2nd stage)	F	22	10.5	8.09	2.41	23	3.08	2.00	1.08	35

Table 5 Extent and degree of degradation of different composting experiments

Experiment No.	Type of bin	Duration of Exp. (days)	Degree of degradation (%)
Exp-1	Passive	30	45
	Forced	30	48
Exp-2 (2nd stage)	Forced	40	2
Exp -3	Passive	30	68
Exp-4	Passive	36	58
	Forced	36	59
Exp-5 (2nd stage)	Forced	22	35
Exp-6 (intermittent waste addition)	Passive	42	31
	Forced	42	60

CONCLUSIONS

The following conclusions are drawn based on the results of the experiments:

(1) Similar set of composting using similar initial waste mixture shows almost similar area under temperature curve, that is the area is almost same for forced and passively aerated composting. In first experiment (Exp-1) the areas were 8174 ^{o}Ch and 9541 ^{o}Ch for passively and forced aerated bin, respectively. In another experiment (Exp-4) the areas were 10584 ^{o}Ch and 10350 ^{o}Ch for passively and forced aerated bin, respectively.

(2) The range of volatile solid degradation for passively aerated bin was 45-68 % with a range of area under temperature curve 8000-9000 ^{o}Ch and that of forced aerated bin; it was 48-59 % with a range of area under temperature curve 9000-10000 ^{o}Ch. It seems that the degradation is almost similar in both the processes.

(3) Almost no leachate and offensive odor were detected during the both composting experiments. This can be taken as effectiveness of the bin composting process.

(4) Most of the mass balance shows the general trend of volatile solid reduction from beginning to end of the process. This creates a physical feeling of mass reduction in composting process.

Considering the similar range of degradation and area under temperature curve for both the system, passively aerated bin composting can be used for batch purpose. It does not require any external energy for aeration. However, further study would be required to achieve the optimum composting degradation for a passively aerated bin with intermittent waste addition.

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Study on the Quality and Stability of Compost through a Demo Compost Plant

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ABSTRACT

This study is concerned with the performance of a Demo Compost Plant set-up for the development of acceptable composting technology for Bangladesh. The Demo compost plant was set-up at the adjacent area of existing compost plant of SAMADHAN. Here four different composting technologies are considered and the compost was produced using the Municipal Solid Waste (MSW) collected from the adjacent areas of the plant. The performance was verified through physical inspection, laboratory test of the compost. From the analysis of the experimental findings conducted so far it is revealed that passively aerated (horizontal aeration system) composting technique is suitable for Bangladesh.

The characteristics of compost depend on the waste composition and their properties. As the waste directly from kitchen, percentage of rapidly degradable waste is greater than others and toxic substance and metal type waste are less in the used waste for demo compost plant. So that qualities of generated composts satisfy the standard. The biologically stability or maturity of compost affects successful utilization in agricultural lands. The self-heating tests have been used to measure the degree of stability of compost.

INTRODUCTION

The scope and importance of conversion of waste into organic manure from both agricultural and environmental viewpoints demonstrate the need for under taking large scale composting product as well as marketing for product. Composting is an environment-friendly element of the integrated solid waste management strategy that can be applied to mix Municipal Solid Waste (MSW) Management or to separately collected leaves, yard waste and kitchen garbage.

Composting has been practiced in rural areas for centuries. Farmers traditionally put agricultural and some animal waste on their fields. This is mainly seen as a means of enhancing the soil. However, composting of urban waste has a different motivation. The main motivation is to reduce and recycle the waste, particularly comparatively low-value components of waste. Within the context of urban solid waste management, composting projects become more challenging. There is a different set of stakeholders and processes, involving communities, city governments, donors and private sector (Ali, 2004).

Disposal of increasing quantities of urban solid waste is became a major challenge for municipality. More stringent environmental regulations for new landfill sites and incinerators have introduced many new techniques of waste disposal. This includes costly and cost effective solid waste management policies. It is found from the characteristic analysis of solid waste particularly the domestic waste that it contains mostly organic wastes as kitchen garbage is the dominant part of domestic waste in Bangladesh. The huge quantity of organic waste, above 70% of total wastes (WasteSafe, 2005), can therefore be dumped directly into the landfill or can be degraded. If the waste dumped directly into the open landfill may create different problems due to long-term (20-30 years) anaerobic reactions. The anaerobic reaction usually generates methane and other air pollutants. The leachates of this anaerobic decomposition also pollute under ground water. On the other hand, if the degradable part of organic solid waste converted to compost offers a short term waste management. The composting is controlled aerobic biological decomposition of organic matter into stable, humus like product called compost. It is essentially the same process as natural decomposition except that it is enhanced and accelerated by controlling environmental conditions and mixing organic waste with other ingredients to optimize microbial growth.

The main objectives of composting are to reduce its volume, weight and moisture content, minimize potential odor, decrease pathogens and increase potential nutrients. This process minimizes spread of diseases because of the destruction of some pathogens and parasites at elevated (composting) temperature. The final product of composting is known as compost can be beneficially used as soil conditioner, fertilizer or other purposes. Never mix immature compost with the soil and cover this layer with soil because the natural decomposition process is not finished. With a lack of oxygen (by covering the compost- soil mixer with soil) anaerobic processes start and this is harmful for the plants (Bachert et al. 2008). Also immature compost has some environmental effects for further degradation reaction.

Historically the composting is applied in the different civilization including Europe, China and Bangladesh. In ancient day mostly animal manure and agricultural wastes are composted to produce organic fertilizer and to supplement the organic in the field, which are still popular in Bangladesh. Different types of composting ranged from crude to sophisticate technology, small to large and open to enclosed technologies are practiced all over the world considering the economy of the process, reaction rate, product quality (extent and degree of degradation) and market demand of the product. Despite the huge potential to convert a significant portion of MSW of Bangladesh into compost, this sector suffers several setbacks. With the view of the above objectives, a suitable composting technology for Bangladesh should be evaluated. To search an acceptable composting technology for the country, a Demo compost plant is built as a part of WasteSafe II research project in cooperation with a NGO named as Samadhan, in its premises at Khalishpur area of Khulna city in Bangladesh. The outcome of this research works are illustrated here to understand the impacts related to sustainable composting technology.

METHODOLOGY

After construction of demo compost plant, 1st set-up composting was studied using three type of aeration systems. There are two types of passive aerator frame - one is horizontal frame and the other is vertical. Horizontal frame is made by bamboo frame and vertical frame is made by perforated PVC pipe (Figures 2a & 2b). Length, width and height of horizontal frame are 2.4 m, 60 cm and 60 cm, respectively. Length and diameter of vertical frame are 1.5 m and 15 cm. There are pores on the surface of vertical frame with 6 mm dia @ 50 mm c/c. The aerator shown in Figure 2c was used for forced aeration. The forced aeration arrangement is also made by the PVC pipe of 10 cm dia and 2.4 m long. For forced aeration composting, a locally made air blower is bought and fabricated which is functioning well so far (Hasan et al. 2008).

(a) *(b)* *(c)*

Figure 1 Various types of aeration arrangement

Based on the findings of the 1st set-up of composting, in the 2nd set-up of test, forced aeration system was dropped (Figure 1c), while passively aeration system using both the bamboo (Figure 1a) and PVC pipe (Figure 1b) were continued. The forced aeration system, where a blower used which suck out the entrapped air into the compost pile and give the space for the fresh air into pile, runs by electricity. In Bangladesh there is shortest of power so, the system shutdown frequently. On the other hand, forced aeration system becomes expensive, which makes the high cost compost.

Collection of Waste

For marketing reasons, only separately treated green waste has a future. Over the last decades, some countries have shifted to separately collected green waste, so as to ensure a marketable quality of the product. This tendency was particularly marked in Germany, Holland, Austria and Switzerland, where the agricultural use of compost from MSW is forbidden since 1986. In many countries, composting is still considered a treatment process for MSW prior to landfilling (Ludwig et al., 2003).

The wastes which are used for composting in demo compost plant are mainly kitchen wastes collected by door to door collection system. There are three rickshaw vans engaged daily to collect the waste at the Samadhan Compost Plant from different householders of ward no. 14 and 15 of Khulna City Corporation.

Separation of waste

Separation means removal of non-biodegradable or non-compostable material from highly compostable materials. It is a necessary operation for any compost plant. From the Table 3, it can be seen that about 6% materials are non-biodegradable and unsuitable for composting. In demo compost plant separation is done by manually. Organic Waste are the remaining/unused part of vegetables, fruits, fishes, grasses, leaves, waste foods etc. which are sorted in the next step and un-compostable waste are Coconut shell, mango seeds, jack fruit seeds, bone, dead animal and birds, cloths, napkins, branches of trees, earthen pots etc which are thrown in dustbin although those are organic. In Figure 2, it is shown that the worker sorts the mixed solid waste. Sorting is started manually upon receiving the van from collection. Organic, inorganic and non compostable materials are separated immediately. Composting material and Re-cycling materials keep separate. In-organic and un-compostable waste are thrown in dustbin within the same day.

Shredding of waste

Material will compost best if it is between 12 to 25-12 mm in size (Raabe, Website). From the Table 6, it is found that about 40% material is greater than the mentioned size. After sorting of the waste, the larger particles are shredded in to smaller particles to increase the degradation rate and facilitates better aeration through the compost pile. In demo compost plant cutter is used to shred the wastes and shredding is done manually. A photograph of shredding process at demo compost plant is shown in Figure 3.

Figure 2 Sorting process of collected household solid wastes

Figure 3 Shredding processes of household solid wastes.

Mixing of Different Components

In demo compost plant, no additives were used with the waste in the experimental compost piles of 1st set-up except Samadhan's compost pile. The composting process of Samadhan's compost piles is reported at Sarwar et al. (2008). The shredded wastes are mixed with proper proportionate of water to obtain desired moisture content in the waste mixture. In composting system, suitable moisture content is necessary to avoid anaerobic condition and also for rapid degradation of organic waste.

To improve the temperature curves as per theory and the degradation rate of waste, two additives charts are introduced at the 2nd set-up according to the C: N ratio, which taken 16.08 for Khulna city (Alamgir et al. 2005), and the experience of the Samadhan Compost Plant. These two additives charts are applied to three types of compost piles at 2nd set-up. Additives Charts are presented in Table 1.

Table 1 Name of the mixing materials with waste and quantity

Components	Quantity		
	Compost pile #1	Compost pile #2	Compost pile #3
MSW	3000 Kg	3000 Kg	3000 Kg
Cow dung	55	55	45
Chicken liter	45	45	60
Saw Dust	75	75	-
Compost residue	150	150	150

Piling of Waste

After proper mixing of wastes at 2nd set-up, mixed wastes were mounted on aerator manually in two types of aerators. In this set-up three types of aerators were used to examine their performance as describe below and shown in Figure 4. However, different types of Compost pile at 1st set-up can be obtained at Hasan et al. (2008).

Compost Pile #1

In this compost pile a bamboo frame was used as aerator (Figure 1a), which lied horizontally into the compost pile. Total weight of mounted waste after mixing the additives was 3325 kg and the dimension of this compost pile was 105 cm width, 245 cm length and 138 cm height and formed about trapezoidal shaped cross section at the both direction e.g. along the length and along the width (Figure 4a). At the top of this shape were 87 cm and 138 cm along the width and length of the compost pile respectively.

Compost Pile #2

Here as an aerator perforated PVC pipe (Figure 1b) was used, which is placed vertically in the compost pile. In this compost pile, also 3325 kg wastes are mounted. Size of this compost pile is 256 cm length, 163 cm width and 115 cm height and formed about trapezoidal shaped cross section at the both direction (Figure 4b). At the top of this shape were 62 cm and 132 cm along the width and length of the compost pile respectively.

Compost Pile #3

This compost pile was same as compost pile #1, only difference from that is additives mixing. From the Table 1, it is shown that in compost pile #1 & #2, ratio of the additives are same but in compost pile #3, one type additives is absent and ratio is different. Sometimes sawdust is not available. To evaluate the difference, sawdust was cut off from compost pile #3. Here total weight of mounted waste after mixing the additives was 3255 kg and the dimension of this compost pile was 210 cm width, 245 cm length and 95 cm height. At the top of this pile were 75 cm and 132 cm along the width and length respectively. Compost Pile #3 is shown in the Figure 4c.

(a) Compost Pile #1 *(b) Compost Pile #2* *(c) Compost Pile #3*

Figure 4 Different types of compost piles of 2nd set-up at Demo Compost Plant

Turning of Compost Pile

Oxygen uptake is a very useful parameter, because it is a direct manifestation of oxygen consumption by the microbial population and hence, of microbial activity. Microbes use oxygen to obtain the energy to carry on their activities. A very effective means of monitoring for adequacy of oxygen supply is by way of the olfactory sense, namely, detection of odors (Tchobanoglous and Kreith 2002). A lack of oxygen likely favors the growth of anaerobic organisms which cause unpleasant odors. Turning is an important factor during the composting process to ensure sufficient air (Enayetullah et al. 2006). In aerobic composting more air is needed for more oxygen. When temperature reaches to more than 70^0C then it is reduced by turning. Turning makes inner materials to come out and outer materials to go in. Due to turning the composting process accelerate and uniformity can be achieved. Wastes are brought down from the pile then spread over the floor for certain period and after that these are brought back on aerator.

At 1st set-up, wastes were mounted on aerator for 80 days, because after 80 days the temperature of compost piles becomes more close to ambient temperature. Compost piles were turned in every week along this period. There was no development of odor problem during composting at this set-up.

Based on the experience of Samadhan compost plant, 2nd set-up was designed for 9 weeks, where wastes were mounted into compost pile for 6 weeks and degraded wastes were kept for maturation for remaining time. Since no odor problem at 1st set-up, turning was done only one time along first 6 weeks at 2nd set-up. Though turning is very useful for accelerate the composting process, practically it is painful for workers, causes health hazards, and also time consuming because the whole process of turning are done manually as shown in Figure 5.

Figure 5 Pictorial view of turning process

Maturation of the Compost

Since maturation phase is over within 80 days, degraded wastes, which were degraded at 1st set-up, were kept for one week at a designated place of the plant for drying and becoming suitable for screening.

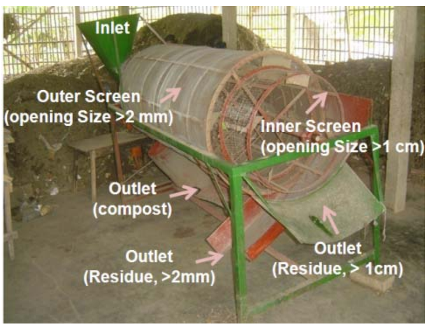
The wastes at 2nd set-up became compost within 6 weeks and the temperature came down to below 40^0C. Some of the wastes remain un-composted with higher moisture content, which can not be sieved. Compost shifted to another place for maturing after 6 weeks then after next 3 weeks the compost became matured and became suitable for screening.

Before screening, the degraded wastes were downloaded from piles and spread on the floor having thickness of 100-150 mm for one day. Degraded wastes became black-brown color, granular, soil odors or odor less at end of maturing stage.

Screening

Based on the general grain size of compost, 2 mm square hollow sieve fitted on wooden frame (Figure 6a) was used to find out the compost at 1st set-up. Before screening into the 2 mm hollow sieve, degraded wastes were screened into 12 mm square hollow sieve. A rotating screening system (Figure 6b), where two types of sieve (2 mm and 12 mm sq. hollow) are fitted, was used to screen degraded waste of 2nd set-up. Which pass through into the 12 mm hollow screen and retain on the 2 mm hollow screen are known as residue. Residue can be used back to the compost pile with the fresh waste to help the degradation process and reduce the odor and remaining portion is thrown away.

(a) Wooden frame screening system



(b) Rotating Screening System

Figure 6 Pictorial view of screening systems

QUALITY CONTROL AND ASSURANCE

The quality of composting process, plant environment and the outcome largely depends on the observation, monitoring and action taken to ensure the quality control. The aspects those were considered in the demo compost plant are described in the followings:

Monitoring of Temperature

Temperature is a very useful parameter because it is a direct indicator of microbial activity. The biologically produced heat generated within a composting mass is important for two main reasons:

1. To maximize decomposition rate; and
2. To produce a material, which is microbiologically ‘safe’ for use. (Polprasert 1989)

The temperature was measured daily at the three different position of compost piles.

Optimization of Moisture Content

Physical inspection is used to check the level of moisture content in the pile. A hand full of waste from 50-75 mm deep is taken and pressure is applied with finger, if no water comes out then it means water is needed, if 3-5 drops of water comes out then it means moisture content is satisfactory, if more water than that comes out then it means moisture content is higher than the standard. If water is needed, then water is applied using a sprinkler (Enayetullah et al. 2006).

A hand full of waste was taken from 50-75 mm deep of all compost piles and pressure was applied by fingers. In most of the cases some drops of water came out which indicated the satisfactory quantity of moisture content presence in the compost.

Self Heating Test

The self-heating test is widely adopted at solid waste composting plants as a simple and inexpensive test to determine the biological stability of the produced compost (Koenig et al. 2001). Procedure of self-heating test was developed in Germany. It is a sample test and an excellent indicator of biological maturity, if properly conducted and does not require sophisticated equipment (Bari and Koenig 2002). To determine the stability of compost, which produced from the 2nd set-up composting of demo compost plant, self heating test was conducted. Different type composts, which produced from 1st set-up, were also tested for stability Index (SI).

Quality of Final Compost

Not all the composts have the same quality. What goes in as feedstock partly determines what comes out. Compost quality depends on the composting process used, the state of biological activity, and, most importantly, the intended use of the compost. Just as beauty is in the eye of the beholder, the end use defines compost quality (Cooperband 2002).

There are some specific chemical, physical and biological parameters that can be used to evaluate compost quality. To evaluate the quality of final composts from 1st and 2nd set-up, composts were sent to Bauhaus University Weimar, Germany. In the laboratory, all the relevant properties of the composts were performed using the required equipments and methods such as “EDEV H 55”, “DIN EN 10694”, ”BGK e.V. (Federal assurance association compost)- Method book” methods.

RESULTS AND DISCUSSIONS

The relevant parameters were measured at different stages of composting process and the out put i.e., compost samples were also tested to determine its properties. The results and the relevant discussion on these natures of results are illustrated in the following sections:

Characteristic of Waste

Some important physical characteristics of the input wastes like composition, moisture content, density and particle size were determined. The physical characteristics of 2nd set-up compost piles were shown in the Tables 2 to 6. The characteristics of 1st set-up compost piles already reported in Hasan et al. (2008).

The compositions of collected wastes are shown in the Table 2 and in the Table 3 the percent of biodegradable wastes and non-biodegradable wastes are shown. From the Table 3, it can be seen that about 6% materials are non-biodegradable and unsuitable for composting, where there is 7.5%

and 20.5% unsuitable materials for composting at commingle waste for residential area and mixed MSW respectively (Alamgir et al. 2005). By sorting these wastes, plastic, robber, cloth, glass, stone and other non degradable materials were removed as possible. Bulk density and moisture content of the waste are shown in the Table 4.

Particle size distributions of wastes are given in the Table 5. It was performed after completion of sorting. From this distribution Table 6 can be composed, where the percent of large size (>25 mm) and small size (<25 mm) materials are shown. From Table 6, it is found that about 40% material is greater than the designated size, which should be shredded.

Table 2 Composition of waste for the compost piles of 2nd set-up composting

Type	**Quantity (%)**		
	Compost Pile #1	**Compost Pile #2**	**Compost Pile #3**
Food	88.81	84.12	82.54
Paper	2.41	1.95	1.49
Plastic	0.6	0.76	0.85
Robber	0	0.01	0
Cloth	2.54	1.66	1.71
Yard waste	4.32	6.35	7.02
Glass	0	0	0
Stone	0	4.02	5.1
Metal	0.03	0.02	0.01
Eggshell	0.72	0.55	0.64
Bone	0.57	0.56	0.64

Table 3 The percent of biodegradable waste and non-biodegradable wastes

Waste Type	Compost Pile #1	Compost Pile #2	Compost Pile #3	Average
Biodegradable	96.83%	93.53%	92.33%	94.23%
Non-biodegradable	3.17%	6.47%	7.67%	5.77%

Table 4 Bulk density & Moisture Content of waste for the compost piles of 2nd set-up composting

Property	**Compost Pile #1**	**Compost Pile #2**	**Compost Pile #3**
Bulk Density (kg/m^3)	1181	1110	1150
Moisture Content (%)	47	48	56

Table 5 Particle Size distribution of waste for the compost piles of 2nd set-up composting

Sieve Opening (mm)	Percent retained		
	Compost Pile #1	Compost Pile #2	Compost Pile #3
100	0%	9.89%	7.69%
75	8.51%	13.19%	10.00%
38.2	21.28%	23.08%	23.08%
19.1	28.37%	24.18%	26.92%
9.52	14.89%	13.19%	12.31%
4.76	12.06%	5.49%	8.46%

Table 6 The percent of large size (>25 mm) and small size (<25 mm) materials

Material size	Compost Pile #1	Compost Pile #2	Compost Pile #3	Average
> 25 mm	29.79%	46.16%	40.77%	39%
< 25 mm	70.12%	53.84%	59.23%	61%

Temperature

Composts should be free from weed seeds and pathogens. Weed seeds and most microbs of pathogen significance cannot survive exposure to thermophylic temperature. Thermophylic is the temperature range from about 45 to 75^{0}C (Tchobanoglous and Kreith 2002). Pathogens and such bacteria will be rapidly destroyed when all parts of a compost pile are subjected to temperatures of about 60^{0}C (Skitt 1972). These higher temperatures, e.g., 60-70^{0}C for about 24 hours, should be maintained for pathogen destruction (Ahmed & Rahman 2000). There are other temperature-time frames for pathogen destruction like 65^{0}C for at least three days (Enayetullah et al. 2006) and 55^{0}C for at least 72 hours or three days (Cooperband 2002). So, it is preferable for the temperature of the composting pile to stay at 55-65^{0}C for at least three days.

Temperature curve of different compost piles of 1st and 2nd set-up are shown at the Figures 7 and 8, respectively.

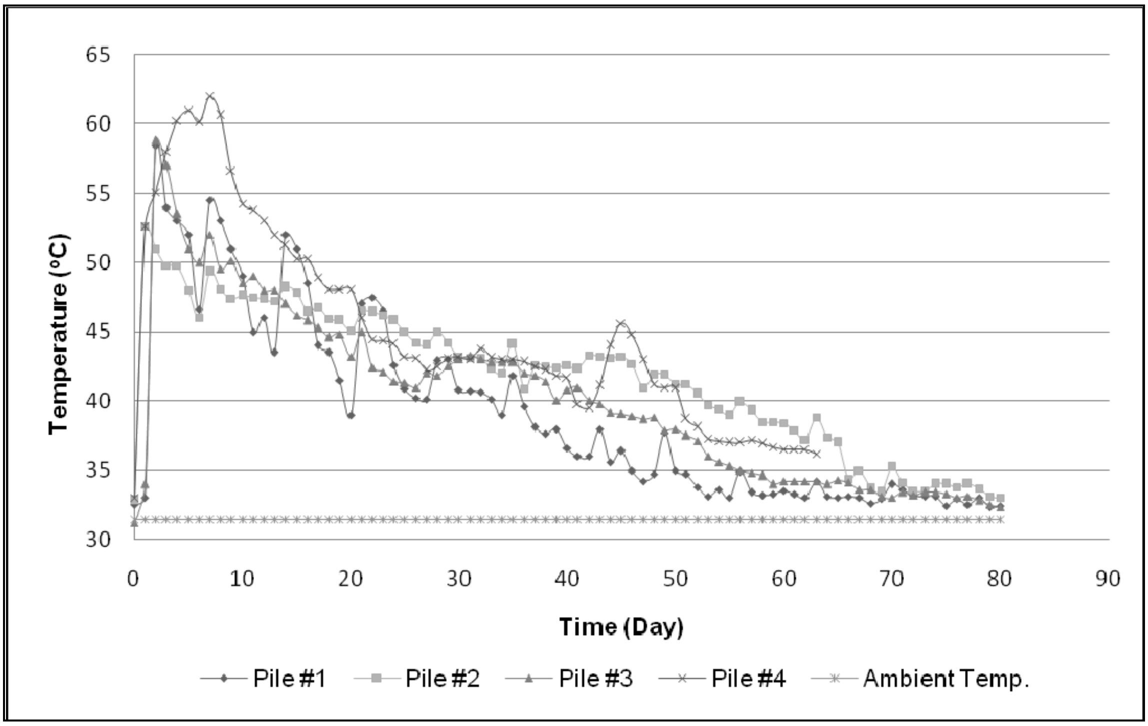


Figure 7 Temperature curves of compost piles of 1st set-up composting

The temperatures in four piles of 1st set-up are sharply raised to 50 to 60^{0}C. Cause of frequent turning (every week), many peaks along the composting period are made at the curve of first two compost pile that means pile #1 and pile #2. Since the pile #3 is forced aerated, it doesn't turned. So, there are no such peaks at curve of pile #3. After peak the temperature were decreased to around 40^{0}C in most of the piles until 6 weeks as shown in Figure 7. Since the temperature, which is higher than 60^{0}C, stayed for five days, Compost from pile #4 can be said pathogen free. Sometimes slightly lower temperatures would also ensure pathogen destruction, provided that all pathogen bearing material was brought into the composting reaction by adequate turning of windrows, mechanical agitation in drums or by the periodic air sucking technique (Skitt 1972). So, composts from pile #1 and #2 have a good probability to be pathogen free. Due to much power fluctuation, aeration was not sufficient for pile #3. So, this compost has a chance to be infected by disease-causing organisms. Most of the temperature followed the general pattern indication the smooth operation as temperature is usually used as a feed back parameter of the process.

From the Figure 8, it is found that there are two remarkable peek at the temperature curves of compost piles of 2nd set-up. First one is just after placement of compost pile and second one is after turning. Since the temperature, which is higher than or equal to 58^{0}C, is stay for three days, Compost from pile #1 can be said pathogen free. But there is risk to infect by pathogen. The temperature of Compost pile #3 is higher than or equal to 60^{0}C for three days. So, the compost of this pile is pathogen free. Most of the temperature followed the general pattern indicating the smooth operation of pile #1 and #3. The temperature of pile #2 does not follow the general pattern and not sufficiently higher. After 6 weeks the temperature of all compost piles decreases to less than 40^{0}C.

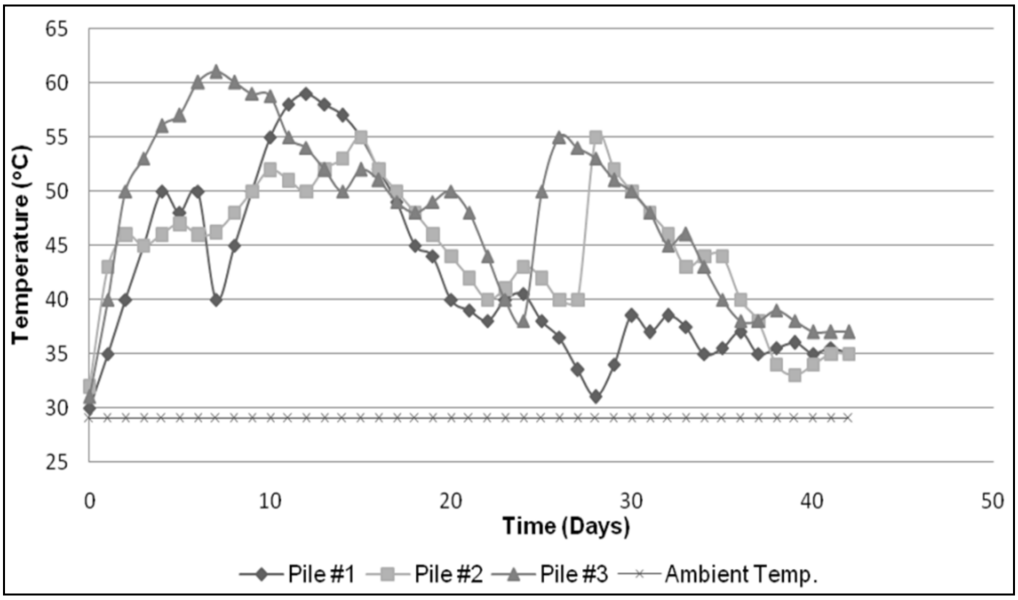


Figure 8 Temperature curves of compost piles of 2nd set-up composting

Self Heating Test

By plotting temperature, which are found by self heating test of different final composts of 1st and 2nd set-up composting, vs. time in day, following two figures, Figures 9 and 10, are found. From Figures 9 and 10, value of T_{max}, I_{max} and A_{72} are found, which are shown at the Table 7. Based on Iannotti et al. (1994) as cited by Epstein (1997), degree of biological stability or Stability Index (SI) of final compost, which produced from different type of compost piles of 1st and 2nd set-up composting at Demo compost plant, are also found from the table 7. Although the stability indexes of all composts are same, the composting period at 2nd set-up is less than 1st set-up, which may occur as the additives have an important role to accelerate the composting process.

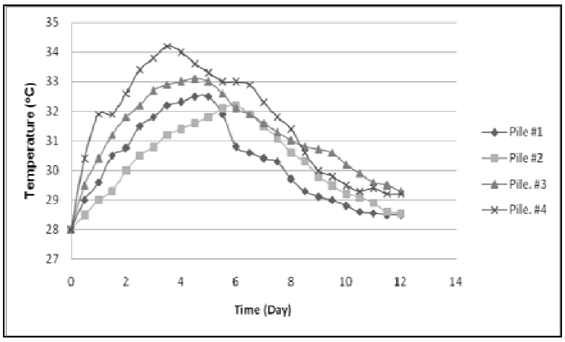


Figure 9 Temperature Curve during Self Heating Test of 1st Set-up

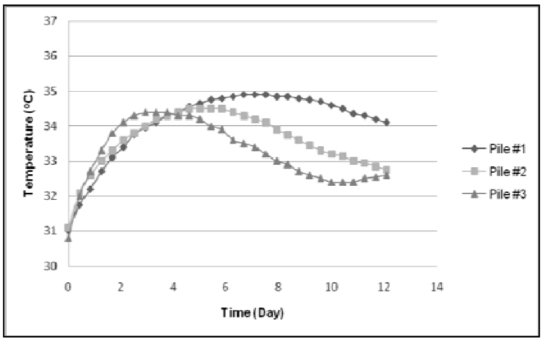


Figure 10 Temperature Curve during Self Heating Test of 2nd Set-up

Table 7 Degree of biological stability or Stability Index of final composts

	1st Set-up Composting				2nd Set-up Composting		
	Pile #1	**Pile #2**	**Pile #3**	**Pile #4**	**Pile #1**	**Pile #2**	**Pile #3**
T_{max} (°C)	32.6	32.2	33.1	34.2	34.9	34.5	34.4
I_{max} (°C/h)	0.07	0.06	0.12	0.17	0.12	0.11	0.14
A_{72} (°C-h)	2189	2120	2225	2300	2362	2378	2412
SI	IV	IV	IV	IV	IV	IV	IV

T_{max} = Maximum Temperature, I_{max} = Max. Temperature Increase, A_{72} = Arrea under temperature curve after 72 hours.

Properties of Final Compost

The measured values of various parameters of composts, sampled from 1st and 2nd set-up composting, are shown in Tables 8 and 9

Table 8 Quality of final composts of the 1st set-up composting

Parameters	Pile #1	Pile #2	Pile #3	Pile #4	Unit
Dry matter (DM)	55,35	61,85	79,45	56,5	Weight %
Loss on ignition/ volatile solids burn loss of DM	26,1	15,6	15,4	18	Weight % (DM)
Total C (TC) of DM	14	10	9	9	Weight % (DM)
Respiratory activity (AT_4)	3,5	2,5	1	2	g O/ kg
pH-Value	7,74	8,40	8,51	8,38	-
Salt content/ salinity	1,47	1,80	1,43	1,52	g/ 100 g
Total nitrogen	1,27	0,72	0,67	0,95	Weight %
Nitrate nitrogen	1165	547	535	594	mg/ kg
Ammonia nitrogen	73	64	59	72	mg/ kg
Potassium	1,15	1,06	1,02	1,24	Weight % as K_2O
Magnesium	1,51	1,47	1,46	1,48	Weight % as MgO
Phosphorus	2,25	1,55	1,54	1,84	Weight % as P_2O_5
Lead	22	17	30	92	mg/ kg
Copper	68	66	51	59	mg/ kg
Zinc	277	301	345	271	mg/ kg
Cadmium	0,35	0,3	< 0,2	0,5	mg/ kg
Mercury	< 0,1	< 0,1	< 0,1	< 0,1	mg/ kg
Chrome	20	18	20	20	mg/ kg
Nickel	9	9	11	11	mg/ kg

Table 9 Quality of final composts of the 2nd set-up composting

Parameters	Pile #1	Pile #2	Pile #3	Unit
Dry matter (DM)	61,4	70,8	74,7	Weight %
Loss on ignition/ volatile solids burn loss of DM	17,95	18,45	21,9	Weight % (DM)
Total C (TC) of DM	9,5	8,5	9,5	Weight % (DM)
Respiratory activity (AT_4)	4,5	7	3	g O/ kg
pH-Value	8,9	8,2	7,9	-
Salt content/ salinity	1,39	1,62	1,74	g/ 100 g
Total nitrogen	0,62	0,68	0,99	Weight %
Nitrate nitrogen	93	391	403	mg/ kg
Ammonia nitrogen	33,5	27,5	39,1	mg/ kg
Potassium	0,86	0,76	0,79	Weight % as K_2O
Magnesium	1,49	1,47	1,45	Weight % as MgO
Phosphorus	1,64	1,86	1,69	Weight % as P_2O_5
Lead	153	35	42	mg/ kg
Copper	87	78	110	mg/ kg
Zinc	516	495	564	mg/ kg
Cadmium	1,5	0,95	0,8	mg/ kg
Mercury	0,2	0,3	0,3	mg/ kg
Chrome	32	27	30	mg/ kg
Nickel	11	12	11	mg/ kg

Presence of heavy metals at compost keeps an important role to negative impact on plant and also on environment. There is no standard for compost quality for Bangladesh. However, comparison can be performed with the standards for compost used in agriculture from Switzerland, India and Great Britain (2006), which is given at a users' manual on composting published by Waste Concern (Enayetullah et al. 2006).

The levels of heavy metals presence in the composts of 1st set-up satisfy the three standards but in case of 2nd set-up, only two standards (exclude Switzer standard) are satisfied. The increase of quantity of heavy metals may be due to less sorting and/or mixing of additives such as sawdust. Because sawdust is brought from the local wood industries where there is a possibility of contamination. However, it needs more investigation to make definite conclusions on the increase of heavy metals in 2nd set of composting.

In this field investigation, the perforated PVC pipe was used as an aerator at compost piles to increase aeration for its chimney effect. From Figures 7 and 8, it is found that, there is no significant benefits at temperature curve. Stability Index (SI) of the composts from this pile are same with SI of other composts (Table 7) and the quality are not different significantly from others (Tables 8 and 9). Moreover, it is more difficult to place properly into the compost pile than horizontal frame and there is also a possibility of damage of aerator during turning.

CONCLUSIONS

Separately collected wastes save sorting time because less amount of unsuitable materials present in the compostable waste. Horizontal bamboo frame is suitable to use as an aerator at the composting process in Bangladesh. To shred the material properly and to avoid health hazard due to direct contact, small mechanical equipment should be introduced. Additives with required quality should be mixed properly with wastes to shortening the composting period. Since turning is an important factor for rapid composting and to produce stable and harmless compost, it should perform at the designated interval. Because of hard working and time consuming nature, it is strongly recommended to introduce mechanical equipment for turning.

ACKNOWLEDGEMENT

The authors greatly acknowledged the financial support provided by European Commission through WasteSafe II project under EU-Asia Pro Eco II Programme (ASIE/2006/122-432).

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Digestate Conditioning at Agricultural Biogas Plants–An Innovative Approach

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ABSTRACT

Caused in an increasing biogas plant density and regional limitation of agricultural land in parts of Germany the disposal of biogas plants digestates (storage, transportation and application) becomes more and more expensive. The treatment of digestates offers the possibility to lower some drawbacks of long-time storage and direct agricultural application (nutrient losses and emissions). The paper at hand focuses on the potential of low-tech procedures and reports first results of nutrient recovery experiments (in laboratory and pilot plant scale). Phosphate precipitation (struvite and calcium phosphate formation) as well as ammonia stripping has been investigated. The results show the principle feasibility even if there is further optimisation required. So by steam stripping N-removal rates of 62% to 92% could be obtained. Regarding the phosphate precipitation an inhibition of the chemical process occurred. Nevertheless P-removal rates between 30% and 70% could be reached, which shows the general applicability.

BACKGROUND

Usually it could be differentiated in procedures for partial and total treatment. Partial treatment means the separation of nutrient-rich component currents and the disposal of the remaining fluid (liquid manure) at internal land. Total treatment means on the other hand the extensive separation of all ingredients. The purified liquid phase could be directly discharged in a recipient or used as process water respectively. Figure 1 is given an overview of provided procedures on principle (Weiland 2002).

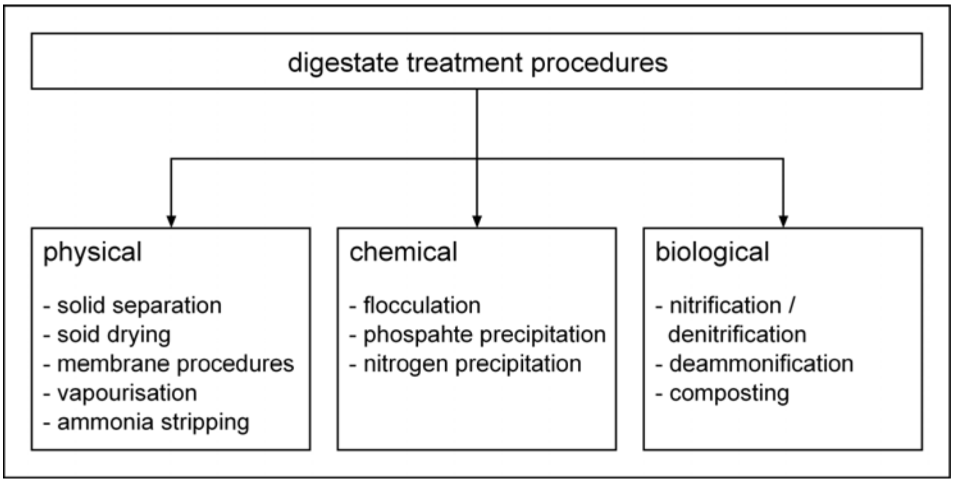

Figure 1 General digestate treatment procedures

The present procedure of digestate disposal is mainly reduced to a temporary application as organic soil conditioner or fertilizer. But the legal framework in Germany set a limit for maximal nutrient load at 170 kg N per hectare and year on field and 210 kg N per hectare and year on grassland (DüV 2007). That means a restrictiveness for this disposal way. Plant owners have to extend their near-by areas or to enlarge their traffic routes. Costs rise. So especially in regions with a high density of livestock or biogas plants the treatment of digestate should be an inherent part to avoid disposal shortages. Available solutions come from biowaste digestion or wastewater treatment with high level of technology and therefore high specific expenses. Thus they are reserve to large plants which have better conditions to handle such investments. For the majority of biogas plants there is a lack of low-tech-options and alternative strategies regarding the usage of digestate have to be developed.

The presented investigations deal with the possibility to install a competitive digestate conditioning in plants with a capacity up to 500 kW. With that they could extensively reduce the volume of substrate for disposal and in addition participate in the market of providing organic fertilizer. It is to investigate to what extent an adaptation of established methods in the field of wastewater treatment or sludge stabilization can be take place. For this purpose differences concerning material flow, quality standards and economic conditions of both sectors (wastewater treatment plant – biogas plant) have to be considered. Primarily this includes a simplification of the high-engineered and complicated procedures of wastewater technology.

The separation of solids is necessary for any following step and can be understood as a fixed module. Membrane processes (ultrafiltration and reverse osmosis) are commonly linked to high investment as much as operation costs and complicated to finance by small biogas plants. The same is true for the biological treatment of the effluent. For this reason they will be neglected. Drying is not generally excluded but more a reserve or an alternative solution. On this account the procedural elements are reduced to following components (see also Figure 2)

- solid-liquid-separation via separator or decanter (depends on the volume), if applicable without polymers,
- nutrient recovery as an two- or more-stage column and
- effluent treatment using a soil filter

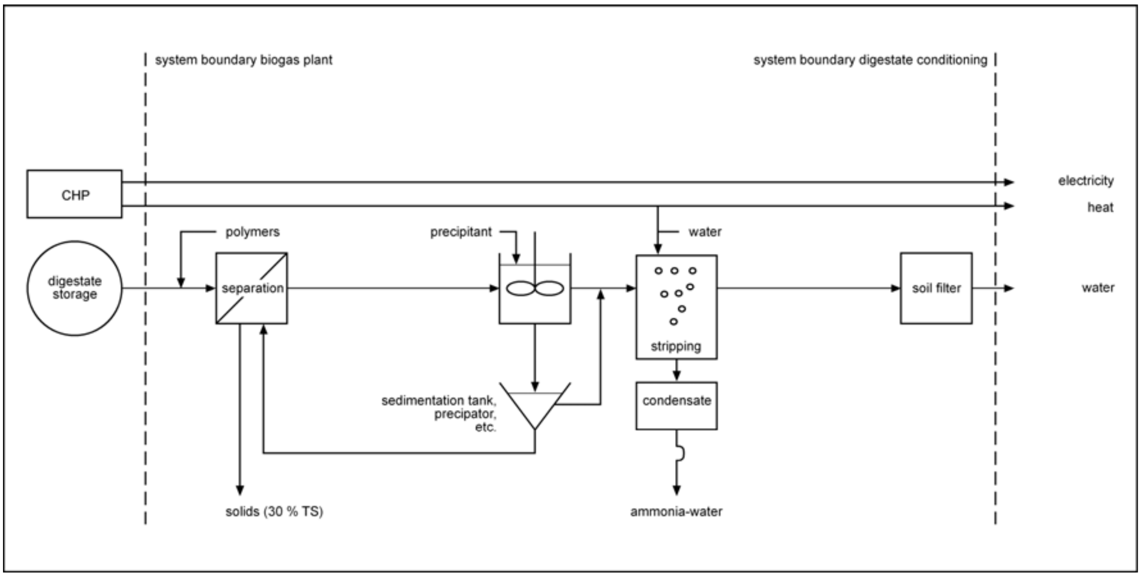

Figure 2 Selected procedure steps for digestate treatment

Central component is the part of nutrient recovery especially phosphorus and nitrogen. The possibility of self-supporting phosphate fertilizer would have a great significance in terms of resource recycling. The focus is on phosphorus recovery by struvite (MAP) and hydroxyapatite (HAP, calcium phosphate) formation in digestates from agricultural biogas plants.

Pang (2008) showed that P recovery from pig manure by MAP or HAP-precipitation could be obtained by pH-value adjustment with sodium hydroxide (NaOH) from 8 to about 9. P removal efficiencies of 60% (for digested manure) or 85% (for raw manure) could be observed. The Mg/P-ratio of 1,3 was sufficient for struvite formation. Mg und phosphate contents in pig manure samples were often sufficient for this ratio, so that chemicals didn't have to be added. If the Mg-content was lower as the necessary molar ratio, $MgCl_2*6H_2O$ as Mg source was used.

METHODOLOGY

The final products of the whole digestate treatment will be an organic soil conditioner with high phosphorus content and a nitrogen fertiliser (ammonia water). Therefore the purity of phosphate sludge great was not of great importance. The Magnesia and Calcium ions in digestates were not seen as competitors but P-precipitation on both ways by struvite formation or calcium phosphate formation were allowed. Only removal efficiency was of importance.

The digested samples were obtained at four different regional biogas plants (BGP) as shown in Table 1.

Table 1 Used input of the selected biogas plants (BGP)

	Gathering	Input
BGP 1	influent chamber final storage	cattle manure maize silage
BGP 2	interim storage	maize silage cattle dung wilted silage bruised grain
BGP 3	final storage	swine manure maize silage dry poultry dung
BGP 4	influent final storage	cattle manure maize silage

Three series of tests were completed. In preliminary experiments were obtained, that the suspended solids are not acting as crystallisation seeds. Moreover the polyphosphates, which are adsorbed on the solids, can be resolved by raising pH value, so that the soluble phosphate content is increasing. For that reason all samples were prepared by solid-liquid-separating to reduce the suspended solids load. In the first series the separation took place by centrifuge at 5000 rpm (9 min). In the second series the separation was improved by adding of cationic polymers. In the third series the effluent from the stripping pilot-scale reactor was used. This sample was separated by press screw separator and the ammonia content was widely reduced by steam stripping. The size of reaction vessels ranges between 500 ml and 1 litre.

RESULTS AND DISCUSSIONS

MAP-precipitation

Struvite precipitation was attempted in batch experiments (jar tests). To 500 ml liquid appropriate amounts of $MgCl_2*6H_2O$ were added as Mg source to obtain different Mg/P-ratios between 1.4 and 3. The initial Magnesium content in digestates was measured but not taken into account for the calculation of magnesium chloride amounts. The pH was increased by addition of NaOH to values between 9 and 10. The samples were stirred for 1 h with magnetic stirrers. After a settling period of 1h, 2h and 72h the supernatant samples were extracted, diluted 1:100, filtered by a glass fibre filter and finally analysed for soluble PO_4-P (photometric). In the second series initial Mg and Ca contents in digestate liquid phase were also measured to find out their influence on P-precipitation.

At P precipitation from centrifuged liquid (BGP 1) a P-removal rate of maximal 35% could be measured after 1h settling time. The pH adjustment from 9 to 10 distinctly favoured phosphate removal.

The flocculation of digestates by adding cationic polymers before centrifugation caused further improvement of removal rate. This occurred apparently through the sorption of negatively loaded phosphate anions on the cationic functional groups of polymers. Perhaps the advanced reduction of suspended solids and organic matter also improved precipitation. A great variety of maximal reachable P removal rate was detected. The experiments showed that an increasing settling time from 1 h to 24 h and more (72 h) had a favourable effect (see Figure 3). The P removal rates after 1h settling period amounted at about 30% for substrate BGP 1. The other substrates showed a lower removal rate. On the contrary the removal rates of most liquids had been between 65 and 70% after 72 h. An exception is the liquid of BGP 2, which more than doubled the removal but reached at least maximal 32%. These results are in contrast to other reports, which considered 30 min reaction time for struvite formation (from swine or calf manure) as sufficient (Laridi et al. 2005 and Nelson et al. 2000).

The effect of pH value holds a great differentiation. In some liquids the pH elevation advanced the P-removal (BGP 2 and 3) and the best P removal rates were obtained at pH 10, for other liquids pH 9 was the optimal condition (BGP 1 and 4). The influence of pH at short settling times of about 1h was of special importance. At long settling times of 24h and more the effect of pH on precipitation was reduced and the PO_4-P concentration in supernatants was more or less equalized.

In the third series of tests with effluent of ammonia stripping process the Mg/P molar ratio was varied from 0.7, 1.5 to 3. In one test synthetic struvite powder was added as crystallisation seeds to provide the struvite formation. The results show (Figure 4) neither pH-value nor Mg/P ratio had significant effect on precipitation performance. The P removal rates of all liquors dropped under 30%. It is to assume that this deterioration of performance can be connected with limitation of ammonium. Before the steam stripping (series 1 and 2) ammonium was in large excess relative to phosphate content. After the stripping the NH_4-N/PO_4-P ratio was about 1.9. According to literature a NH_4-N/PO_4-P molar ratio of 6 and more is required for optimal struvite formation (Montag 2008 and Nelson et al. 2003).

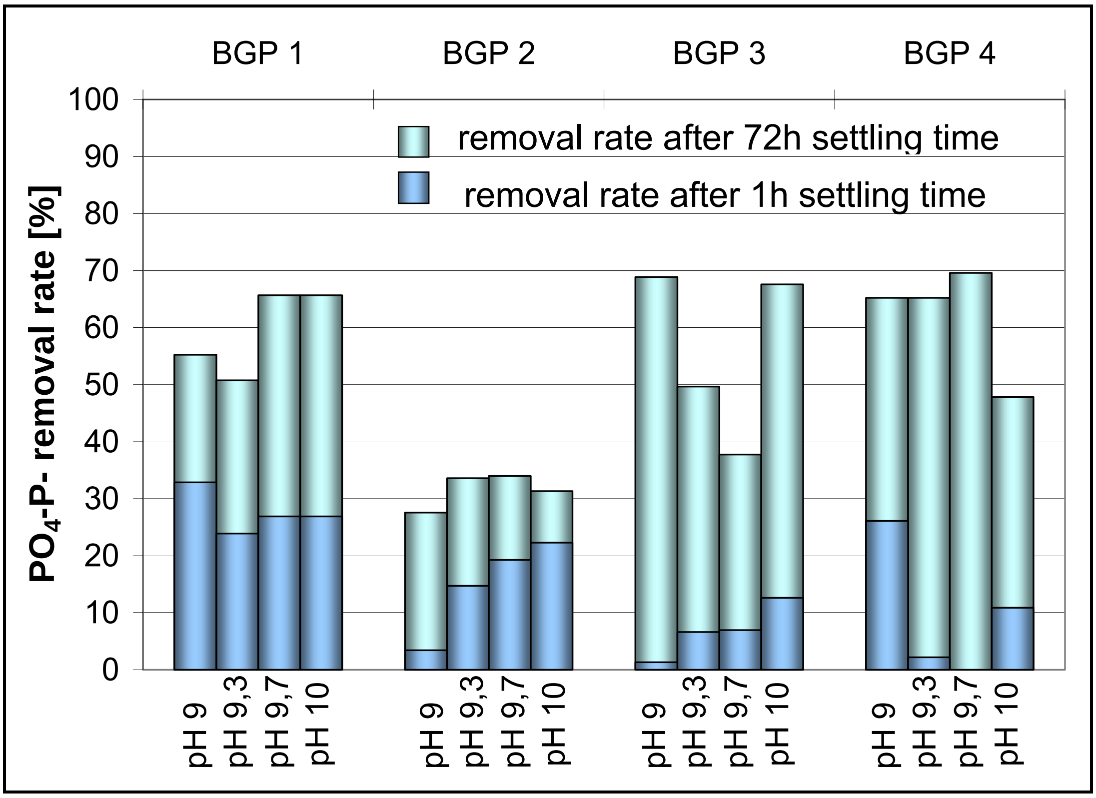

Figure 3 Struvite formations – effect of settling time on P removal

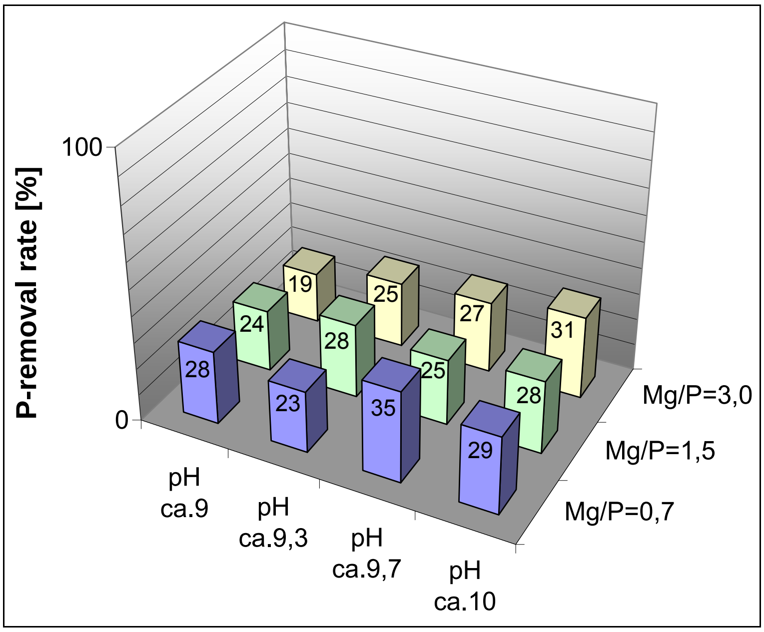

Figure 4 Struvite formations after ammonia stripping – effect of pH and Mg/P molar ratio on the P removal rates (substrate BGP 1, settling time 24h)

The addition of crystallisation seeds had an unexpected effect. The seeds were resolved in liquids despite of Mg-source addition. This led to a rapid increasing of Mg and PO_4-concentration in supernatants (Figure 5). The P precipitation occurred very slowly and reached less than 10% respective to initial phosphate content after 24h reaction time.

To identify the precipitate composition the concentrations of all struvite component parts (Mg, PO_4-P and NH_4-N) were measured before and after reaction (Table 2). The molar ratio of Mg:PO_4:NH_4 in struvite crystals amounts 1:1:1. The measured removal of these species conducted Mg:PO_4:NH_4 = 2,59:1,23:1. This suggests that the precipitate consisted only in parts of struvite. A pH decrease obtained during the reaction (binding of OH-iones) and the disproportional removal of Mg ions compared to other struvite species pointed at Mg $(OH)_2$ formation. The higher decrease of phosphate comparing to ammonia removal can occur partly by precipitation of calcium phosphates or other magnesium phosphate forms.

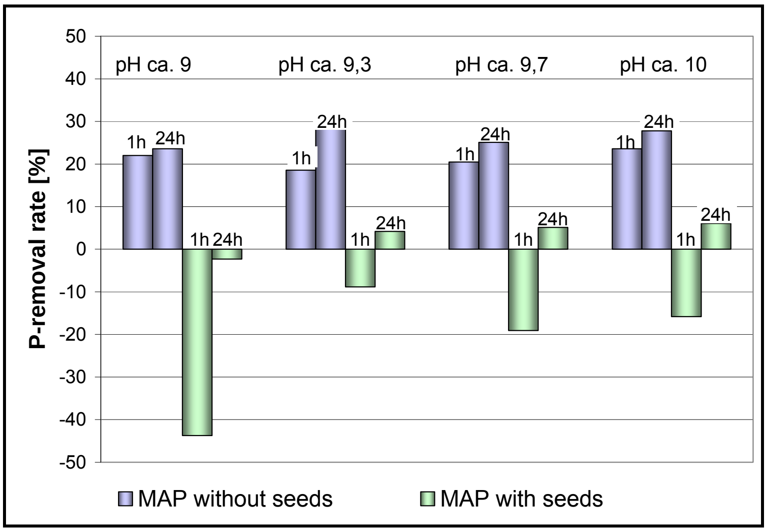

Figure 5 Struvite formation after ammonia stripping – P removal at Mg/P of 1,5 and various pH with and without adding of crystallisation seeds

Table 2 PO_4-P-, NH_4-N-, Ca^{2+}- und Mg^{2+}-concentrationes in liquid of BGP 1 before and after struvite precipitation (after ammonia striping, Mg/P=3; pH 9,7; 72h)

		PO_4-P	Ca^{2+}	Mg^{2+}	NH_4-N
Original substrate	mg/l	140	204	91	120
	mg/l	4.52	5.09	3.74	8.57
Adding of chemicals	mg/l	0	0	13,56	0
X/P molar ratio	mg/l	1	0.82	3.83	1.97
Supernatant sample (pH 9.7;72h)	mg/l	102	144	357.5	106
	mg/l	3.29	3.59	14.71	7.57
Δ(removal)	mg/l	1.23	1.5	2.59	1.0

Calcium Phosphate Precipitation

The calcium phosphate precipitation was investigated at pH range of 10.0 – 12.0. The pH adjustment was managed by 3% lime slurry. The separated liquid phase was pre-treated similar to struvite formation tests. Also three series of experiments have been completed:

- with centrifuged digestates,
- with flocculated digestates and
- with digestates after solid-liquid-separation and steam stripping

After the addition of lime slurry the liquids were stirred for 30 min, followed by a settling period of 1h. The supernatant samples were extracted, diluted 1:100, filtered and after that analysed for soluble PO_4-P.

In the first and second series of tests an intensive flake formation at pH above 10,5 have been noticed. The flakes have been very voluminous (bulky) and settled very well at the initial phase of settling period of about 10 min. In the first test series a phosphate decrease between 74% (BGP 1) and 88% (BGP 3) was measured. In the second series the total (collected) P removal was further more improved by flocculation at 88% (BGP 1) and 90% (BGP 3). The pH elevation up to 11 favoured the precipitation. Further pH raise had only a negligible effect on P reduction. The precipitate analyses revealed nearly 100% of calcium carbonate. This implied that the P removal occurred mostly by sorption of phosphates on carbonate flakes or they had been enclosed in flakes.

Despite of good removal rates the P recovery with lime slurry precipitation has some important drawbacks:

- The digestates have mostly high buffering capacity because of high content of carbon dioxide, ammonium and organic acids. This caused high consumption of lime slurry for pH elevation. The lime slurry consumption amounted between 10 and 22 kg $Ca(OH)_2$ per m³. After flocculation the lime slurry consumption could be reduced about 20%.
- The addition of chemicals (polymer solution and lime slurry) increases the liquid volume significantly. The additional liquid volume was between 0,36 and 0,74m³/m³. This volume can be reduced only marginally by usage of more concentrated lime slurry (5% instead 3%). The other possibility, which is however not practicable, is the production of lime slurry with precipitation effluent.
- The third minus is the big amount of precipitate, which mainly consists of $CaCO_3$. This should be dewatered and applied. But it is to consider, that carbonate based fertilizer is only appropriate (suitable) for acidic soils.

Ammonia Stripping

It was mentioned above, that the digestates significantly consist of carbon dioxide, ammonium and organic acids. This leads to a high buffering capacity. With the steam stripping it was expected to reduce the buffers and thereby the alkaline consumption for precipitation.

The equilibrium between ammonium and ammonia in one solution can be moved to the side of ammonia ions with the increase of pH and/or temperature. The distribution of ammonia between solution and surrounding gas phase is described by Henrys law. The high temperature favours also the transfer from liquid to gas phase due to an increased Henry coefficient. Steam stripping is a thermal separation process in which preheated substrate will be put in closer (intensive) contact to steam in a packed column. The combined effects of steam and heat force the volatile ammonia (or carbon dioxide or volatile organic acids) to transfer from the liquid to the vapour phase. As contact proceeds down the tower, the substrate becomes depleted (stripped) in ammonia while the vapour phase becomes enriched as it travels up the tower.

The ammonia stripping by steam was investigated in discontinuous pilot scale experiments. Figure 6 shows an flow chart of the pilot plant. The digestates from BGP 1 were separated by press screw separator and stored in 1m³ storage tanks. In this case the steam was generated at about four bar pressure in a steam generator and injected in the bottom of the tower to provide heat and vapour flow. If the process should be implemented in continuous operation, the exhaust heat of the CHP could undertake this task. The digestates were fed in the column on top after passing a heat exchanger. They trickled through the expansion elements and depleted from ammonia. The hot tower effluent (90-99°C) ran through the heat exchanger again as heating medium. Then it was collected in 30L temporary storage tanks to take samples and to gather the effluent volume flow. The off-gas vapours were condensed into a low-volume NH_4-concentrated liquid stream as a process product (ammonia water).

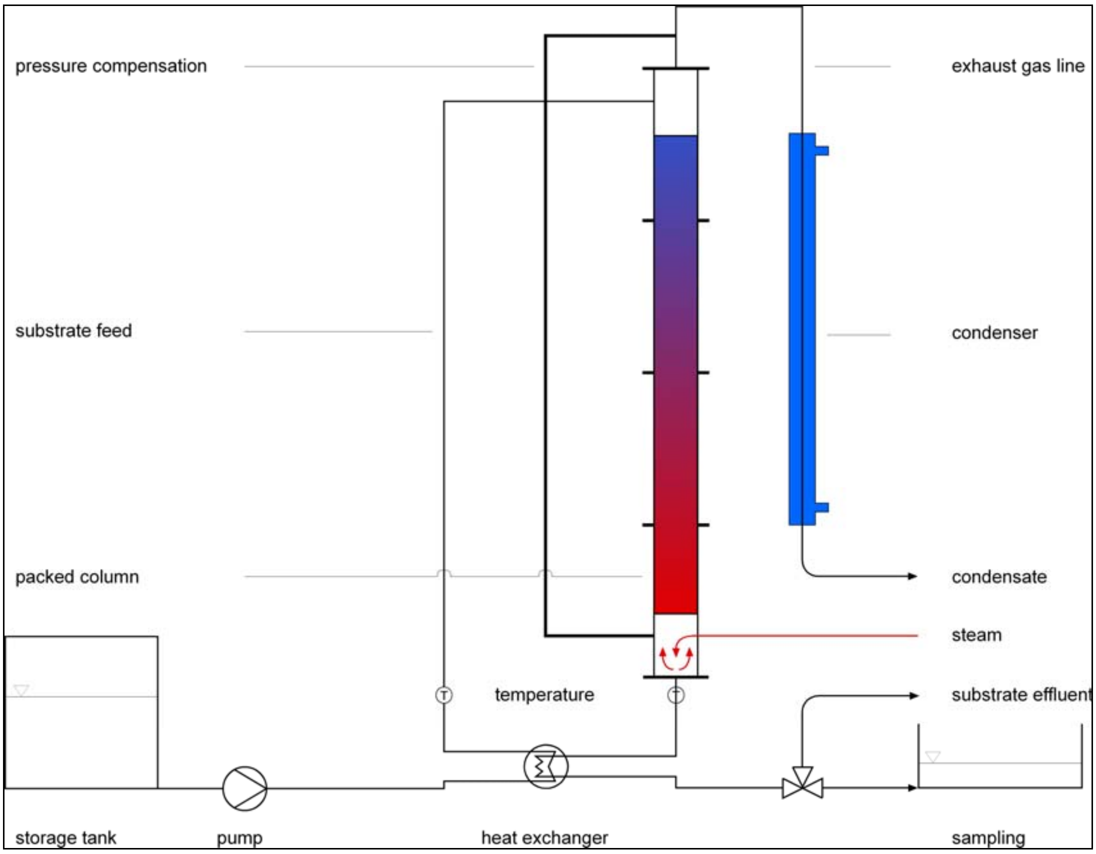

Figure 6 Flow chart of steam stripping pilot plant

Every hour samples were taken from the inflow, from the N-depleted substrate and from the condensate. The values of pH and NH_4 were analysed. Additionally volume flow rate of feed, effluent, condensate and the temperature were recorded in constant intervals of 1h. The steam flow rate could not be measured, because it was regulated only by valve. Instead of the water volume flow to the steam generator was measured to estimate the steam quantity.

The average feed flow rate was about 45 L/h. The equilibrium between NH_4^+ and NH_3 was controlled by temperature but without pH-elevation with sodium hydroxide. Process temperature was 90-99°C and steam-feed-ratio approximately 0,142.

Nitrogen could be depleted from the original substrate very well. The average initial concentration of ammonia was about 1100 mg/l (from 1058.46 to 1140.41 mg/l). It decreased to 68 – 173 mg/L in stripped effluents. Thus the calculated removal rate (based on ammonia freights) of at least 62% and maximal 92% was reached. As process product a condensate with about 3,3 Mass-% of NH_4^+ could be achieved.

Figure 7 shows the relation between condensate volume flow and ammonia removal. With increasing condensate flow rates diminishing effluent ammonia concentration obtained. The same applies to ammonia load in effluent. This indicates at preceding nitrogen removal. But the quality of condensate as product deteriorates in respect of increasing dilution of ammonia water. Regarding process optimisation the operating point with highest possible ammonia removal and acceptable condensate quality is to find. But also the economic point is to consider. More condensate implies more steam and consequently higher cost of energy.

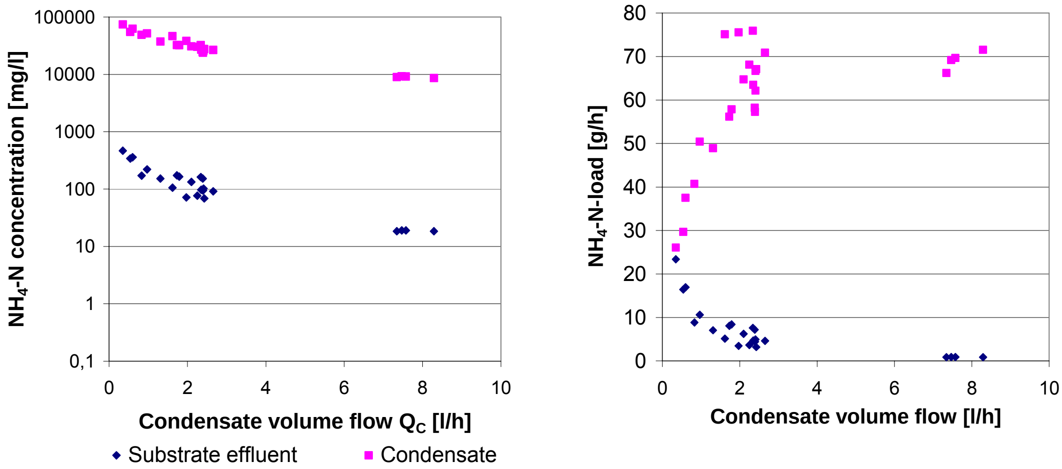

Figure 7 Steam stripping – ammonia concentration (left) and ammonia loads (right)

An increasing condensate flow rate means at the same time more heat medium connected with higher process temperature. The same can be reached with intensification of feed preheating in the heat exchanger. Graphs in Figure 8 give an example for better nitrogen removal with increasing feeding temperature.

The NH_4-N balance in Figure 9 was calculated based on the measured NH_4-N concentrations and volume flow rates of substrate feed, substrate effluent and condensate. It is shown that the ammonia load in substrate effluent and condensate after the stripping process is higher than the ammonia load on the input side. Probably this can be caused by the partial decomposition of organic nitrogen matters during the stripping process induced by high temperature and elevated pH in the column.

During the stripping process a significant pH elevation in depleted substrate was obtained (pH range between 9.7 and 9.9), although pH decrease was conversely expected. The effluent pH was in fact higher than the pH of the NH_4 enriched condensate (pH range of 9 and 9.5). This leads one to the assume that a simultaneous stripping of carbon dioxide and perhaps of volatile organic acids occurs.

The operation of the steam stripping pilot plant was discontinuous as mentioned before. A continuous operation could not be ensured because there was an interruption after five days. The disassembly showed that the column was clogged with solids (Figure 10).This was caused by insufficient solid matter reduction via press screw separator. Therefore the design has to be improved. Otherwise alternative technologies of separation could be an applicable solution

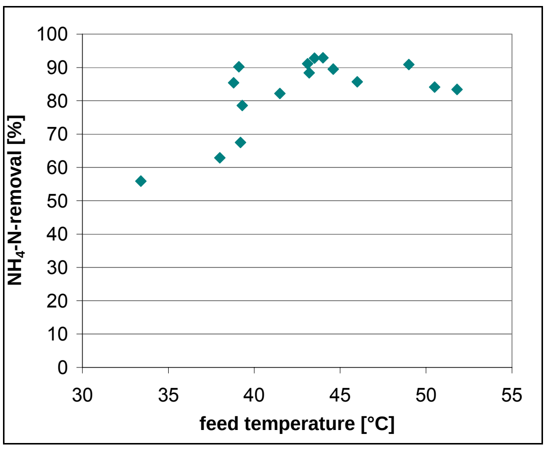

Figure 8 Stripping – correlation between temperature and ammonia removal rate

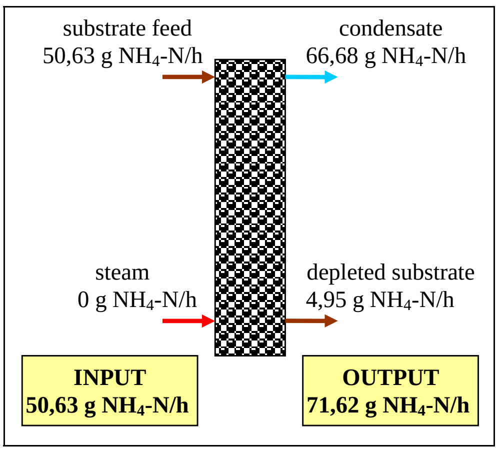

Figure 9 Stripping – NH_4-N-balance

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Figure 10 Steam stripping – clogged column with solid material

CONCLUSIONS

The flocculation of digestates with cationic polymers (sorption of phosphate anions at cationic groups) has a good potential for P removal. Removal rates amounted between 53% (substrate BGP 3) and 77% (substrate BGP 1). But the high consumption of polymeric solution emerge high operational costs. Furthermore the availability for plants of phosphates adsorbed at cationic polymers is not investigated and thus the usage as fertilizer is not clear.

The struvite precipitation from digestates seems to be inhibited. In literature inhibition effects of colloids (Burns et al. 2001 and Green et al. 2004) and organic chelating agents (Laridi et al. 2005) were reported. Despite of high Mg content relative to phosphates (initial Mg content and Mg ions from chemical source) the liquids seem to be unsaturated. This can explain the dissolution of added struvite crystals.

The phosphate removal with lime slurry was investigated and worked well. P-removal rate improved with rising pH till a value of 11 and amounted at maximal 88% or 90% with flocculation respectively. The disadvantages of this method are the high consumption of lime slurry and the inherent increase of liquids.

The P removal occurred by adsorption of phosphates on carbonate flakes or their enclosing in flakes. Due to this removal mechanism the P-precipitation is to install before the stripping process.

The steam stripping in packing column is suitable for nitrogen recovery as ammonia water. N removal rates from 62% to 92% were possible. A condensate with about 3.3 mass-% of NH_4^+ was recovered as process product. The intensive preheating of substrate favours the transfer of ammonia from liquid into vapour phase and thus improves the removal rate. A continuous operation of the pilot plant was not reached, because the column was clogged with solids.

Both investigated processes – steam stripping and P-precipitation – require an advanced reduction of solids. The solid-liquid-separation by press screw separator did not show acceptable results.

In conclusion it is to state that these processes are principally conceivable but need further research to eliminate the concomitants. With an optimised process chain the aim of a low-tech digestate treatment should be possible.

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Developing an Innovative and Marketable Control System for the Rotting Process in Composting Plants

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ABSTRACT

Nowadays, in many composting plants controlling the rotting process is based on experienced data, estimations and temperature measurements. Under these conditions the rotting process does not flow in an optimal way leading to high expenses and a product of minor quality. For changing this state of things the aim of this research is to develop an innovative and marketable control system for the rotting process which can be applied in different types of composting plants. Based on this control system the project team aims to develop a practical and trustable computerized control system for data documentation, supervision of execution and quality assurance. The required parameters will be recorded by a measuring probe with an integrated radio transmitter, which is currently under construction.

INTRODUCTION

During the last few years the quantities of waste have been increasing all over the world, especially in emerging nations. Therefore these countries have to deal with the treatment and disposal of the increasing amounts of waste. In emerging countries biological waste represents a proportion up to more than 70 percent (Fricke et al. 2002); in the industrial countries more than 40 percent. Because of these circumstances a big amount of waste can be applied to biological treatments like composting and fermentation plants. At the same time more and more treatment options for biological waste are occurring. To get an advantage over other techniques and for using the resource “biological waste” as best as possible, efficiency increase and a product of constant quality are required. In consideration of the budget it is not possible to advance the technical equipment for the composting process very far, so that the problems have to be solved by a process controlling. Nowadays, in many composting plants controlling the rotting process is still based on experienced data, estimations and temperature measurements, by what the composting process does not operate in an optimal way. The results may be high expenses and a product of minor quality. To enhance these conditions a monitoring and controlling system will be developed at the “Bauhaus University Weimar” in cooperation with “Jansen Antriebstechnik GmbH”. The controlling system operates in combination with a measuring probe which collects the necessary input data at the composting windrow and sends it to the computer system via radio transmission. The required input parameters are:

- Temperature
- Humidity
- Carbon dioxide and
- Oxygen

With the incoming data necessary actions for optimizing the rotting process can be evaluated and the plant operator obtains a recommended course of action for his composting plant.

POSITIONING OF THE MEASURING PROBE AT NON-AERATED TRIANGLE WINDROWS

Currently, temperature reading points are mandatory by German law, but their positioning is not further specified. Therefore, one focus of this project is to define significant reading points for these measurements. The first step was to analyze the isothermal lines in non-aerated triangle windrows, both in the profile and in the centre line. This was achieved by using two different kinds of analyzing methods. The first one was a temperature measuring realized by the use of sensors, which were spaced in the windrow in a square matrix of 20 cm resolution. This procedure was repeated in windrows of different ages. Through a visualization of the results the dynamical behavior of the temperature in non-aerated triangle windrows could be figured out. An example for the distribution of the temperature in a four week old windrow is demonstrated in Figure 1.

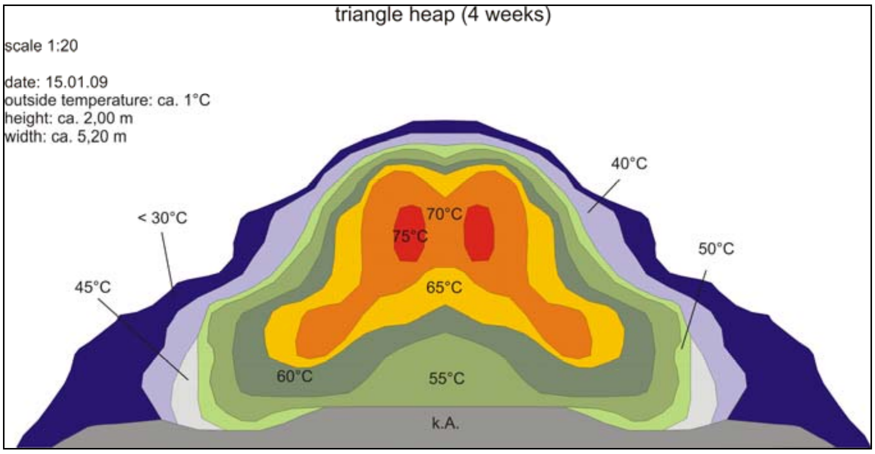

Figure 1 Isotherm lines in a four week old non-aerated triangle windrow

Another method for analyzing the isotherm lines in the windrow was realized by the use of an infrared camera. With the help of a wheel loader the front of the windrow was removed to get the actual temperatures inside the windrow. With both analyzing methods the same kind of isothermal lines occurred. As can be seen at the photograph demonstrated in Figure 2 the hottest area, in this case round about 65 °C, can be found within the upper third, exactly as it is the case with the first analyzing method (Figure 1).

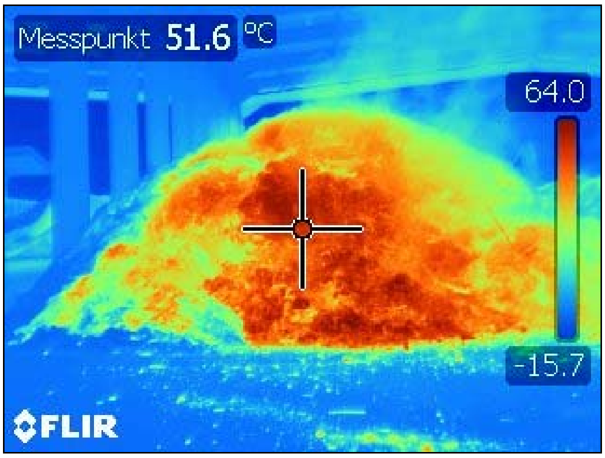

Figure 2 Infrared picture of a 14 weeks old non-aerated triangle windrow. Picture taken by: J. Schmidt

The collected data were analyzed based on the requirements of the German law. To achieve a hygienic safe composting product, it is mandatory to maintain an actual retention time for the whole material of 14 days at a temperature of at least 55°C, alternatively a retention time of seven days at a temperature of 65°C. The documented evidence of a successful sanitation of the organic material is getting more and more important for the legal and internal guidelines. Another demand with respect to the measuring points is the registration of the highest temperatures in the windrow, because according to the current state of knowledge, optimal micro-organic degradation rates are achieved within a temperature range of 40 to 60 °C; by the time the temperature rises over 75°C enzymes may denaturize (Hartmann 1989). By means of the photographs and the illustrated temperature distribution it can be seen that low temperatures mainly appear at the base of the windrow. Therefore, to detect and to avoid a cooling of the windrow one measuring point has to be set in the center, close to the base. The hottest area of the windrow can be found within the upper third, for which reason the second measuring point has to be set in this area. By means of the predominating temperatures at these two points the necessary control steps can be determined. For non-aerated triangle windrows with a height range between 170 cm and 250 cm the measuring points were determined at depths of 120 cm and 60 cm from the top. The measuring probe can be inserted in the windrow in two different angles (see Figure 3). The dynamical behaviors of the temperatures at these points are exemplarily demonstrated in Figure 4.

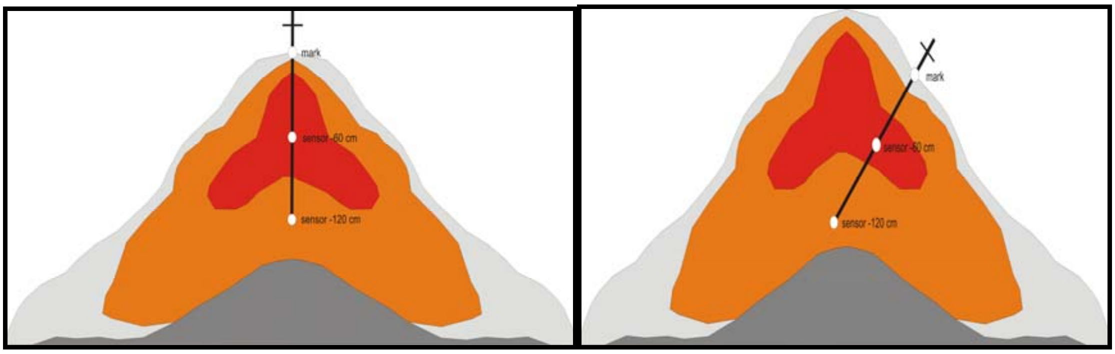

Figure 3 Possible positions to insert the measuring probe: vertical or with an angle of 45 degrees

In this example the temperature at position two was increasing in the third week, so the rotting process had to be influenced. In this case the material had been turned and maybe irrigated, whereby the temperature was re-increasing in the fourth week. The main problem of this rotting process was a temperature rise over 70°C at point one; at the end of the rotting process the average temperature at point one is even 80°C. This means during the last weeks, high biological activity still existed in the rotting material, a condition which normally should be avoided.

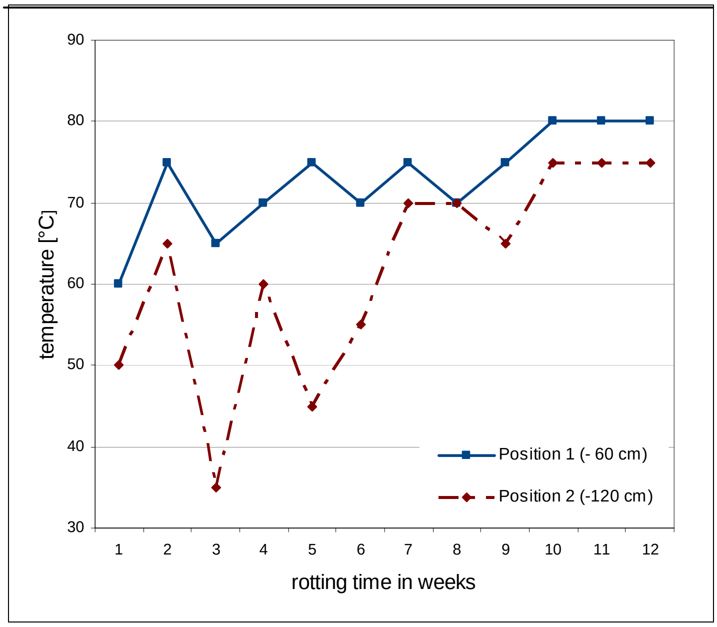

Figure 4 temperature gradients at measuring points of 60 cm and 120 cm from the top of the windrow.

CONTROLLING THE ROTTING PROCESS

At the top of the measuring probe is a radio transmitter which sends the detected data to a measurement and advice system to document, visualize and analyze the incoming data and to control the observance of the requested verification management of a confident sanitation. Via an internet connection the incoming data can be retrieved at every place the operator prefers, whereby he is able to calculate the employment of machinery.
At the "Bauhaus-University Weimar" a model based controlling system for composting plants had been invented a few years ago. This program, called NaviRott®, is based on the input parameters:

- Plant system (geometry of the reactor or windrows)
- Surrounding temperature and humidity
- Total mass
- Organic mass
- Moisture content
- Water capacity
- Grading
- Biodegrading activity
- Perfusion distribution

Because it is very difficult and therefore expensive to analyze all the parameters of a running system, a generalization of the input data is currently under realization. In the future, the operator only has to enter the season, the type of incoming waste and the total mass of the input material; all other data will be evaluated based on empirical data.

After adapting the system to real operating conditions, it will be possible to evaluate the incoming data and to compare them with a control curve to indicate variances with negative influences on the composting process. These disadvantageous conditions are highlighted to the operator, whereby he is able to affect and improve the product quality during the process.

One of the most important points of the controlling system is the documented evidence of sanitation for each individual charge. Against the background of an increasing appearance of pest organisms in the basic product the phyto-hygienic degradation of these organisms during the composting process will become likely more important in the future. For a definitive killing of these pest organisms the biological waste has to be heated above a special temperature for a certain time period (see chapter 2). By German law, it is mandatory to document the sanitation by the three following formulas to get a certification mark (§11 and §12 of the amend BioAbfV (BioAbfV 1998) :

- Temperature protocol of the BGK (Bundesgütegemeinschaft Kompost e.V.)
- Charge protocol
- Confirmation of sanitation

These documents are integrated in the controlling and monitoring system; the database is collected and integrated automatically. It is possible to stop the rotting process immediately when the sanitation has finished.

CONTROL SYSTEM IN NON-AERATED WINDROWS

Just a few possibilities to affect the process exist for non-aerated windrows as there are:

- Irrigation
- Windrow turning
- Irrigation and turning
- Alteration of the rotting period

Up to now plant operators normally rely on experienced data, estimations and random temperature measurements. Furthermore, it is very common to turn the windrows in a fixed rhythm like for example every third week, independent from the actual conditions of the material. In this manner an optimal rotting progress can hardly be reached.

To collect continuous data of non-aerated and aerated windrows and to test the measuring probe under “rough operating conditions”, measurements are taken at two composting plants for a period of one year.

Up to now just a temperature sensor is integrated in the measuring probe, so currently carbon dioxide, oxygen and moisture are detected by manual measurements in a rhythm of 14 days. Hence we just have continuous temperature data. Exemplarily, a temperature sequence is demonstrated in figure 5. The outdoor temperature does not affect the temperature in the core of the windrow; just in a depth of 10 cm a low influence could be ascertained. In principle the temperature of the analyzed windrow is too high (see chapter 2), which probably is partly based on the fact that the windrow had not been turned yet.

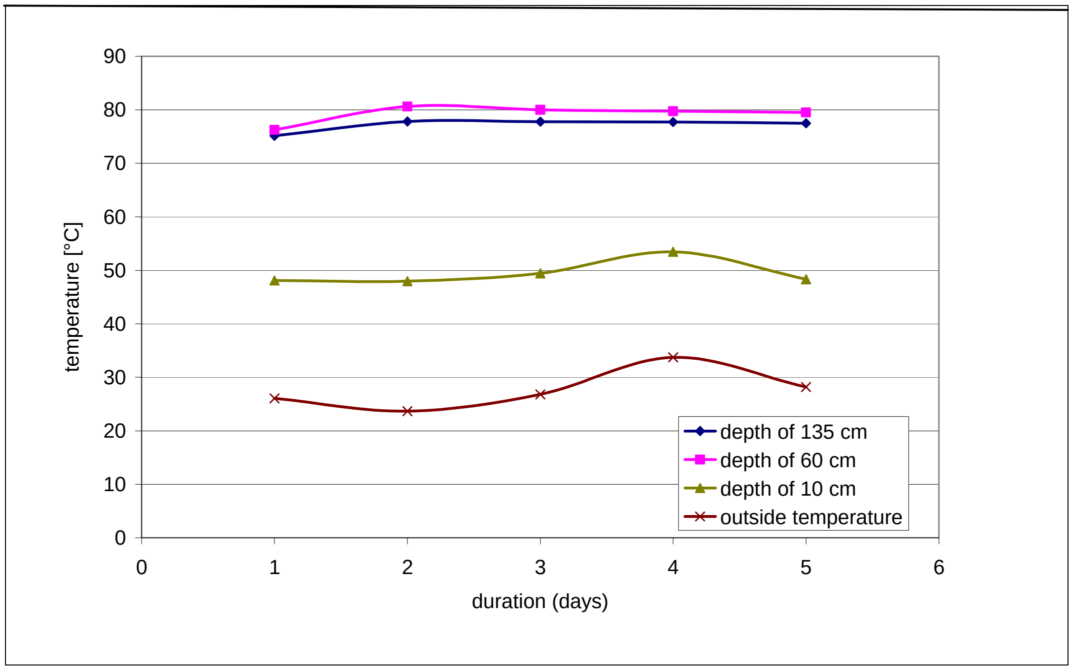

Figure 5 Temperature sequence in an eight weeks old non- aerated windrow, which had not been turned yet

CONTROL SYSTEM IN AERATED WINDROWS

In aerated windrows the rotting process can be affected and controlled in addition to the possibilities named in chapter 3.1, also by a modification of the aeration. Possible conditions for increasing the aeration rate may be:

- temperature over the optimum
- anaerobic conditions
- major demand of oxygen

To figure out in which case what kinds of controlling steps have to be recommended a couple of test runs in laboratory scale are performed. The tests are still ongoing, so it is not possible to make a final conclusion yet. Additionally a test series with one year duration is currently carried out. The measurements are made in the same way like at non-aerated windrows. The measuring probe, collecting temperature data, is to be seen in Figure 6.

The next step is to develop recommendations for the plant operator depending on measured data. Temperature and biological activity (measured by carbon dioxide) can be controlled by the height and moisture as well as turning and aeration rate of the windrows; whereof the aeration rate will be the most important controlling parameter. Usually aerated windrows are equipped with defined heights, turning and irrigation rates; therefore the increase or decrease of the aeration rate is the easiest way to influence the ongoing process.

Figure 6 Measuring probe “NaviRott®” in a windrow of bulking material and pre-treated organic waste

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Energy Supply, Waste Management and Climate Effects by Use of Biogas Technology in South African Prison Farms

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ABSTRACT

An alternative variant of energy supply via biogas using residues was studied which should replace fossil fuels and electricity from grid in case of South African prisons which are operating agricultural farms that include pig and cattle farming. A biogas plant, including combined heat and power production, the use of waste heat for warm water, the application of digested manure in agriculture and the direct use of biogas for steam and warm water were studied and variants of crops and manure were considered. The layout and implementation were proposed based on experiences of European biogas plants. Best results were achieved if biogas was used as an alternative fuel to petrol. Only in the case of higher prices for electricity other variants such as combined heat and power will be possible. Climate effects are between 1,000 and 3,000 tons CO_2-equivalents annually depending on the realized biogas plant.

INTRODUCTION

As many developing and emerging countries South African is faced with increased challenges in energy supply that results in insufficient availability of power and growing prices of every type of fuel. Only during last year increase of electricity costs was recorded by 30%. Moreover, the environmental impacts of the energy supply are extremely high, since coal is the main source. As an alternative, under given economic constraints, the application of biomass via biogas processes seems promising for the production of electricity, for heating or cooling, as well as for the production of high energy fuels. This is true for all economic spheres including the prison sector, which is characterized by a full or partly self-supply of food for prisoners by means of prison farms for crop production and animal farming. At present, huge amounts of residues are wasted, including crop residues, animal production manure, sewage sludge, and food leftovers.

The objective of this study was to elucidate the potential application of such residues used as substrates for biogas processes in a typical South African prison for which Groenpunt prison close to Johannesburg, was chosen. Focus is on the balancing of current and future substrate availability, which can be used for energy production; assessment of the energy needs of the different energy users, including needs of electricity, warm water for room heating, steam for kitchen use and fuels for emergency generators, and transportation; and determining under which conditions a biogas plant is profitable, with associated beneficial environmental impacts.

STATUS OF GROENPUNT PRISON FARM

Groenpunt prison is situated 60 km south of Johannesburg. The complex covers an area of slightly more than 1000 ha. It consists of prison facilities, agricultural buildings, animal stalls and a water treatment plant. Agricultural production is carried out on an area of 470 ha. This area is fertilised through cattle dung and organic fertiliser, augmented by sewage sludge from the water treatment plant. The area provides immediate food for the prison and feed for animals. The planted food includes vegetables such as sweet potatoes, cabbage and pumpkin. The planted area encompasses 27 ha, ten of which are for cabbage production. Approximately 20 ha are irrigated by direct use of water from the Vaal-River and sewage treatment plant effluent. Corn for animal feeding is planted on 170 ha. The residual land is grassland.

Animal stock is used primarily for meat and milk production, consisting of 120 milk cows, 50 meat cattle and 2 000 pigs (equivalent to 200 saw units). Occasionally horses are used as work animals. Animal feeding is through concentrated feed mix combined with feed from feed markets. Harvested plants are used as additives to the present feed. Milking is done through a milk station and consequently cooled by a refrigeration system.

Compilation of the Usable Substrate

Organic substances suitable as substrates for biogas production include residuals from animal waste, residuals from water purification, agricultural products or wastes, and left over of food stuffs from the prison population. The substrate groups and amounts are depicted in Table 1.

Table 1 Available substrate amounts

Substrate	Amount (fresh) (t/a)
Grass cuttings (fresh)	7800
Sewage sludge	5840
Corn silage	1520
Cattle manure (fresh)	500
Grain (milled or pressed)	370
Leftovers (from the kitchen)	255
Cabbage	100
Pig dung	100
Feed rest/cattle	50

The total usage of fields and expansion for greater yields of substrates such as hay, corn, etc. is conducive to high yields if enough irrigation is available. This could be achieved through the usage of the purified water from the sewage treatment plant. The annual amount from the support of the Vaal River is approx. 130,000 m^3. The utilization of this treated waste water has the advantage of contained plant nutrients. However, this kind of use must be approved by the relevant water authority. Another water source is condensation water from the biogas plant that amounts to about 5,000 m^3 annually.

Through use of substrates outside the Groenpunt prison system, such as bio-waste and agricultural wastes a good prognosis follows. A cattle farm, approximately 20 km away has an excess of manure from around 18,000 head of cattle that could be utilized. The herd is primarily fed from hay and grass. Because of the concentrated amount of manure from such a large herd, the manure is gathered and stored at a central location. The manure is, through the sitting process, nitrogen rich and because it is not thinned out to liquid fertilizer, relatively energy rich. This manure could be used as an extra substrate which would certainly affect the output efficiency within the plant.

Situation of Energy Usage and Energy Provision

Different kinds of energy are required for both prison building and personnel housing. Heating is for the holding cells of prison itself and for administration rooms. Steam and warm water supply is used in the kitchen for approximately 3,700 people. Refrigeration energy is applied for food and slaughter operations. For power outages, power generation must be considered. Fuel for vehicles belonging to the prison must be supplied for transportation processes.

To accomplish the fuel and power supply various energy sources are utilized which through careful planning could be replaced by biogas technology.

Coal is delivered monthly with an approximate mass of 50 to 60 tons from a company 150 km away. With a load of 25 tons, two separate loaders are needed with 7 200 km annually travelled to deliver the coal. The coal is high quality pit coal with a heating value of 26 MJ/kg.

Electrical energy is supplied by Eskom, with more than 95 percent of its energy generated derived from coal (which means high values of specific greenhouse gas emissions – see Table 6). A total electrical power supply of 17 000 kWh is needed daily through a year's average. The daily power consumption is differentiated through the various months with an extreme difference of almost twice as much during the cold 6-month winter period when a peak of 30,000 kWh per day is reached in

June. Electrical costs in South Africa averaged at € 0.04/kWh during last years but rose by 30% in 2008 and again 30 percent in early 2009.

Diesel and petrol are used as fuel for both emergency generators and the prison's vehicles. Generators are required since Eskom started major load shedding operations due to power shortages throughout the country. Groenpunt uses five generators that are necessitated by the prison's operations. At present the amount of diesel fuel used for vehicles is estimated at about 120 ton annually. The fleet is equipped with both diesel and petrol vehicles.

Inmate quarter heating is by geysers with an installed capacity of nearly 1450 kW. Steam is produced by heating coal in a total amount of 700 t per year at high heating value (26 MJ/kg). Emergency power generators are operated by diesel fuel. Electricity from grid for lightening and machinery amounts to 10 MWh daily.

Energy needs are summarized in Table 2 which also indicates how much energy could be replaced by biogas.

Table 2 Needed energy and replacement by biogas, potentials

Energy user	Energy need (MWh/a)
Inmate quarters heating	3 172
Steam production for the kitchen	5 060
Hot water supply for kitchen and laundry	85
Emergency power generator	800
Electricity for lighting and machinery	3 650
Fuel provision	1 500

GENERAL CALCULATION SCENARIOS

A biogas installation can contribute to addressing energy needs through different variants of gas utilization. However, generally it is to be considered that an immediate conversion of the existing energy structure to one of only consisting of biogas utilization is not effective. Instead, the most efficient type of energy production is to be chosen. For example, the hot water supply of the prison should no longer be heated through the electrical geyser system but rather through solar heating panels. The various scenarios possible through using biogas technologies are shown in the proceeding sections.

Scenario 1 (basic scenario): A complex biogas plant

Energy production by the complex biogas plant is through combined heat and power production in a block heater. This scenario can be changed through variants of the economic conditions such as cost reduction for construction and usage of multiple generators, as well as addition of substrates. Variants considered will include the use of higher amounts of substrates due to expanded usage of fields and the usage of external substrates.

Scenario 2: Cut down version of a biogas plant without block heater

This scenario is taken into account for reducing total construction costs of the plant itself, since the main costs of building the plant involve the installation and maintenance costs of the block heater. The removal of the block heater is then obviously a simplified variant of a biogas plant. However, a problem in such a reduced plant is of course how one heat does and completes the process for the biogas production effectively. The following variants for this scenario should be considered.

Biogas would be used as an alternative to using coal with the associated positive influence on social and economical values (with regard to smoke and ash fallout). In each case the generated biogas quantity is dependent on the substrate availability. A partial amount of the generated heat can be used for the reactors. On an investment side, coal burning steam generators would have to be rebuilt (there are elements available on the market that are relatively cost effective). Taking into consideration the location of the biogas plant itself, it would be advantageous to have the generator in the vicinity of the heating house.

Refrigeration is needed for food storage. On the international market biogas is widely accepted as a very cost effective option for usage in refrigeration requirements. Cooling generators are principally used in the same way as the heating pumps and are widely available on the open market.

Scenario 3: Biogas plant with gas purification and gas liquefaction

Using biogas as a direct fuel for vehicles is becoming an international trend that has led to adding bio-fuel outlets to gas (petrol) stations throughout several countries. This scenario would lend itself to the plant at Groenpunt, however the entire complex would have to be converted to allow for this optional energy basis. Alongside economic differences a positive ecological effect would be realized. A precondition is that the gas must first be purified and compressed (equipment is available on the market and already in use).

COMPUTATION RESULTS

Complete Biogas Plant

A complete biogas plant with block heater with an output of 250 kW electricity is possible at Groenpunt according to usable substrates. Gas production amounts to about one million cubic meters annually. Two digesters are needed with a total volume of around 2 000 m^3. The plant would encompass an area of around 1 200 m^2 (30 m x 40 m). A typical plant of such type is displayed in Figure 1 (Markert 2007, 2008). The total investment costs would be € 835 000.

Figure 1 250 kW biogas plant outlay (courtesy Dr. Markert offices)

In addition to electrical energy the plant would produce 700 MWh/a as heat. The process residues consist of 2 900 m^3/a fermented waste to be used as fertilizer. An amount of 5 800 m^3 condensed water is produced during the biogas process and can be used for irrigation.

Under current economic data the plant would not be, economically viable. Even considering no interest rates there a small loss of about € 10 000 per annum exists. The cost of produced electricity would be € 0.107/kWh, which is nearly double that of the prevailing electricity price. Positive yields would be possible as soon as the price of electricity is increased to € 0.09/kW (see Figure 2) or when state grants are supplied. Bottom line yields could be achieved from a grant of € 650 000.

Enlarged Biogas Plant through Use of Extra Substrates

By use of additional amounts of grass silage or cattle manure from external sources, higher power output would be possible. In the case studied an extra annual amount of 5 000 t grass and 9 200 t cattle manure is estimated, which results in doubled power efficiency to 500 kW electricity. Grass is used as silage produced from irrigated fields by use of water from sewage water treatment plant, on about 120 hectares. Other sources of grass would also be usable. A yield of 45 ton per hectare is considered. Cattle manure is from a nearby cattle farm. Transport costs or benefits for the treatment of the manure as a service will be taken into consideration.

Additional grass silage will bring positive yields if accompanied with state grants. Additional cattle manure will bring a positive yield if the price is under € 1/t. If better economical factors are present such as low interest rates, long credit durations, etc; even manure costs would be acceptable up to € 7/t.

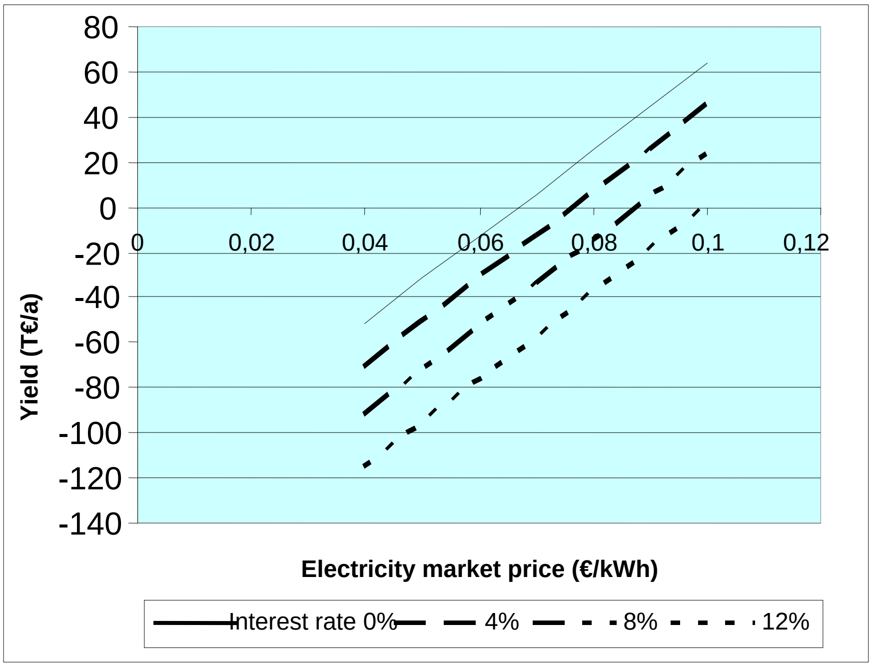

Figure 2 Yield of the biogas plant through changes of electricity price

Warm Water Supply

Supplying warm water to different sections of the prison complex through the geyser system is possible. As soon as the price for electricity exceeds a value of € 0,045/kWh, a positive yield is foreseen.

Conversion of Biogas as Fuel Instead of Petrol

In that scenario the use of biogas for prison vehicle fuel production is considered. According to Scenario 1, the biogas plant would produce 250 kW_{el}. A daily amount of 2900 m3 biogas is produced. With a heating value of 4.85 kWh/m^3 energy output of 14.200 kWh per day results. This is equivalent to an amount of 1400 liters of petrol. At a price of 0.50 EUR per liter of petrol an annual benefit of EUR 250000 results. With the addition of the bonus of petrol equivalents to the biogas plant's economy, the yield is as presented in Figure 6, with interest rates of 0 to 12%/a over 10 years.
Following technical changes must be considered in such a case: A tanking centre with biogas as fuel rather than fossil fuel products is to be foreseen. The vehicle fleet can be supplied as well as surplus fuels sold on the open market in the event that the fuel is not totally consumed by the prison itself. The vehicles must be converted to biogas or new vehicles purchased. Conversion costs run at € 2 000 - 3 000 per vehicle. The conversion is not possible in diesel vehicles. The other factors that must be taken into consideration are gas purification, cooling and sealing, preferably in the vicinity of the biogas plant itself. As a buffer for needed heating for the biogas plant, a boiler plant for 80 kW would be inserted, with investment cost at approximately € 15 000.

Choice for Economical Advantage Variants

First choice is usage of biogas in place of petrol, which is already economically viable at the current price level. The second best variant is the production of hot water for heating of quarters instead through the electrical geysers. If no heat is needed during summer season produced heat can be used in refrigeration using a heat pump installation.

ECOLOGICAL CALCULATION OF ADVANTAGE VARIANTS

Any results need to be accompanied by an ecological balance to study the effect on the environment. This aspect is an important one in South Africa due to the fact that he county ranks 11th among the most important carbon dioxide emitting countries. Moreover, beneficially, the Clean Development Mechanism (CDM) sets the standards through which financial support is granted in areas of development. A good carbon balance would result in much better support. In this way the ecological decision criteria will preferably be how many CO_2-equivalents are produced ("Greenhouse potential", Soyez 2008).

Both variants that are economically viable are compared as possible options at present. Essential comparison factors are the replacement by biogas of fossil fuels or electrical energy.

In case of replacement of fossil fuels by biogas originated fuel with an amount of 511000 l petrol annually, greenhouse gas reduction by about 1022 t CO_2-equivalents annually results. If electrical energy for room heating through geysers is replaced by biogas an amount of 3090 t greenhouse gas emissions will result assuming a nearly 1 t value of CO_2 emissions for RSA electrical mix. In comparing the two variants, one sees the advantages at three times with regard to room heating. However, the alternative use of solar energy for room heating would be an even better ecological variant to the CO_2 balance. Therefore, the prevalence of Variant 2 must be questioned, and it seems that not one of the two variants is to be preferred without considering concrete and detailed local conditions.

Even though the calculations on hand regarding substitution of fossil fuels do not totally encompass all the effects on the balance, the results already show that the reductions are relevant and have considerable positive environmental effects. They could be economically considered if international accepted CO_2-prices for Clean Development Mechanism (CDM) measures, which actually are between € 20 to € 30/t CO_2-eq. are adopted. This will result in yields of € 20 000 to € 60 000 per year if a CDM activity is started, which can be used for investments in biogas technology.

CONCLUSIONS

A biogas plant for the production of electricity and heat via cogeneration is technically feasible in Groenpunt prison farm on the basis of waste amounts and agricultural byproducts. A power capacity of 250 kW and 700 MWh heat are applicable. Such a plant is not yet, but will become economically feasible if energy prices are higher than € 0.06/kWh. By use of external substrates the capacity of such a plant can be doubled. By direct use of biogas for warm water preparation or room heating, as well as for petrol substitutes, profitability can be achieved. Environmental effects for these options are in the range of 1 000 to 3 000 t CO_2-equivalents annually. Through the CDM mechanism this may result in an extra profit of between € 20 000 and € 60 000 that can be used for investment. The result indicates that the waste and energetic situation in prison farms should be thoroughly considered to come down with benefits in economy and ecological respects. Concrete on site calculation is necessary.

ACKNOWLEDGEMENT

The paper was made possible through a grant by the International Offices of German Federal Ministry of Education and Research (BMBF) and the South African National Research Foundation (NRF) (Grant No. 39.6.F2A.6.A). This support is much appreciated.

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ISBN: 978-984-33-0761-3, Vol. 2, pp.585-591

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Feasibility of Sustainable Recycling of Municipal Solid Waste as Compost in an Effort to Organic Farming

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ABSTRACT

The feasibility of decomposed municipal solid waste (MSW) use as compost was examined by growing of tomato plant in pot. Its prospect in reducing conventional fertilizer use and impact on disseminating heavy metals were evaluated with the objective of sustainable recycling as organic amendment for plant growth and development as well as assisting to preserve congenial environmental. The obtained results in the present study illustrated that the application of MSW compost supplemented with urea for tomato cultivation enhanced significant plant growth such as plant height, longevity of leave greenness, branch and fruit development and dry matter production. The plant height, fruits number and fruits weight per plant, spad values (greenness of leaves) and branch number per plant were increased significantly ($P \leq 0.01$) over control by MSW compost application supplemented with urea. Moreover, all of these values were insignificant with the results obtained at treatment of 100% urea application. The MSW compost supplemented with urea treatments also enhanced to reduce the total dry leaves number per plant. The treatment 50% MSW compost + 50% urea provided the lowest number dried leaves per plant, which was significantly lower than the control and 100% urea applied treatments. The total dry matter production was also enhanced at MSW compost treatments but it was lower than the 100% urea contained treatment. The assessment of nutrients and heavy metals uptake did not present any impressive results by MSW compost applied treatments but the heavy metals levels in fruits were much lower than the international standard limit. Finally, the present study suggests that the MSW compost application is quite potential to reduce the use of 50% urea (at least) in agronomic and horticultural practices.

INTRODUCTION

Municipal solid waste (MSW) disposal has become a major dilemma for many countries. Because of environmental concern, its disposal as landfills and soil application has chance to disseminate trace/heavy metals to food chain or leach from the soil to endanger groundwater quality (Epstein et al. 1992 and Kaschl et al. 2002). The agricultural application of MSW compost is limited by its high heavy metals content, which is undoubtedly phytotoxic and zootoxic (Alloway 1995), its presence in food chain may cause harmful effect for human (Chaney 1980). Therefore, its disposal and management require proper attention for human and animal health and protection of groundwater. The quality of MSW generated in a city depends upon a number of factors such as food habits, standard of living and degree of commercial and industrial activity in the city. Therefore, the concentration of different trace metals in MSW varies from city to city. In Dhaka city approximately 3500-4000 metric tons of MSW are generated per day (Bari et al. 2007). Environmental safe disposal of such huge volume of MSW is really a problem to concern people. However, the use of MSW compost is increasing in many countries all over the world. Several studies have shown that the use of MSW compost in agriculture is beneficial to soil, crops and environment (Hicklenton et al. 2001 and Rodd et al. 2002). However, the effects of MSW compost depend on the amount of organic carbon, both organic and inorganic N, the extent of compost maturity, the content of heavy metals, the addition of mineral fertilizers, prevailing soil characteristics and climate (Grecchio et al. 2004). Agricultural crop land is the largest potential scope for compost use. Municipal solid waste compost acts as potential organic amendment.

Application of organic amendments not only improves the soil health, microbial populations, moisture retention capacities, nutrients availability through changing the soil physical, chemical and biological properties (Aggelides and Londra 2000) but also promotes plant growth by nutrients use efficiency and reduces use of inorganic N (Molla et al. 2005 and Meunchang et al. 2006). Municipal compost is also used as a source of nutrients, particularly minor elements, because most of the commercial fertilizers rarely contain minor elements. The organic matter in compost also acts as a relatively long-term reserve for major nutrients like nitrogen, phosphorous, and potassium. It is estimated that 10 to 15 percent of nitrogen in this organic matter may be released during the first growing season through mineralization, with residual nitrogen released over the next 2 to 3 years (Naylor 1993).

Moreover, efficient use of MSW compost may reduce the fertilizer cost as well as it may help soil and groundwater environment improvement by reducing excessive use of inorganic fertilizers. Based on above facts, the present study was undertaken to investigate the effect of municipal solid waste compost on growth performance, yield attributes and nutrients/heavy metals uptake by different parts of tomato in pot culture.

MATERIALS AND METHODS

Collection and Preparation of MSW Compost

The decomposed MSW compost was collected from Gazipur Municipality area in polyethylene bag. All the foreign materials were separated and removed from it unless it was more or less uniform in looking before use. Prior to utilization the quality of the compost was evaluated through monitoring of germination index of mustard seeds (result was not presented here) by using water extract. The collected MSW compost was found suitable for conducting the experiment.

Pot Preparation, Fertilizer and Treatment Application

Clay loam soils were collected from surface soils of agricultural farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University for pot preparation. For making uniform sizes of clods and moisture, the soils were air dried for two days in glasshouse. Based on the treatments, required amount of fertilizer and MSW compost were thoroughly mixed with soil before taking into pot. Twelve kg soil was used in each earthen pot in the experiment. The TSP and MP (1.32 and 1.5 g per pot, respectively) were applied as basal dose. The treatments were assigned based on the standard rate of urea for tomato of the used soil. The six treatments were (i) T_1: Control, (ii) T_2: 100% urea, (iii) T_3: 100% MSW compost (iv) T_4: 25% urea + 75% MSW compost, (v) T_5: 50% urea + 50% MSW compost and (vi) T_6: 75% urea + 25% MSW compost. The treatment 100% urea was equivalent to 2.64 g urea (i.e. 1.21 g N) per pot. The used MSW compost contained 0.82% N (wet basis) and 148 g MSW compost equivalent to 1.21 g N was applied per pot at treatment of 100% MSW compost. The amount of urea in respective treatment was applied in three equal installments such as basal, 25 and 50 days after transplanting (DAT) of seedlings.

Seedling Transplanting and Crop Management

Tomato (*Lycopersicon esculentum*) var. Rattan was used as test crop in the present experiment. Seedlings were raised in seedbed and two similar sized of one month old seedlings were transplanted in each pot. Irrigation, pesticides, fertilizer and other necessary intercultural operations were assured in regular interval and based on necessity.

Parameters Considered for Evaluation

Biometrics measurements such as plant height, number of leaves and fruits, fruits weight, dry matter production, greenness of leaves were recorded for evaluation of the feasibility of MSW compost utilization in organic farming. Uptake of major nutrients and trace (heavy) elements were considered in evaluation by chemical analysis of plant tissues. Plant samples were oven dried at 70^{o}C for 3 days for dry weight measurement and chemical analysis.

Chemical Analysis of Plant Materials

Oven dried grinding samples (< 1.5 mm) were used for chemical analysis. Total N was analyzed by using Micro-Kjeldahl method (Black 1965). Phosphorus was determined based on description of Olsen et al. (1965). The procedure described by Jackson (1973) was adopted for extraction of potassium (K) followed by atomic absorption spectrophotometer for its assessment. Similarly for Ca and Mg, the extraction procedure was adopted based on Hunter (1984) followed by atomic absorption spectrophotometer for its quantification. Aqua Regia extraction method (Cottonie et al. 1979) followed by atomic absorption spectrophotometer were used for assessment of heavy metals (trace elements).

Experimental Design and Statistical Analysis

The experiment was conducted in completely randomized design (CRD) and replicated four times. Analysis of variance and comparison of means were conducted separately with the statistical package MSTAT-C. The means were compared by using the least significance difference (LSD) test.

RESULTS AND DISCUSSIONS

Biometric Measurements

Municipal solid waste compost application in pot for tomato cultivation influenced on biometric measurements of plant such as number of branches and leaves per plant, plant dry matter production, number and weight of fruits, greenness of leaves. Plant height of tomato was influenced by MSW compost application in pot (Table 1). All MSW compost added treatments enhanced plant height compared to the control. MSW compost supplemented with urea treatments provided higher plant height than the sole MSW treated plant, also which were closer and insignificant with the results of 100% urea added treatment. Comparatively the treatment of 50% MSW compost + 50% urea showed the superior performance in plant height of tomato among all treatments.

Number of branches per plant was minimum in control. The increased values were observed in all treatments compared to the control (Figure 1). Almost equal and the highest number of branches was attained at 100% urea and 75% MSW + 25% urea added treatments, which increased significantly ($P \leq 0.05$) compared to the control. The second highest result was recorded in the treatment of 50% MSW + 50% urea. Moreover, the branches per plant proportionately increased in enhanced MSW compost application. Alternately the number of dried leaves per plant (Figure 1) was recorded minimum in all compost added treatment except 100% MSW. The lowest number of dried leaves per plant was observed in 50% MSW + 50% urea added treatment, which was significantly lower than the control.

Table 1 Plant height of tomato plants at different days after transplanting (DAT) in pot culture with MSW compost amendment

Treatment	Plant height (cm) at different DAT			
	10	30	60	90
Control	7.63	16.56	41.25	46.25
100% Urea	9.38	23.75	55.88	61.38
100% MSW	9.25	22.75	50.25	52.38
25% MSW + 75% Urea	8.38	16.88	51.00	56.00
50% MSW + 50% Urea	8.23	18.00	54.38	63.38
75% MSW + 25% Urea	8.63	19.25	56.38	58.00
LSD (P(0.01)	NS	5.66	9.78	6.39

Gradual decreased number of dried leaves attained in enhanced compost added treatment except the 75% MSW + 25% Urea. It implied that this ratio of MSW compost and urea was not so suitable and its performance was as like as 100% MSW treatment. The highest number of dried leaves attained in control treatment. The present result is in the agreement of the report presented by Molla et al. (2005) in corn plant plantation with domestic wastewater sludge compost amendment. The MSW compost supplemented with urea treatments also enhanced greenness (SPAD value) of the leaves (Table 2). The obtained results showed that it influenced higher greenness of leaves compared to urea (insignificant) until 90 DAT. Both fruits/plant and fruits weight/plant were enhanced after MSW compost application compared to the control (Table 3). The highest number of fruits (55 per plant) was recorded in the treatment of 75% MSW + 25% urea followed by the treatment of 50%MSW + 50% urea (47 per plant). The 100% urea treated plants provided 38 fruits per plant and the minimum were in control (11 fruits per plant). Though the higher percentage of MSW compost contained treatments offered significantly ($P \leq 0.01$) higher number of fruits compared to the treatment contained sole urea but their weights (i.e. fruits weight/plant) were similar. It implied that comparatively smaller size but higher number of fruits attained in compost added treatment and alternately bigger size and lower numbers attained in sole urea contained treatment. MSW compost enhanced higher fruit setting. Influence of MSW compost on dry matter production was also noticed in the present study (Table 4). The highest total dry weight was attained at 100% urea treatment. The second highest and closer values of dry weight were observed in three treatments of MSW compost supplemented with urea. Significantly (P≤0.01) higher fruits dry weight was attained in all treatments compared to the control. But the closer fruits dry weight was recorded in three treatments (100% urea, 50% MSW compost + 50% urea and 75% MSW compost + 25% urea).

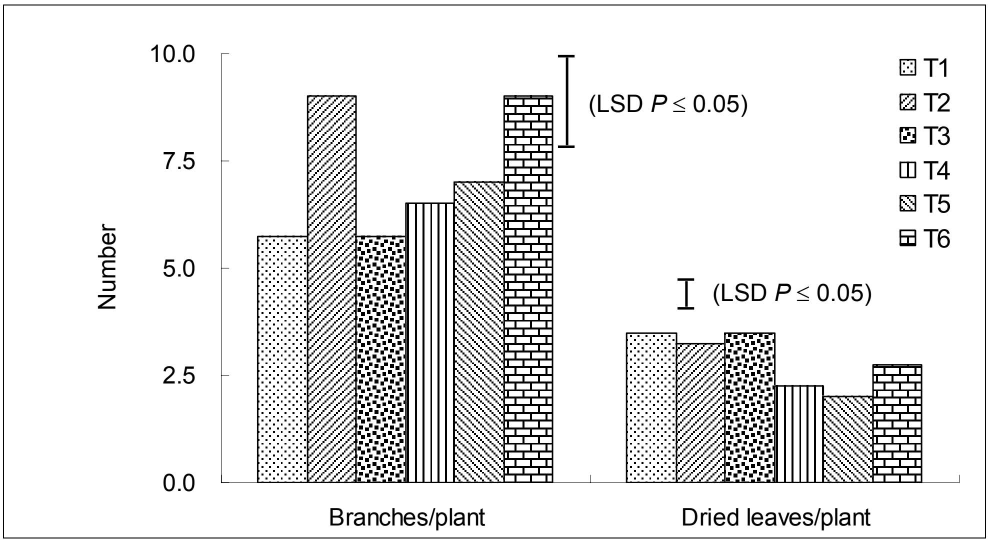

Figure 1 Branches/plant and dried leaves/plant of tomato grown in pots with MSW compost.

Table 2 SPAD values under MSW compost application of tomato at different growing stages in pots

Treatment	Days after transplanting		
	30	60	90
Control	40.88	34.50	31.85
100% Urea	42.20	49.85	42.15
100% MSW	41.30	31.70	34.45
25% MSW + 75% Urea	41.98	50.18	46.13
50% MSW + 50% Urea	41.45	45.58	42.20
75% MSW + 25% Urea	41.26	44.68	37.60
LSD ($P \leq 0.01$)	NS	10.32	9.34

Table 3 Impact of MSW compost on number and weight of tomato fruits per plant in pot culture

Treatments	Fruits/plant	Fruits weight (kg/plant)
Control	11.00	0.42
100% Urea	38.00	1.86
100% MSW	27.00	1.07
25%MSW+75%Urea	26.00	1.34
50%MSW+50%Urea	47.00	1.86
75%MSW+25%Urea	55.00	1.87
LSD ($P \leq 0.01$)	4.62	0.14

The highest but insignificant (compared to 100% urea treated plant) fruit dry weight was attained in 75% MSW compost + 25% urea treated plant. The significantly highest root and shoot dry weight was observed in 100% urea treated plants. The second highest of shoot and root dry weight were recorded in 25% MSW compost + 75% urea and 75% MSW compost + 25% urea treatment, respectively. The impact of compost on superior plant growth was most likely due to increase in N availability as well as its slow and steady release (Erhart et al. 2005). Moreover, the compost applied treated plants might obtain some additional plant nutrients for their growth and development

(Meunchang et al. 2006). In addition, application of organic composts enhanced the improvement of physiochemical status of soil health (Aggelides and Londra 2000), which favors the better plant growth and development (Molla et al. 2005 and Meunchang et al. 2006).

Table 4 Effect of MSW compost on dry matter production and its partitioning into different organs of tomato plant in pot culture

Treatments	Dry weight (g)			
	Root	Shoot	Fruit	Total
Control	12.75	35.28	27.54	75.57
100% Urea	27.54	148.00	130.98	306.52
100% MSW	18.13	57.08	73.41	148.62
25%MSW+75%Urea	21.15	136.95	94.36	252.47
50%MSW+50%Urea	23.25	112.50	126.58	262.33
75%MSW+25%Urea	23.85	99.25	134.75	257.85
LSD ($P \leq 0.01$)	2.54	9.94	11.22	-

Nutrients and Heavy Metals Uptake

The uptake of N, P, K, Ca and Mg did not follow any particular profile among the treatments (Table 5). Exclusively any particular treatment did not show superior nutrients uptake. But nutrient analysis profile in control treatment implied that the soil was quite fertile. The results in the present study showed that the deviation in nutrients uptake by root and shoot among different treatments was narrow. Mostly the nutrients uptake depends on their presence of available forms in soil solution. Obviously the availability of nutrients depends on several physical, chemical and biological properties of soils. The composts conserve some favorable environments in soil-plant system through maintaining better physical properties, aggregation and aeration ability (Kostov et al. 1996), increase total porosity, and saturated hydraulic conductivity of soils (Aggelides and Londra 2000), which ensure better water and nutrients regime for improved physiological activities such as higher dry matter production through enhanced harvest of atmospheric CO_2. These are the probable explanations of comparatively encouraging plant growth and development in the present study of MSW composts with supplemented urea application.

Similarly heavy metals uptake did not follow any specific pattern among the treatments as above discussed nutrients (Table 6). But the accumulation of Zn and Fe in fruits was the highest in treatment of 100% MSW compost than the others. Perhaps it originally contained higher amount of these metals and enhanced application rate (100% MSW compost) increased its higher uptake in fruits than the other treatments. Regarding the use of MSW composts in agriculture soils USA, EC and Australia standardized the limits of 2800, 100 and 300-1500 for Zn and 1500, 300 and 1000 (mg kg^{-1}) for Cu, respectively (de Bertoldi et al. 1990 and He et al. 1995). The highest accumulation of Zn, Fe and Cu in fruits was observed 56.33, 948.00 and 2.35 (mg kg^{-1}), respectively in the present study. The obtained amount of these metals in fruits was quite low compared to the aforesaid standard. It implied that the use of present MSW compost in food chain could not make any threat to living beings.

Table 5 Nutrients content (%) in root and shoot tissues of tomato plant grown in pot using MSW compost

Treatments	N		P		K		Ca		Mg	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Control	0.704	0.722	0.187	0.290	1.224	1.552	0.121	0.364	0.103	0.140
100% Urea	1.092	0.730	0.273	0.220	1.632	1.423	0.162	0.444	0.140	0.160
100% MSW	0.853	0.486	0.260	0.292	1.427	1.510	0.121	0.525	0.111	0.161
25%MSW+75%Urea	0.693	0.874	0.217	0.227	1.386	1.552	0.162	0.362	0.128	0.152
50%MSW+50%Urea	0.653	0.598	0.200	0.190	1.425	1.385	0.122	0.485	0.124	0.159
75%MSW+25%Urea	0.768	0.323	0.240	0.187	1.461	1.713	0.241	0.401	0.157	0.143
LSD ($P \leq 0.01$)	0.09	0.06	0.02	0.02	0.11	0.11	0.02	0.02	0.02	0.02

Table 6 Heavy metals concentration (mg kg^{-1}) in root, shoot and fruit of tomato plant grown in pot using MSW compost

Treatments	Zn			Fe			Cu		
	Root	Shoot	Fruit	Root	Shoot	Fruit	Root	Shoot	Fruit
Control	78.97	75.23	37.58	3791.5	1894.5	474.75	22.00	8.725	2.15
100% Urea	52.64	48.89	33.84	3791.8	1896.0	473.50	21.75	8.800	2.18
100% MSW	60.17	60.21	56.33	3792.3	948.0	948.00	19.63	4.400	2.18
25%MSW+75%Urea	52.65	60.14	33.83	2843.8	1893.8	473.25	13.23	4.425	2.23
50%MSW+50%Urea	56.21	56.40	33.87	2844.3	1898.8	472.50	17.60	4.375	2.35
75%MSW+25%Urea	52.67	52.65	41.36	2844.0	946.8	649.00	21.75	4.400	2.25
LSD ($P \leq 0.01$)	5.35	5.87	4.66	643.76	307.84	167.55	6.177	1.95	0.66

CONCLUSIONS

Generally compost possesses the potential physical properties, aggregation, and aeration ability that ensure adequate water and nutrients regime at the period of plant growth. Therefore, the application of compost enhanced superior crop growth compared to conventional fertilizer while supplemented with urea. In the present study all of the biometric measurements in MSW compost plus urea supplemented treatments clearly showed the significant ($P \leq 0.01$) improvement over control as well as closer or above (in some cases) to the values obtained in 100% urea treated plant. It is clearly implied the use of MSW compost could reduce the cost about 50-75% of urea in agronomic or horticultural practices. No doubt the heavy metals contamination to the food chains and environment by such kind of organic wastes is a great threat to living beings. But the present results assured that the used MSW compost and techniques were almost free from such kinds of risk. Finally, the present finding is an encouraging message of potential recycling of municipal solid waste, which could reduce the cultivation cost of agronomic and horticultural product and help sustain congenial environment of urban area.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.593-597

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Vermicomposting (A Part of Innovatve Integrated Farming) for Sustainable Resource Utilization from Organic Waste in Fulbari-3 at Chitwan in Nepal

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ABSTRACT

This paper describe the findings of the investigation on vermicomposting to ensure sustainable resource utilization from organic wastes.Single variety of composting worm known as red worm (Eisenia fetida) was used as pilot program of vermiculture in a small wooden box of size (2×1.5×1.5) feet for the study. The protective measures were applied by putting the box in a metal frame with stands deep in bowls filled with water and cover by metal gage on the top. The bed was prepared by using five kilogram of chopped and dry straw and 25 kg of buffalo dung (15 days old). A total of 100 red worms were placed in the box and covered by black plastic. The temperature and moisture were maintained at a constant level by putting it in shadow and occasional sprinkled with water. Though the study is continue, at the end of 52 days of vermiculture, the E. fetida increases in number from 100 worms to 348 worms. Similarly, 625 numbers of cocoons were also recorded from the box. The weight of vermicompost so produced was nine kilograms while the remaining organic matter constitute of 12 kg. A total of 378 individuals from different sectors visited the research center (at Innovative Integrated farming site) and observed the vermiculture and were made aware and encouraged about the technique. The study indicated that vermicomposting of domestic waste could be an effective technology to convert the negligible resource into some value added products like vermicompost and worms on a low-input basis and also pave the way to reduce solid waste management in developing countries like Nepal in eco-friendly and sustainable way.

INTRODUCTION

Human activities create waste. Intense human activities in urban areas have direct consequence of environmental pollution that challenges the human civilization. Hence, appropriate and safe solid waste management are of the greatest importance to allow healthy living conditions of people. Typically one to two thirds of the solid waste generated is not collected (World Resources Institute et al.1996) which mixed with hazardous waste, human and animal excreta contributing to the environmental pollution that pose risks to the public health. The rapid increase in population and the urbanization of the city has added problem to the collection, transfer and management of waste. Most of the solid waste generated in Nepal is domestic waste consisting of about 78% biodegradable organic waste (CEDA 1990). Being a developing country, the emphasis on collection is very natural; however, Government of Nepal is aware of safe and reliable disposal and treatment of solid waste at landfill sites. But, the organic waste management has always been a major environmental and social problem and management of cites' waste becomes a political issue. The geo-scientifically viable, environmentally suitable and socially acceptable sanitary landfill sites are also very limited in the metropolitan cities. If the landfill space is scarce it may be necessary to consider incineration. But, monitoring equipment is costly and requires aggressive maintenance and servicing by trained technicians. The proper management of waste can reduce the hazard of waste, recover material for recycling, produced energy from the waste, or reduce its volume for more efficient disposal. So, the Waste Hierarchy term ‘4 Rs’ or ‘Reduce-Reuse-Recycle-Rethink’ has also been used for the same purpose. A relatively recent idea in waste management has been to treat the waste material as a resource to be exploited, instead of simply a challenge to be managed and disposed off. The practice of treating waste materials as a resource is becoming more common, especially in metropolitan areas where space for new landfill is scarce. Therefore, the research focuses to establish the use of redworms *Eisenia fetida* for vermicomposting, so as to reduce the organic waste at the site of generation.

The term Vermicomposting, also called vermiculture or worm composting, is an aerobic composting process in which certain varieties of earthworms are used to break down organic materials. Vermicomposting is an eco-biotechnological process that transforms energy-rich and complex organic substances into stabilized humus-like product, vermicompost. It is considered as an excellent product, since it is homogenous, has reduced levels of contaminants and tends to hold more nutrients over a longer period without impacting the environment. The worms mechanically break down the organic materials by eating them, and biochemical decomposition occurs via bacteria and chemicals in the worms' digestive system. Vermiculture requires considerable labor and careful control of composting conditions, including temperature, moisture, and the mix of ingredients. Its successes to date are limited to relatively small-scale or pilot programs. However, some epigeic earthworms: *Lumbricus terrestris, Eisenia fetida, E. andrei, Eudrilus eugeniae* and *Perionyx excavatus* have been appeared as key sources to combat the problems of organic waste disposal on a low-input basis (Kale et al. 1982; Butt 1993; Elvira et al. 1998; Dominguez et al. 2001; Garg and Kaushik 2005; Suthar 2006). Recently, Suthar (2007a and b) demonstrated the potential of a new species, i.e. *P. sansibaricus,* for waste decomposition operations.

The integration of composting worms' aside frog culture, catfish (*Clarias batrachus*) culture may have great value because the worms can be given to frogs or fishes as highly nutritious food. In turn, greater amount of organic fish yield assist in sustainable utilization of resource from organic waste. For the purpose, an innovative works in Nepal has been established in Fulbari-3, Chitwan by Association for Nature Conservation and Social Upliftment, Nepal (ANCSU, Nepal).

Study Site

The intensive study on vermicomposting in association of integrated farming has been operating in the Fulbari-3, by the active members of ANCSU, Nepal. The farming site is located nearby the Shreepur Secondary School of Fulbari VDC, and is 10 km far away to south-west from Chowbiskoti chowk, Bharatpur, Chitwan. It is situated in inner Tarai lowland of southern central part of Nepal, has three main seasons: winter, spring and monsoon; and has subtropical climate with relatively high humidity.

OBJECTIVES

General Objectives

To explore the population dynamic of composting worm, convert degradable organic waste into valuable compost; explore the potential multipurpose uses of worms in different sectors; and develop the slogan: Fohar lai Mohar Banau (i.e. make dollar from waste).

Specific Objectives

- to aware and encourage the local people for household level vermicomposting so as to reduce the organic waste at their site of origin.
- to duplicate the concept of integrated farming with the inclusion of vermicomposting in national level.
- to assist deprived farmers for income generation through resource utilization judiciously.

METHODOLOGY

Materials Used

Single variety of composting earthworm, also called as red worm (*Eisenia fetida*) was used for small scale vermicomposting technology. A wooden box of size (2×1.5×1.5) feet was used for the study. The protective measures (as figure 1) were applied by putting the box in a metal frame with stands deep in bowls filled with water and cover by metal gage on the top for protection against ants and rodents.

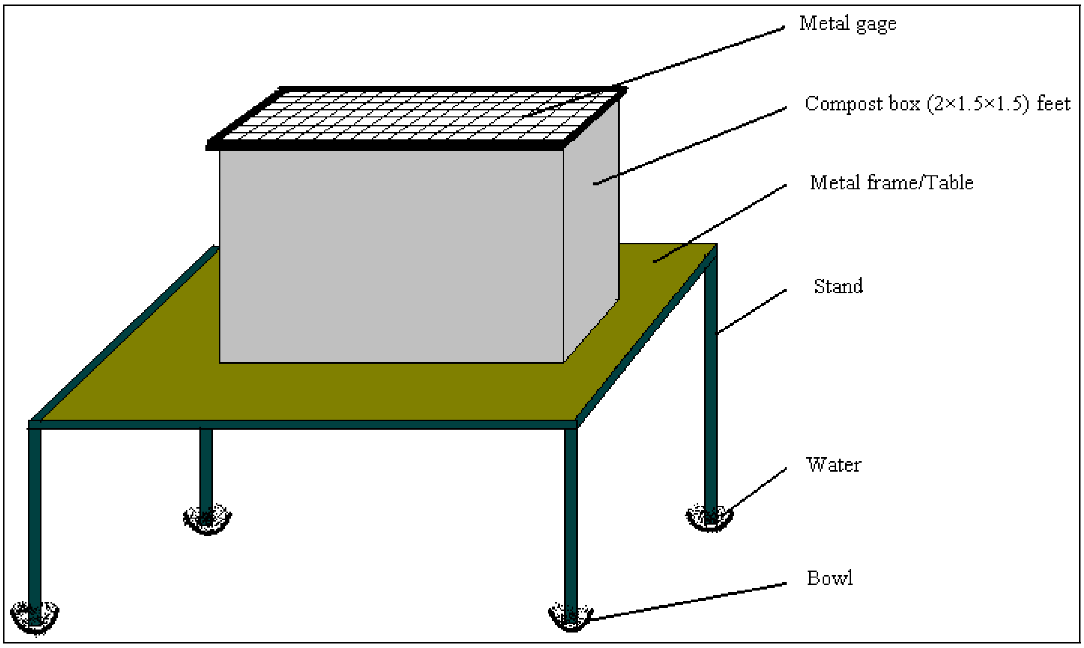

Figure 1 Protective measures applied during vermiculture

Methods

The bed was prepared by using five kilogram of chopped and dry straw and 25kg of buffalo dung (15 days old). A total of 100 red worms were placed in the box and covered by black plastic. The temperature and moisture were maintained at a constant level by putting it in shadow and occasional sprinkled with water.

Population Count

After 52 days the total number of red worms and its cocoons produced were counted and the vermicompost so produced was weighted. The data so obtained were purely experimental and was tabulated and analyzed to find out the cocoon and reproduction rate.

Cocoon rate = No. of cocoon/worm

Reproduction rate= No. of cocoon/worm/day

Awareness Programs

Several schools leveled and community awareness programs were conducted for providing awareness and encouragement to the local people by demonstration and talk programs in integrated farming site.

Possible Applications

The potential uses of red worm in various fields were explored through the secondary data, and its applications were conveyed among the participants of awareness program.

Integrated Farming Practices

It has targeted to reduce greenhouse gases produced from misused organic wastes from most of urban areas in Nepal that has been converted into food chain through red worms *(E. fetida)*, frogs and catfishes (*C. batrachus*) in eco-friendly and sustainable way.

RESULTS AND DISCUSSIONS

Population Dynamic of Red Worm (*Eisenia Fetida*)

The vermicomposting process refers to earthworms feeding on organic matter and microbial degradation. In a vermicomposting process, inoculated earthworms maintain aerobic condition in the wastes, convert a portion of the organic material into worm biomass and respiration products and expel the remaining partially stabilized product (vermicompost). At the end of 52 days of vermiculture, the *E. fetida* increases in number from 100 worms to 348 worms. Similarly, 625 numbers of cocoons were also recorded from the box. Thus, the cocoon rate calculated was 6.25 and the reproduction rate of individual worm inside the experimental box was 0.12. The weight of vermicompost so produced was nine kg, while the remaining organic matter constitute of 12 kg. It was found that some epigeic species like *Perionx exacavatus* have higher cocoon production and reproduction rates which were 19.98 and 0.13 respectively (suthar and singh 2007). Although the cocoon production rate was quite higher, the reproduction rate was almost similar in compare to the *E. fetida*.

Awareness

A total of 378 individuals of various categories (Table 1) were visited the research site and observed the vermiculture technique and made aware and encouraged about the technique by providing the information and its beneficial outcomes. There is no doubt that the household level vermicomposting definitely control over the organic solid waste piled up on the surrounding environment.

Table 1 Number of observers

S.N.	Category of Observers	Address of observers	No. of observers
1	Technicians	Prolinova, Pokhara	21
2	Farmers	Organic Agriculture Producer Co-operative, Chitwan	65
3	Students	Rampur Agriculture Campus, Chitwan	11
4	Farmers committee	Nepal Bee keeping Association	7
5	Farmers	Local farmers	66
6	Students	Shreepur Secondary School, Chitwan	190
7	Teachers and staffs	Shreepur Secondary School, Chitwan	18
		Total	378

Vermicomposting and Its Applications

Vermicomposting is a simple technology, and possess an Eco-friendly system to reduce the volume of organic solid waste at the site of generation and produce high quality compost (i.e. make dollar from waste). The vermicompost has high Nitrogen (1.5 to 2.2%), Phosphorus (1.8 to 2.2%), and Potassium (1.0 to 1.5%) level and moisture content. The nutrients contain remains for long time (5 yrs) in soil that help to improve the soil structure and fertility and balance the pH level of soil (University-3 2001). Besides its agricultural importance the worms can be used as medicine in various diseases like: piles, rheumatism, jaundice, pneumonia, tuberculosis, small pox, wounds and inflammation. It can be use as aphrodisiac and pregnancy test. It has high protein content (70%), so can be use as food for man, poultry farming, fish and frog farming etc (University-3 2001).

Integrated Farming

Only vermicomposting program has not been flourished in Nepal because of marketing problem of worms. The integrated farming has consumed all the worms in artificially developed ecosystem. The nutrient materials and energy, in turn, deposited in fishes has been relished by people. Hence, the money from catfish, frogs, worms as seed and tourism may sustain the system. On the other hand, manure obtained from vermicomposting may be good source of money for sustainability. This model project could be copied to control solid waste pollution in other big cities of Nepal. In this way the innovative farming of red worms in integration with frog and fish has been run in Chitwan, lowland Nepal. The project has ambitious aim to control the waste production at household level, developed an artificial ecosystem and educational park targeted for all academician and agricultural groups of the world.

CONCLUSIONS AND RECOMMENDATIONS

The growth, reproduction efficiencies and composting potentials could be a species-specific character, or it could be related to the quality of the substrate used for their culture. Vermiculture does not necessarily kill all pathogens. In particular, some viruses and parasites can survive the process. Therefore, if the input materials present a high risk of containing pathogens, the finished product could still contain pathogens. This may be of particular concern in developing countries, where organic waste used in vermicomposting may not be source-separated. However, this study clearly indicates that vermicomposting of domestic waste could be an effective technology to convert the negligible resource into some value-added products, e.g. vermicompost and earthworms on a low-input basis.

As the degradable organic content of the waste is very high it is worthwhile to adopt biogas production. Therefore to reduce the hazard of waste, produce energy from waste, and to reduce it in volume for more efficient disposal biogas cum composting could be the best alternative method rather than land-filling. So, for the better tomorrow it need to be address for the sustainable utilization of resources from the waste instead of dispose. The study recommend following points:

- To reduce the impurities like pathogens present in compost all the organic waste should be source-separated domestic or market wastes.
- The integrated (earth worm, frog and fish) farming should be copied in several cities for sustainable resource utilization of organic waste.
- Government should be emphasizing on large scale alternative method of biogas cum composting technique to produce energy from waste.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.599-606

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Energy Balance of Biowaste Compost Used as Organic Fertilizer in Farming

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ABSTRACT

The dry matter of compost from separate collection in Germany contains 1.4 % of nitrogen, 0.6 % phosphorus and 1.2 % potassium. Therefore compost can and should be seen as an organic N-P-K fertilizer, which has the ability to substitute industrially produced mineral fertilizers. Using an amount of 10 tons compost per hectare and year will make the use of mineral P and K fertilizer in a common crop rotation unnecessary. Furthermore liming for soil protection purposes will be done. The amount of mineral nitrogen fertilizer needed is halved when compost is used over a long period. Using compost must lead to a reduction of the use of mineral fertilizers. If the mineral fertilizers would not be reduced, the surplus nutrients would be washed out and could lead to a contamination of surface and ground water. The amount of reduction of fertilizers must therefore be calculated and must consider the amount of nutrients, especially the right amount of nitrogen, from compost. The ability of compost to substitute mineral fertilizer, for the production of which energy and natural resources are needed and green house gases are emitted, can be credited positively to compost, a surplus that could be benefited in CDM-projects.

MAIN TEXT

Normally organic fertilizers are fertilizer that contain all the main nutrients i.e. nitrogen, phosphorus and potassium as well as micro nutrients (e.g. Mg, Cu, As, etc.). It should however be observed that the substances to be imputed as plant nutrients in the miscellaneous organic fertilizers are not always the same. Thus, especially with compost and even with straw, only a fraction of the nitrogen can be imputet for the fertilization (BGK 2006).

Macronutrients, Phosphorus and Potassium

Phosphate and potassium from compost have a similar effect as P and K from mineral fertilizers. Both nutrients are completely available to the plants from compost and highly efficient fertilizers. Therefore the complete content of both these nutrients will have to be calculated in the fertilizer planning (Peretzki and Heigl 2005). The following Table 1 lists information on literature and quality assurance data of compost compiled by the BGK. The BGK data (2008a) refer to a data base of more than 2500 samples from quality assured composting plants and can therefore be assumed secure. It is difficult to explain the deviation of the values from those of Gutser (1999) and Mönike (2007) as compared to other sources.

Table 1 Total phosphorus content of compost

Source	P – total [P_2O_5 in % of TM compost]
Gutser, 1999	0.3
Reinhold, 2002	0.83
Mönike, 2007	0.3
BGK, 2007	0.4 – 1.0
BGK, 2008a	0.64 (mature compost)
	0.80 (fresh compost)
LTZ, 2008	0.5 – 0.7

One reason could be that this exclusively concerns green waste compost and not bio-waste compost. This has, however, not been explicitely mentioned in the sources.

The comparatively high percentage of P_2O_5 (Phosphate) in bio-waste compost is mostly the limiting factor by a fertilizer evaluation, because through fertilising with compost the necessary quantity of phosphate in the fertilizer calculations is first reached. This however, depends on crop rotation. Reaching the desired value of P_20_5 usually results in reaching the necessary quantities of potassium fertilizer, calcium and other micro nutrients (Mg, S, B, Cu, Mn, Mo, Zn) (BGK 2006; Pfündtner 2003 and LTZ 2008).

Table 2 total potassium from compost

Source	K –total [K_2O in % of TM compost]
Gutser 1999	0,8
Reinhold, 2002	1,26
Mönike, 2007	0,9
BGK, 2007	0,6 – 1,6
BGK, 2008a	1.1 (matured compost) 1.3 (fresh compost)
LTZ, 2008	0.8 – 1.3

Table 2 shows the total potassium in compost. Even for this the specifications in literature are congruent, for further considerations the BGK (2008a) values are consulted as the database is known (over 2500 samples), giving the highest possible security. Analogous to phosphorus, the quantities of K2O in compost are also to be rated as high. They could therefore also be the limiting factor for administering compost instead of fertilizers.

It is to be noted that, the common administration of 10 mg TM compost / (ha *a) for both nutrients fully compensates the reduction through agricultural use, higher amounts administered would in fact cause an increase of nutrients in the soil (LTZ 2008). Therefore, additional fertilizing with mineral P or K fertilizers is mostly not necessary.

Macronutrient Nitrogen N

There are large differences in the total nitrogen content of different composts. These vary, depending on the origin of the composted materials and the degree of composition between 0.8 and 2.0 percent of the dry mass. A relatively small fraction of nitrogen is found with green waste compost in which the percentage of nitrogen is very low. Nitrogen percentages in the upper range are found with bio-waste by which it should be noted that fresh compost contains a little more nitrogen than mature compost. Table 3 shows values of the total nitrogen content in bio-waste compost, taken from some literature sources.

The BGK 2008a figures have been deduced, as noted from a broad sample base. 824 samples were taken for fresh compost and 1849 samples for mature compost from RAL – quality assured plants and evaluated. These values can be assumed statistically secure and correspond to the data in literature. Consequent considerations will be on the basis of these values. The values show 1.30% total nitrogen with regard to the dry matter for mature compost and 1.53% for fresh compost.

Table 3 Total nitrogen from compost

Source	N –total [% from TS compost]
Gutser, 1999	1,4
ÖWAV, 2002	1.2 – 2.0
Reinhold, 2002	1.52
Mönike, 2007	1.5
BGK, 2007	0.9 – 2.0
Wendeland et al, 2007	1.3 (greenwaste compost) 1.4 (biowaste compost)
BGK, 2008a	1.30 (mature compost) 1.53 (fresh compost)
LTZ, 2008	1.2 – 1.6

The nitrogen in organic fertilizers comprises mainly of two fractions which are ammonium (NH4) and nitrate (NO3), on one hand and organically bonded nitrogen on the other. Whereas the ammonium and nitrate are immediately available as plant nutrients, the availability of organically bonded nitrogen is quite varied. A small part of this nitrogen mineralizes in the year of application and is available to the plant cultures (Wendeland et al. 2007. The percentage of available nitrogen in the year of production is therefore given in literature mostly from the sum of ammonium nitrogen and nitrate nitrogen (soluble nitrogen) together with the assumption of 5% organically bonded nitrogen. The high degradation stability of the composted organic substance has already been taken into consideration here (Reinhold 2006).
Table 4 shows the ammonium mentioned and the available nitrogen generally summed up as „N – quick“ from different sources.

Table 4 Calculable percentage of nitrogen in the year of application

Source	N – quick [% of total N]
FAC, 1995	10
Poletschny, 1995	15 – 20 (mature compost) 10 – 15 (fresh compost)
VDLUFA, 1996	10 – 15 (Bio-waste compost)
Diez et Krauss, 1997	16
Gutser, 1999	0 – 10
ÖWAV, 2002	5 – 20
BGK, 2006	5 – 20
Wendeland et al, 2007	0 – 15
BGK, 2008b	5 – 15
Gibbs et al, 2008	4 – 8
LTZ, 2008	0 – 3 (greewaste compost, freshcompost) 5 – 10 (bio-waste compost, degree of decomposition IV /V)

Just like the total amount of nitrogen, the quantity of available nitrogen from compost (quick efficient nitrogen quantity) in the year of application also depends on various influencing factors. What becomes clear however is that on an average 5 – 10% of the total nitrogen from compost becomes available to the plants and that the amount of available nitrogen increases with increasing degree of decomposition. At a decomposition degree of II only 0 to 5% of the total N is attributable in the first year whereas at a decomposition degree of IV ir V, 5 – 15% of the total N can be reckoned with (see Table 4).

Apart from this the differences in the type of compost will have to be taken into account. Thus the application of wood-rich, green-waste compost could cause a temporary N immobilisation which will have to be adjusted by the addition of an N-fertilizer (LTZ 2008). The C/N ratio is the deciding factor here, i.e. the ratio between carbon and nitrogen in the compost. A wide C/N ratio as in e.g. green-waste compost can lead to nitrogen immobilisation, whereas a narrower closer ratio will cause stronger mineralisation. According to Amlinger (2000) a C/N – ratio of 10.5 – 14 depending on the type of soil, can lead to immobilisations and values smaller than 8 to increased mineralisation. This explains the C/N ratio of humus of 9 – 12:1 which adjusts in the soil in the temperate latitudes (Jenny 1930 and Capriel 2007]. The effects of a wide C/N ratio will have to be compensated during fertilizing by additional N-fertilizers (LTZ 2008). It is therefore recommended to use quality assured compost for which the ratio is known. Table 5 lists data on the distribution of C/N ratio for quality assured compost from the quality assurance of BGK.

Table 5 C/N – ratio for fresh and mature compost from the quality assurance by BGK (BGK 2008)

	Frish comost	Mature compost
Median	18.2	15.5
Percentil 10%	12.7	11.5
Percentil 90%	24.5	22.4

With continued application of compost fertilizers the intermediate release of an appreciable amount of the slow–acting nitrogen through mineralisation, will have to be reckoned with independent of the C/N ratio. This is about 2 – 3% of the total nitrogen content per year and has been covered by numerous literature sources (see Table 19).

The successive yearly or as is common the three-yearly application of organic fertilizers therefore leads to an enrichment of the slow-acting nitrogen and a subsequent increase in the total amount of nitrogen released. The data available in literature concerning the amount for total availability, varies between 20% and (BGK 2006) – 80% (Wendeland et al. 2007), Gutser (1999) even calculated 100% depending on the area and duration of application.

The reasons for these deviations are influences that cannot be brought directly into connection with compost. Some such influences are crop-rotation [Wendeland et al, 2007], character of the soil in which the compost is applied (Amlinger et Götz, 2000 and ÖWAV 2002] or climatic influences (Amlinger et Götz 2000).

In contrast to this, the degree of decomposition which is a deciding factor for the quantity of nitrogen available to the plants in the year of application, does not play a role anymore for long term considerations. This has been covered by a number of tests on the one hand (e.g. Amlinger et Götz 2002), but can also be deduced logically on the other, as the maturing of the compost inevitably continues even after application in the soil.

The relatively inaccurate data on the total availability of nitrogen with long time application of compost as fertilizer hides the danger of undesired high eluviation loss of N on one hand and on the other hand a larger part of the total nitrogen in compost could be considered as usable for plants. Mineral fertilizers can therefore be decreased accordingly by the added up amount or even entirely left out. Usually however supplementary fertilization with mineral N-fertilizers is necessary.

Data from the various sources concerning the attributable fraction of nitrogen in long term fertilization with compost is depicted in Table 6.

Table 6 Attributable fraction of nitrogen in long-term fertilization with compost

Source	Test period[a]	N – attributable [% of total N]	Degree of mineralisation [% / a]
FAC, 1995	3	20 – 30	5 – 10 in 2nd and 3rd year
Diez et Krauss, 1997	7	44	1.5 – 5
Aichberger et al, 1998	8	20	2 – 4
Gutser, 1999	30 – 50	100 (calculated value)	2 – 3
Buchgraber, 2000	10	35 – 40	1.5 – 2
	20	50 – 60	
ÖWAV, 2002	9	Up to 65	3 – 8
Wendeland er al, 2007	Not known	50 – 80	1 – 3
LTZ, 2008	9 – 12	20 – 35	-

The grading of nitrogen mineralization according to ÖWAV (2002) amounts to 5 – 20% in the year of application, 8% in the following year; 5% in the 3rd to 5th year and 3% from then on. The values however have been assumed on the higher side as maximum possible eluviations of nitrogen related to the water balance are to be determined. If the long-term value (50 years) calculated by Gutser is still not considered, the actually available nitrogen from compost gets limited to a range of 20 – 40% of the total nitrogen content.

This value can be related to the values given in literature on the attributability of nitrogen in the first year and the yearly degree of N-mineralisation in the following years as given in table 19. If 10% N-availability is assumed in the first year and then a mineralisation of 3% yearly, we arrive at a value of 37% total availability after a medium term of 10 years.

Liming / Constituents That Have an Alkaline Effect

The pH value of compost lies between 6.4 and 7.7. Compost is therefore pH neutral and works against acidification of soil. Apart from feeding the soil with macronutrients, compost is also a valuable source of alkaline effective materials. These materials are calcium carbonate and magnesium carbonate and the focus is on calcium carbonate.

According to LTZ (2008) a only a medium dose of 20 mg TM compost every three years can adjust the loss of lime in light soils and higher doses of 30 mg even that of heavy soils. The data given in literature is analogous to this (ref. Sources in table 20) and states that medium amounts of compost are equivalent to a maintenance liming and therefore represent a savings potential on mineral CaO fertilizers. Already acidulated soil cannot be redeveloped (ebenda).

Experiments conducted by Kluge (2006) show a clear increase of pH value related to the given quantity of compost. Fig. 6 shows the correlation between compost quantities of 5, 10 and 20 mg dry mass. The starting pH value was 6.4 and was stable in the working area. Similar results were also obtained with comparative experiments according to LTZ (2008).

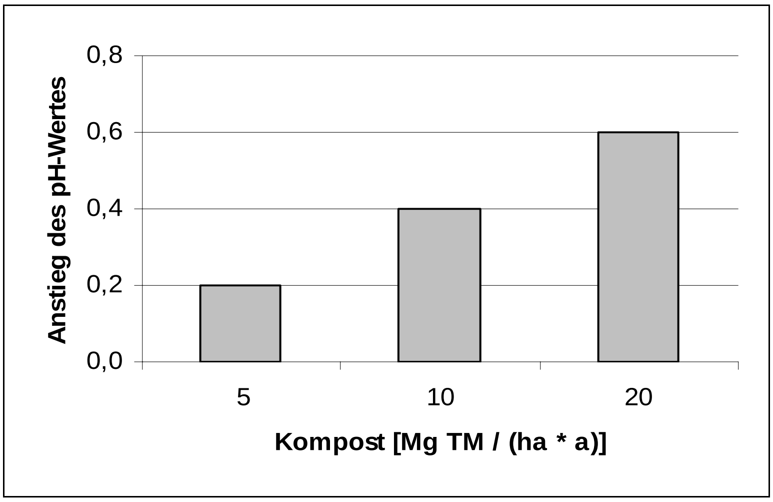

Figure1 Relation between pH value and long-term administration of compost (own depiction by Kluge, quoted in Amlinger et al. 2006)

The content of alkaline effective substance in the compost can be quantified as depicted with the help of a number of literature sources. The sources show a relatively large concurrance in the figures expressing this quantity. All values deviate by 50 kg CaO per mg dry compost. The values from the different sources are shown in table 20, the figures of Amlinger et al. (2006) and Leifert et al. (2007) have been done with reference to the fresh compost and have been converted on the assumed value of TS content of 62%.

Table 7 Administering an alkaline acting substance with the compost fertilizer

Source	P –total [kg CaO equivalent / Mg TM]
Buchgraber, 2000	50
Hartmann, 2002	~ 35
Reinhold, 2002	47.9 (middle value)
Amlinger et al, 2006	48.4 (based on 62% TS)
Reinhold et al, 2006	49.1
Leifert et al, 2007	53.5 (based on 62% TS)
BGK, 2008a	38 – 48 (Median value)
KGVÖ, 2008	50 – 150
LTZ, 2008	30 – 60 (90%-Quantil: 80 – 90)

Nutrient Substitution Potential of Compost

Quality assured compost can be considered as organic NPK fertilizers. In order to create an evaluation basis for the substitution potential of this compost, the results of the former paragraphs have been summarised in table 8. It appears to be reasonable to differentiate between fresh and mature compost for balancing the potential mentioned. The data given in the table are based on the application every 3 years, as this periodical output (e.g. 30 t TM every 3 years) proved to be advantageous with regard to N recovery (u.a. Amlinger et Götz 2000).

Literature research on nitrogen showed that it is not reasonable to consider a short time use of compost as the nitrogen mineralisation takes place in periods between middle term and long-term. This also seems to be appropriate bearing in mind the following considerations for the effects of humus as these too can be described only long term. As already described, it is possible to reckon with about 37% of the total nitrogen contained in the compost after a period of ten years. This value is the same whether it is fresh compost or mature compost because according to Amlinger et Götz

(2000) the degree of decomposition of the compost does not have any effect on the nitrogen availability, if middle-term periods are considered (in contrast to the attributability in the first year).
Taking a short time period into consideration, it would certainly be possible to depict the P and K fertilizer effect as well as the availability of lime; however, this is not reasonable for compiling a comprehensive inspection of the effects of compost.

Table 8 Nutrient substitution potential of fresh and mature composts related to an application every three years for a period of ten years

Autrient/ effective content	Fresh compost	Mature compost
Attributable N [kg / Mg TM]	5.7	4.8
Attributable P_2O_5 [kg / Mg TM]	8.0	6.4
Attributable K_2O [kg / Mg TM]	13.0	11.0
Alkaline reacting constituents cao [kg / Mg TM]	50	50

The legally permissible production of 10 mg dry matter compost per year would mean a charge of 48 – 57 kg nitrogen, 64 – 80 kg phosphorus and 110 – 130 kg potash as available macronutrients for the plants per hectare. Therefore there is sufficient nutrient supply of P and K and secondary and trace elements for most crop roatations. Similarly the administration of compost ensures the alkaline active value of a conservative liming. In order to obtain maximum agricultural profits, only a supplementary fertilization with nitrogen is necessary.

Evaluation of Energy and CO2-Credit through Compost Application

Whoever uses compost instead of mineral fertilizers for whose production energy is used, helps save this production energy. The energy is then to be credited to the compost. It is the same with green-house gases which are produced by the production and application of mineral fertilizers. This is avoided if compost is used and can be credited to the compost.

The following table 9 shows energy consumption and green-house potential in the production of mineral fertilizers for the macronutrients nitrogen, phosphorus, potassium and calcium. The data is based on the production and reimbursement in EU-27. Experience shows that these figures are actually higher in less developed countries (Springer 2009).

Table 9 Summary of primary energy consumption and greenhouse gas emissions in the production of mineral fertilizers [Springer, 2009]

Product	Specific final energy consumption in [MJ / kg macronutrients]	Specific CO_2-emissions in [kg CO_2 / kg macronutrients]
Nitrogen fertilizers – N	67.0	6.92
Phosphate fertilizers – P	21.0	1.00
Potash fertilizers – K	11.2	0.66
Calcium manure – Ca	2.0	0.113

Table 10 Energy and CO_2 - equivalent substitution potential through nutrient content

Nutrient	fresh compost [MJ / Mg DM]	matured compost [MJ / Mg DM]	fresh compost [kg CO_2 / Mg DM]	matured compost [kg CO_2 / Mg DM]
Accountable nitrogen (N)	382	322	39,4	33,2
Phosphorus (P2O5)	168	134	8,0	6,4
Potassium (K2O)	146	123	8,6	7,3
Lime (calcium) (cao)	100	100	5,7	5,7
Total substitution potential	~ 800	~ 680	~ 61,7	~ 52,6

As depicted in table 10, it is possible to evaluate the energy substitution potential and the greenhouse gas saving potential of compost application from these values. It becomes obvious that on using fresh compost, 800 MJ energy and 61.7 kg CO_2 per ton of dry matter compost can be saved. In central Europe, these figures correspond to the energy consumption of the maximum energy consuming composting process. Mostly however, even a surplus of energy is virtually achieved.

CONCLUSIONS

It could be shown that compost is an effective organic fertilizer. Compost contains all important plant nutrients in not so irrelevant magnitude. The application of about 10 tons of compost per hectare of agricultural land can be considered as equal to sufficient fertilization of phosphorus and potassium for a common crop rotation. With long-term application the nitrogen supply is equal to about half the necessary quantity. Likewise, due to the pH-neutral character of the compost it can be considered as equal to liming for preservation purposes. Comprehensive sampling of compost of different degrees of decomposition showed that younger compost contains more nutrients than mature compost. It is therefore advisable to use fresh compost for agricultural purposes.

If the energy consumption and green-house emissions are taken into consideration by the production of mineral fertilizers, more credit can be given to the application of compost as a substitute for mineral fertilizers. Depending on the type of compost this can be upto 800 MJ / Mg DM and 61.7 kg CO2. This ability of compost to substitute mineral fertilizer can be credited positively to compost, a surplus that could be benefited in CDM-projects.

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Recycling and Others

M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.607-616

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Commercial Opportunity of Composting, Recycling and Landfill of Municipal Solid Waste: Bangladesh Perspectives

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ABSTRACT

This paper depicts the commercial opportunity of composting, recycling and landfill conveniences through the prevailing situation in managing of Municipal Solid Waste (MSW) in Least Developed Asian Countries (LDACs) like Bangladesh. This study demonstrates that it is possible to turn MSW into resource through the appropriate process of recycling, composting and generation of Landfill Gas (LFG) as a commercial opportunity. There is a huge opportunity to create job for poor people by involving them in this process. The safe and reliable long-term disposal of MSW is extremely vital to ensure sustainable urban environment. Although source reduction, reuse, recycling, and composting can divert significant portions of MSW, large amount of solid wastes still need to be placed in landfills. Recycling plays an important role in waste minimization and creating earning opportunity for slum dwellers. A major portion of the MSW of Bangladesh is suitable for composting due to its high organic contents. As no sanitary landfill exists in Bangladesh and growing people concern about the adverse environmental impacts of present open dumping practices, possibility occur to contamination of ground water. City authority needs new site for the development of sustainable sanitary landfill also can use this technology commercially utilizing the Clean Development Mechanism (CDM) opportunity.

INTRODUCTION

Solid waste Management (SWM) has become a major environmental problem for the fast growing towns and cities of low and middle-income countries. Most of the urban local bodies in the developing countries are cash-strapped and unable to provide satisfactory SWM services. In most cities not even 50% of the generated MSW is collected. The present SWM system in developing countries is based on the “end of the pipe” solution, i. e., collection-transportation-crude dumping of waste with limited recycling of inorganic waste, mainly by the informal sector.

The physical composition of MSW of the developing countries consists mostly of organic fraction, which is biodegradable. When organic waste remains uncollected, it posses major environmental problems as stated by Rafizul, et al. (2009). In order to avoid this MSW-triggered environmental hazard, use of compost needs to be promoted. One of the sustainable approaches is to look at MSW as a resource, not as a problem. This study demonstrates that it is possible to turn MSW into resource, jobs and commercial opportunity for the poor (Enayetullah et al. 2006). A research-based organization, Waste Concern, postulated that amidst various difficulties, due to the composition of the MSW, with as high as 75% organic content, decentralized composting has been gaining huge momentum and success with support from international agencies and NGOs. In addition, Waste Concern has initiated a large-scale composting plant in Dhaka city producing of organic fertilizer. It was a better opportunity through this project that the organization looks forward with this project to reduce about one million tons of LFG over an eight year period under the CDM oppertunity.

Definitions of sustainability may be expressed as statements of fact, intent, or value with sustainability treated as either a "journey" or "destination" (Alamgir et al. 2003). Where we are now, where we need to be going and how we are to get there are all open to interpretation and will depend on the particular context under consideration. In the rapid growing cities of the developing countries, urban solid waste management is currently regarded as one of the most immediate and serious obligation for sustainable environment faced by the city authorities. Due to inadequate and often inefficient solid waste management and visible environmental degradation, solid waste – generated at an increasing rate – has become an important environmental issue for the concerned stakeholders, especially for the residents of the major cities of LDACs (Least Developed Asian Country). Compared to developed countries, the urban residents of developing countries produce less per-capita MSW, but the capacity of the developing countries to collect, process, dispose or reuse it in a cost effective way is limited.

As a member of LDAC, Bangladesh has lack of a suitable MSW management scheme, which is economically feasible, technologically suitable, socially acceptable, and environmentally sound and sustainable. Major cities of Bangladesh lie in the river-deposited flatlands for that submergence, floods, tidal surge, and cyclones are more crucial in Bangladesh. High population growth rate and increase of economic activities in the urban areas of Bangladesh combined with a lack of infrastructures, appropriate system and associated training, awareness and commitment in modern SWM practices complicate the efforts to improve the solid waste service. Bangladesh should act with product oriented waste management system which will provide necessary financial support and also will create job opportunity. Considering the present situation and the nature of MSW, the opportunity mostly lies with composting, recycling as well as LFG generated.

SOURCES AND GENERATION MSW OF BANGLADESH

Solid waste generation is an inevitable consequence of production and consumption activities in any economy. Generally, it is positively related to the level of income and urbanization, with higher income and more urbanized economies generating higher levels of MSW per capita. In a small community or areas of urban Bangladesh, all sorts of urban activities are running, including industrial and agriculture and the peoples are living side by side in a pose high-rise apartment building with all modern facilities and as well as in slums without any urban facilities, even in absence of health and hygiene condition. MSW generation is an inevitable consequence of production and consumption activities in any economy. Generally, it is positively related to the level of income and urbanization, with higher income and more urbanized economies generating higher levels of MSW per capita. The generation rate of MSW are estimated in six major cities, namely, Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet from the field survey as depicted in Table 1 with respect to source and in Figure 1 for generation rate.

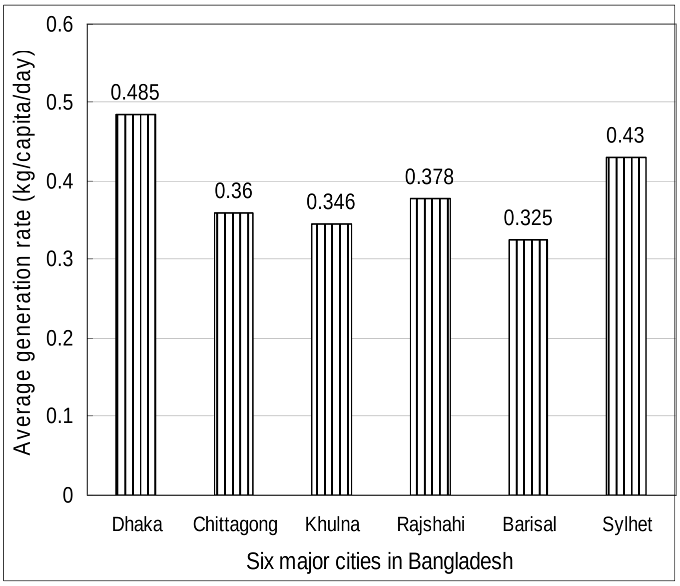

Figure 1 Generation rate of MSW in six major cities of Bangladesh (after WasteSafe 2005)

Table 1 Contribution of different sources in total generation of MSW in the six major cities of Bangladesh (after WasteSafe 2005)

Sources	MSW generated daily from different sources (%)					
	Dhaka	Chittagong	Khulna	Rajshahi	Barisal	Sylhet
Residential	75.86	83.83	85.87	77.18	79.55	78.04
Commercial	22.07	13.92	11.6	18.59	15.52	18.48
Institutional	1.17	1.14	1.02	1.22	1.46	1.29
Municipal Services	0.53	0.51	0.55	1.24	1.15	0.8
Others	0.37	0.6	0.96	1.77	2.32	1.4
Total	100	100	100	100	100	100

COMPOSITION OF MSW

The composition of MSW is used to describe the individual components that make up a MSW stream and their relative distribution, usually based on percent by weight. A complete picture about the composition of MSW is an essential part for selection of appropriate type of storage & transport system, determination of potential resource recovery, choice of a suitable method of disposal, and the determination of environmental impact exerted by MSW (Rafizul et al. 2009). There is an insignificant variation of composition in MSW at six major cities of Bangladesh as illustrates in Table 2 and also in Figure 2. The rapidly biodegradable portion is normally very high as compared to other portions; essentially due to the use of fresh vegetables and absence of food processing industries.

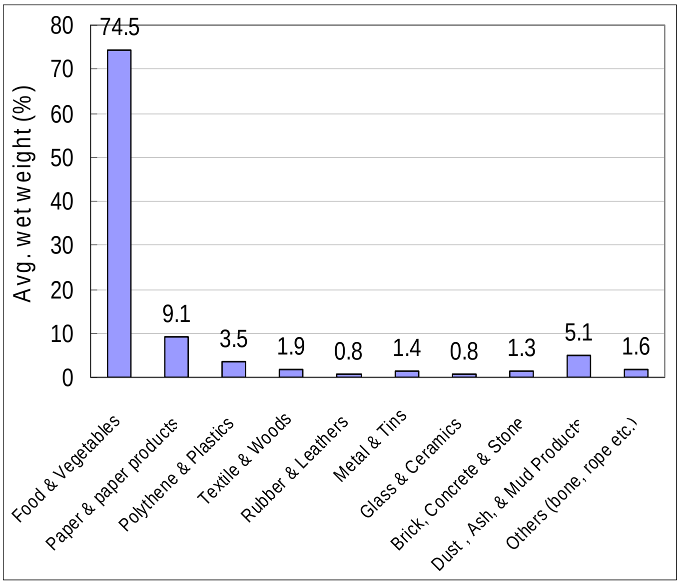

Figure 2 Average composition of MSW in six major cities

Table 2 Physical Composition of MSW in Six major cities of Bangladesh (in wet weight %)

Composition of MSW	DCC	CCC	KCC	RCC	BCC	SCC	Avg.
Food & Vegetables	68.3	73.6	78.9	71.1	81.1	73.8	74.5
Paper & paper products	10.7	9.9	9.5	8.9	7.2	8.4	9.1
Polythene & Plastics	4.3	2.8	3.1	4	3.5	3.4	3.5
Textile & Woods	2.2	2.1	1.3	1.9	1.9	2.1	1.9
Rubber & Leathers	1.4	1	0.5	1.1	0.1	0.6	0.8
Metal & Tins	2	2.2	1.1	1.1	1.2	1.1	1.4
Glass & Ceramics	0.7	1	0.5	1.1	0.5	0.7	0.8
Brick, Concrete & Stone	1.8	1.1	0.1	2.9	0.1	1.8	1.3
Dust , Ash, & Mud Products	6.7	5.1	3.7	6.5	3.1	5.3	5.1
Others (bone, rope etc.)	1.9	1.2	1.2	1.3	1.3	2.8	1.6
Total	100	100	100	100	100	100	100

4R POLICIES OF MSW

Proper legislation and agreements at the national level are required for packaging and product redesign by local initiatives and to prevent recyclables and compostable organics from entering final waste streams. By taking 4R policies (Reduce, Reuse, Recycle, and Recovery) and treatment of wastes can improve the efficiency of SWM systems, recover useable material, recover conversion products and energy.

Many households dispose reusable/recyclable materials with their daily kitchen waste, which should be reused or recycled. Some people also sale these materials to Hawkers/Tokai. 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 & papers 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 them to nearer small recycling shops. In second phase, the poor children of slum dwellers or street children are collecting different items of low market value from on-site storage bins/containers and open storage spaces. The final phase is the recovering of reusable and recyclable materials from UDS. Scavengers collect the recyclable wastes mainly when collection vehicles are being immediate unloading at dumping site. Hawkers and scavengers sale their collected materials to local small scalebusinessman. Businessmen separate every items and stakes individually. Then they sell to merchant. All the buyers of the recyclable items belong to the informal sector and only a few formal manufacturers are involved in using recyclable substance as raw material. The estimated amount of recyclable waste in six major cities as presented in Table 3.

Table 3 Estimated daily recyclable wastes in six major cities of Bangladesh (after WasteSafe 2005)

City	Recyclable MSW (tons/day)	Total generation (%)
Dhaka	420 – 450	8 – 9
Chittagong	90 – 100	7 – 9
Khulna	25 – 30	5 – 7
Rajshahi	15 – 18	9 – 11
Barisal	3 – 5	3 – 5
Sylhet	5 – 8	3 – 4

COMPOST AND COMPOSTING IN BANGLADESH

Biological treatment is a comparatively economical and environmental friendly treatment process for solid wastes. In practice, the main biological process applied is generally composting. Composting is the biological degradation of highly concentrated biodegradable organic wastes in the presence of oxygen (aerobically) to carbon dioxide and water, whereby the biologically generated waste heat is sufficient to raise the temperature of the composting mass to the thermopiles range (50 to 65^oC). The final product of composting is a suitable humus-like material known as compost. The compost, which can be handled, stored and transported without any adverse environmental effect and can be used as organic manure for improvement of soil quality and fertility.

The rate of microbial activity or degradation in the composting mass depends on certain important physical and chemical factors, which should be considered in the design and operation of a composting process. These factors are particle size, C/N ratio, water content, temperature, p^H and aeration (Bari 1999). Physical and chemical characteristics are determined by both field and laboratory analysis as reported in the Feasibility Study - WasteSafe (2005). The samples were collected from different Secondary Disposal Site (SDS) of each city at regular intervals during the project tenure and send them to the laboratory for evaluation. Organic materials with a wide range of pH values from 3 to 11 can be composted, but the more desirable pH value for MSW suitable for composting ranges from 5.5 to 8.5 (Tchobanoglous et al. 1993). The values of pH in MSW below or close to 8.5 for six major cities of Bangladesh as presented in Figure 3.

The highest moisture content is measured as 70%, while the lowest value is 56% for Dhaka and Rajshahi city, respectively. In aerobic composting process, moisture content should be of 50 to 60% during the composting process (Bari 2001). At moisture level above 65%, reducing the interstitial oxygen during composting and causing anaerobic conditions, which produce offensive odors.

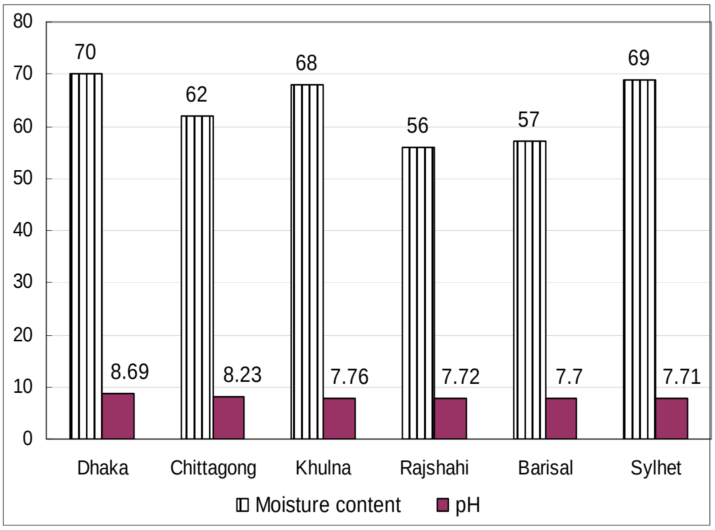

Figure 3 Physical Characteristic of MSW in Six Major Cities of Bangladesh

Composting is natural's way of recycling of bio wastes into new humus used in vegetable and flower gardens, landscaping and many other applications. The MSW of Bangladesh is suitable for composting due to its high moisture and organic contents. In Bangladesh, mainly NGOs are involved in composting. However, this sector is also facing several problems such as finance, appropriate technology, required land, proper location, supply and quality of wastes, quality of compost and marketing facilities. During the last few years several compost plants in Sylhet, Khulna, Dhaka and other cities were forced to stop its operation due to the objection from adjacent inhabitants. In general, health and hygienic aspects are absent in all the composting plant.

During the field survey from May 2004 to October 2004 and also from other sources, it was found that the composting activities have been initiated as organized base (Pilot-scale type) in six major cities of Bangladesh by different organizations including City Corporation, NGOs and CBOs. Mostly the processes adopted in these cities are “windrow” or “active pile” system. The barrel or small container composting methods is also started particularly in urban slums, colonies etc, but has failed to achieve the momentum. The detailed of composting situation in Bangladesh can be obtained Hasan et al. (2008) and Enayetullah and Sinha (2006).

LANDFILL

Wastes those are susceptible to contaminate air, groundwater and surface water are needed to contain in an engineered safe containment system, known as engineered or sanitary landfills. In particular, landfill is the term used to describe the physical facilities used for the disposal of solid wastes and solid wastes residuals in the surface soils of the earth. Once containment has escaped into the ground, it flows from pore to pore through the soil, sometimes travelling several kilometers.

SCENARIO OF ULTIMATE DISPOSAL SITE IN BANGLADESH

There is no controlled/engineered/sanitary landfill in Bangladesh. The sites are situated in and around the city areas of low-lying open spaces, unclaimed land, riverbanks and roadsides. Environmental pollution at open dumping site includes air pollution, water and soil contamination due to propagation of generated leachate, emission of landfill gases, odor, 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 explosions and fire hazards. 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 six major 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 because of their hazards nature. Even the city 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.

Locations of UDS are one of the key factors to reduce the negative environmental impacts and to increase the capacity. But there was no such site selection technique adopted by city authority for the selection of existing UDS. Presently, government issued an order not to fill up any swampy, low-lying areas and water bodies in and around the city. So to have any site for ultimate disposal of MSW, permission is required from a series of governmental offices and agencies. But the sites have been using for such purposes just from the availability of unused government land and near to the city center. To get a suitable site for landfill construction and the related high cost is one of the major concerns of the city authority.

PREVIOUS UDS AND THERE FIX UP PHASE

The filled-up of low laying areas by solid wastes or declared abandoned by the authority, people used to start several activities such as vegetables /fish/fruits market, bus terminals , settlement of floating peoples without taking any counter measures against the inherent problems the sites suffer such as settlement and LFG generation. They also don’t care even about the permission of the authority. Moreover, in some instances authority also starts several activities in the sites without taking any consideration of the nature of sites and any remedial measures. This demonstrates that demand for such land will be still high; therefore, proper attention should be given for the proper handing of waste deposition and utilization of the site after the completion of waste deposition and necessary measurements. To this regards, some previous UDS and their conversion as presented in Table 4.

Table 4 Some Previous UDS and their conversion

City	Location of UDS	Conversion
	Mughdapara	A stadium already constructed
Dhaka	Jatrabari	Market was developed
	Bashantek	Slum rehabilitation project is ongoing
Chittagong	Shulockbahar	High income level Residential area
Khulna	Sonadangha	city corporation office labors residential colony
Rajshahi	The first one	New Market
	Another one	Children park is being constructed.
Barisal	Kawnia - Ex UDS	Sold as housing Plot
Sylhet	Norshingtilla	Sold as housing Plot

FUTURE UDS OF BANGLADESH

In most of the major cities of Bangladesh, it is difficult to have site for ultimate disposal of MSW. Presently, government issued an order not to fill up any swampy, low-lying areas and water bodies in and around the city for prevent initial pollution. So to have any site for ultimate disposal of MSW, permission is required from a series of governmental offices and agencies. Despite this stringency, every city authority and municipalities of Bangladesh need new land for future landfill site and even for present use as most of the municipalities have been dumping the wastes at others land.

According to Urban Planning Department for effective transportation and disposal of solid waste, it is informed that DCC has started the process of land acquisition for future land fill sites. Several legal procedures are required for land acquisition as per the present law. In KCC, the proposed future dumping site uses for fishing and cultivation, mainly paddy. Another important aspect of this site is that local people actually do not know the exact purpose of City Corporation for the acquisition and possession of this area. Chittagong, Rajshahi and Barisal City Corporation yet not selected future dumping sites of MSW. The proposed dumping site selected by Sylhet City Corporation is a low-lying land. During rainy season the site and the surrounding area become full of water having no provision of transport, in dry season, presently, it is used for cultivation mostly paddy. But there is no record as any City corporation is going to take step of any special measures for remediation of the sites before the settlement/activities starts. As the government has convinced to eradicate the present crude open dumping, there is a need the new sites for future landfill. However, once should thinking seriously about the sustainability of the future landfill.

OPPORTUNITY FOR COMPOSTING, RECYCLING AND LANDFILL PRACTICE

The overall opportunities in practice of composting, recycling and sanitary landfill for proper management of MSW is described here, considering the issues in the production oriented ways.

Composting

The dominant fraction of the total generated MSW is organic waste, and these are easily compostable for there physical and chemical components. It is state that behind all low commercial prices there is an easy technology. If we could collect organic waste at the source and can compost in a simple process which is safe and easy to handle, need very little place, not disturb circumstances by creating bad odor, posses excellent quality then it will definitely a profitable business. Because as the source of raw material is in the city and the product will also be sold at the city, there is less transportation cost. For this it is needed to invent appropriate and cost effective technology. This value lies in the organic portion of the solid waste, which constitute about 70-80% of the total generated waste, having considerable potential value, if converted into compost through composting. From the perspective of municipality, organic waste recycling through composting not only reduces disposal costs and prolongs the life span of disposal sites, but it also reduces adverse environmental impacts caused by landfill sites, as the organics are mainly responsible for leachate contamination and methane problems. Recycling and returning of organic waste to the soil would significantly contribute to enhancing the sustainability of the urban area. Involving the population in the use of compost promotes awareness of waste resource recovery while composting activities, creates employment and generates income for them. Typical compost plant and the product in compost sold in local market as shown in Figure 4.

(a) Typical view of a compost plant (b) Typical compost product for marketing

Figure 4 Pictorial views of a typical compost plant and the compost product

Financial success of the scheme is based on the fact that large bulk buyers of compost were found. The compost product is mainly sold to fertilizer producing companies which blend the compost with nutrients to suit different customers. Sales of the products are then done through existing agricultural extension services and retail networks of these companies. Thus the compost marketing strategy of the composting schemes is based on letting others do the individual marketing. A case study shows that composting can be a good alternative to conventional MSW management options, reducing the amount of waste to be transported and dumped and producing a valuable raw material for fertilizers.

Experience has shown that in developing countries large centralized and highly mechanized composting plants have often failed to reach their target and had soon to be abandoned due to high operational, transport and maintenance costs. In many cases small-scale decentralized community based composting plants have been considered as a suitable option for treating MSW as they reduce transport costs, make use of low-cost technologies, based mainly on manual labor, and minimize problems and difficulties encountered with backyard composting. Experience shows that community based decentralized approach to convert waste into resource/ compost/ recyclables with active public-private and community partnership is possible in the country. Government along with NGOs, CBOs and private sectors has taken the initiative to encourage of community based approach. Recently using CDM under the Kyoto Protocol Waste Concern along with WWR (a Dutch company) took an initiative for a composting plant.

Recycling

Recycling is more or less practicing in Bangladesh. But no formal authorities involve with this process, that's why it is still unhealthy process. If we can think about proper recycling process we can export recycling material. Approximately 1,20,000 people are involved with the recycling occupation in Dhaka city. Similar recycling activities are also prevailing in other cities and towns of the country. The poor socially disadvantaged people informal sector are primarily involved with waste recovery and recycling practice in the country. Their recycling activity is reducing a significant volume of waste which otherwise would have to be collected by the local authorities. Almost 15 percent (i.e., more than 467.65 tons) inorganic fraction of the waste is recycled in Dhaka city. In Khulna, there are total 330 recyclables dealers involved in plastic recycling, supply plastic waste as raw materials to 11 small scale plastic recycling factories with 7.5 ton/day (Moniruzzaman et al. 2008). Wastes having economic value in the market are reclaimed and salvaged in different stages by informal sector. A pictorial view of a small scale recycling factor in Bangladesh as presented in Figure 5.

Figure 5 Pictorial view of small scale recycling factory

The recycling activities exert a significant impact on resource conservation, creation of jobs, provision of economic opportunity and reduction in the magnitude of waste disposal problems. A cost analysis is presented to show the income that can be generated through a well-planned recycling program. It is shown that 21.2% of all recyclable waste in Bangladesh is recycled, and it contributes significantly in the countries economy amount through the informal sector. However, if the recycling practice is owned by the formal sector, it can significantly reduce the collection cost. If recycling is adopted as an industry, it can also generate revenues and can also save enormous amount of energy, as well as the natural resources.

The most appropriate ways of managing of MSW are source reduction and recycling of materials but beyond that the remaining solid wastes still have to be effectively managed with environmentally sound technologies (Alamgir et al. 2005). Numerous measures are available such as landfills, composting, anaerobic digestion, combustion or incineration, and gasification. The MSW dumps, which are common practice, are normally left uncovered, not compacted and daily cover system and there are two options for MSW dumping all over the world, one is crude landfill (open dumping) another is sanitary landfill (Rafizul et al. 2009). In Bangladesh context, as all the landfill sites are unmanaged and open dumps, these sites can be less than optimal candidates for LFG energy development because they contain only small amounts of methane resulting from aerobic degradation and rapid waste decomposition. Uncontrolled dumping of solid waste around the world becomes one of the major striking social and environmental issues. The majority of these are located in the developing countries, which generate the solid waste with high rapidly biodegradable fraction. In Bangladesh, like other LDACs, ultimate disposal sites of MSW are situated in and around the city areas at low-lying open spaces, unclaimed land, riverbanks and roadsides (WasteSafe 2005). Considering socio-economic perspectives, landfills are more environmentally sound disposal option for Bangladesh and also has potential to produce more methane. A typical view of a sanitary landfill is as shown in Figure 6.

It is evident that large portion of GHG impact of uncontrolled landfills which are essentially what the solid wastes dumped in Bangladesh and other LDACs. Despite the least preference to select landfill option in MSW management, even in the developed countries, landfill continues to play a major role since a significant part of waste cannot be prevented or recycled (Schraff et al. 2007). From an explicit feasibility conducted in some major cities of LDACs, (WasteSafe 2005) it is realized that properly planned engineered landfill to be only affordable option for the safe disposal of the majority of MSW in the LDACs for the foreseeable future.

Figure 6 View of a pilot scale sanitary landfill at Rajbandh in Khulna of Bangladesh

Landfill Gas and its Reduction

Landfill gas (LFG) is only produced from the biodegradable fractions of MSW, which are essentially the putrescible organic fraction, the paper and board fraction and any non-synthetic textiles. As the composition of MSW in landfill play a very important role about the generation proportion of CH4 and the time to obtain peak generation. Both methane and carbon dioxide are greenhouse gases (GHG) that contribute to the global warming potential (GWP). Methane contribution from landfills is considered more significant due to its greater GWP with respect to CO_2 (21 times more than CO_2 over a 100 year time period).

MSW generates in the urban areas and hence disposed as the open dumped as shown in Table 5 constitutes significant source of GHG emission in Bangladesh. The annual equivalent CO_2 emissions is given in Table 5 as predicted in urban areas of Bangladesh based on the available relevant parameters as illustrated in WasteSafe (2005).

Table 5 Equivalent CO_2 Emission from MSW of Bangladesh

City/Town	Nos. of City/Town	Solid Waste Generation (Gg/year)	Degradable Organic Carbon	Total Equivalent CO_2 Emissions (Gg/year)
Dhaka	1	1950	14.88	2753
Chittagong	1	480	15.83	698
Khulna	1	190	15.58	141
Rajshahi	1	62	15.31	45
Barisal	1	48	15.05	34
Sylhet	1	78	15.53	111
Pourashavas	298	1755	15.19	2449
Other Urban Centers	210	620	15.66	892
Total	514	5183	Avg~15.38	7133

There are two main approaches to reduce direct methane emissions from landfills, namely, methane recovery or reduction of landfilled waste. Both approaches involve several options to manage the gas. Methane can be recovered from landfills and managed either through flaring or usage as an energy source (Alamgir et al. 2008). The LFG recovery offers significant environmental, economic, and energy benefits. In Bangladesh, at present, gas-to-energy projects are unlikely to be implemented due to a weak return on investment and a relative lack of local technical expertise although the country needs to solve energy crisis using biomass, in which MSW is an important input. In absence of such option, Bangladesh can introduce methane recovery with flaring and/or microbial oxidation for the reduction of LFG to reduce the emission of GHG. Methane, a radioactively active GHG, is a basic component of the biogas produced in municipal landfills, which contribute significantly (6-20%) to its total anthropogenic emission to the atmosphere.

Reduction of methane emission is one of the means of stabilization of the climate of our planet. There are two strategies of reduction of methane emission from landfills. One is practical utilization of the biogas as a source of energy. The second option comprises its microbial oxidation in a biocover (covering entire landfill surface) or biofilter (covering a part of the landfill surface). The latter approach is advisable in old landfills, where methane utilization as a source of energy is not possible.

Recent global record reveals that waste handling, mostly landfilling of MSW covers second largest portions (21%) among the different groups of registered CDM projects as shown in Figure 7. While designing a CDM project, it should keep in mind that a CDM project has dual objects: (i) obligatory reduction of GHG emission by developing countries through investment and (ii) ensure sustainable development opportunities in the developing countries. So, the whole process needs to move through an integrated, well-defined and transparent way as the finance flow from the developed country to developing country through CDM project is not a grant rather a business deal between both the parties.

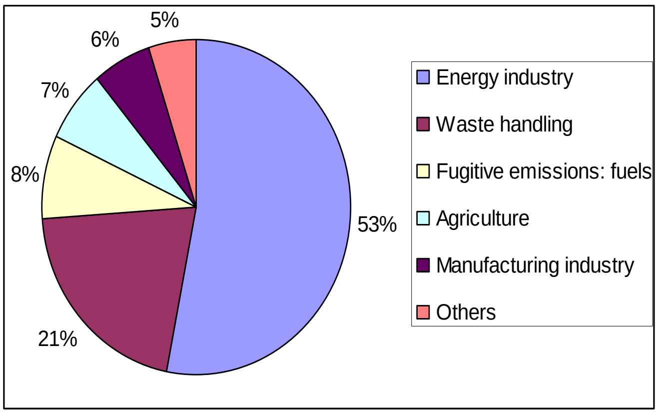

Figure 7 Distribution of registered project activities by scope

CONCLUSIONS

Bangladesh needs to convert the existing recycling, composting and open dumping practices of MSW management in product oriented way ensuring environmental sustainability. As such initiatives will able to reduce GHG globally, there is a strong possibility to get financial support through CDM projects. The establishment of relevant plants and/or factory will open the opportunity for new job markets. The success of such attempts will definite creates very positive impacts on the overall management scenario of MSW. However, the possible options should be investigated further on a case-by-case basis to define areas suitable for commercial opportunity due to composting, recycling and sanitary landfill.

ACKNOWLEDGMENTS

The author gratefully acknowledges the support of the European Commission through the two grants projects of Asia Pro Eco Programme, WasteSafe (Contract No ASI/B7/16-2004/79010) and EU-Asia Pro Eco II Programme, WasteSafe II (Contract No ASIE/2006/122-432).

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ISBN: 978-984-33-0761-3, Vol. 2, pp.617-621

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Synergy among Society, the Urban Environment and Organic Waste Management

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ABSTRACT

In most Latin American communities, it seems evident that waste management issues go hand in hand with new models of urban development. Local reports have shown how waste management practitioners often fail to respond to the need of urbanites in growing localities. This affects the continuity of environmentally sound practices causing a lack of balance between place and nature. The Center Region of Mexico, which comprises 7 different territories, has been the subject of vigorous debates related to its socio-spatial structure and changing models of urban governance. Concurrently, the scope and magnitude of problems related to waste collection and disposal continues to increase. This research aims at tackling those challenges from a social/passive approach based on principles of sustainability, advocacy and pragmatism. The approach taken is to situate people and organic waste in the nexus of household dynamics and every day life practices. The main purpose is to connect the physical, social and cultural organization of individuals; their network of embedded practices and organic waste produced. By integrating social factors, the built environment and organic waste management we add a layer of indicators to the current environmental discussion. Further insight is therefore provided to understand the current waste management situation and future perspectives for Latin American communities.

In this paper, the main objective is to expose the volume of food waste considering exo and endo socio-cultural determinants. Central to this work are everyday food waste production, separation practices and daily household habits. The biological need we have for food makes food waste an essential part of municipal solid waste. Additionally, organic waste constitutes close to 50% of the waste generated in Mexican households. If the goal is to avoid the disposal of organic waste in sanitary landfills, it is necessary to take a closer look at food components in the domestic waste stream.

This study uses a collaborative insider-professional approach. Mixed data collection techniques include a self-administered questionnaire, a waste diary as well as a spring scale test. Participants were trained to use the study material themselves. The idea behind creating a participatory process is to establish an experience of critical reflection in which changes are created through waste awareness, environmental education and collective work. The results show how to foster participatory waste management strategies in the Latin American context.

INTRODUCTION

In most Latin American communities, it seems evident that waste management issues go hand in hand with new models of urban development. Local reports have shown how waste management practitioners often fail to respond to the need of urbanites in growing localities. This affects the continuity of environmental sound practices causing a lack of balance between place and nature.

What synergy means is that the whole is greater than the sum of its various parts and by combining different aspects of something better overall results can be achieved. The Oxford Dictionary defines the term synergy as "the interaction and combination of two or more organizations, substances or other agents to produce a combined effect greater than the sum of their separate effects". In that context, finding synergy between society the urban environment and organic waste management suggests tackling waste issues by looking at other layers of indicators that can respond more effectively to the challenges of the urban environment.

The Central Region of Mexico hosts approximately 34.7 million inhabitants, which represents 36.5 % of the national population (INEGI, 2005). It comprises the Federal District known as Mexico City and the States of Mexico, Morelos, Hidalgo, Puebla, Tlaxcala and Querétaro. The Central Region is one of the largest urban areas in Latin America with 11 metropolitan areas that extend over approximately 87,632 km2. It generates one third of the national GNP, concentrates 40% of industrial employment and 62.3% of the national scientific output. In the study, a particular focus is given to the municipality of Jiutepec located in the State of Morelos and to peri-urban areas of Mexico City such as Ajusco, Tlanepantla and Cerrro del Judio.

METHODOLOGY

This research uses a collaborative insider-professional approach based on the principles of action research (AR). A central aspect of action research is that participants and researchers cogenerate knowledge through collaborative work. When appropriate the researcher may take on the role of a facilitator, allowing the participants to take on a more active role in order to solve a problem, foster social change or generate knowledge.

In this research, collaborative work took place through the support of the Escuela Nacional de Antropología e Historia (ENAH) located in Mexico City. The support provided by ENAH consisted in facilitating the training of local surveyors who were coached between the months of July and August 2009. Their main task was to apply a waste-monitoring instrument, which includes three main components: A questionnaire which was applied in an average of 20 minutes, a waste diary for 7 days and a spring scale test to measure waste produced during a 7 day period.

The instrument was developed in 2008. Before its application in Mexico, the instrument was tested at the University of Sydney from December to February 2009 and at the Bauhaus University in Germany in May 2009. 31 households were monitored in both countries. In Sydney focus was given to the first two main components of the instruments: the questionnaire and diary. The questionnaire includes 65 questions with multiple answers. Participants were asked a range of questions regarding their housing structure, lifestyle of residents and their daily waste habits, the neighborhood they lived in and the level of social engagement which most prevailed in their community. The questionnaire offered the possibility to include the opinion of less articulated and/or communicative participants. The main goal was to find the proper variables to measure the relationship between the urban built environment and the composition of organic waste produced.

In Australia the waste diary was mostly applied. 27 informants ranging from 18-41 years of age participated. This sample included a good balance of both male and female contestants who filled out a journal for 7 days about the type of waste they produced during breakfast, lunch and dinner. The diary was tailored for the New South Wales socio-urban context and was applied in the English language. The diary was distributed as an A4 size brochure and included questions about the type of meal; reference of people who shared the meal; the type of food waste produced and the waste bin used for disposal at home. The diary response rate was 81%. In general feedback was positive. The 7 day period proved to be adequate to collect data about how people deal with their waste at home. We avoided asking the dairy to be filled in during holidays or in unordinary moments of people’s live to ensure a common pattern of behavior between participants.

In Germany, focus was given to applying both questionnaire and diary in the Spanish language. Given that the main study would take place in Mexico, it was necessary to engage participation from a Spanish-speaking group of informants. The waste-monitoring instrument was then translated into Spanish and tested with a small sample of 4 households. Additionally, a spring scale pilot test was undertaken in each household. This allowed us to obtain data on the volume and weight of the waste produced by participants. At that stage, we gave a particular emphasis on the type of scale to use and the capacity of the waste bin for collecting the food waste. It became crucial to give participants the possibility to store their waste at the source of production in a sanitary manner and with as little odor emission as possible. The scale used is a standard kitchen scale, model Beurer with large LCD-display with tare weight function, loading capacity 5 kg and 1 g. graduation.

SOCIAL PASSIVE APPROACH IN MEXICAN HOUSEHOLDS

In Mexico, 27 households were selected through a snowball technique. Each household informant was provided with the study material which included a questionnaire, a waste dairy and a spring scale measurement sheet. Participants were monitored for an average of 15 days. The monitoring activities included repeated visits at the household, continuing communication through text messages, emails and phone calls. Whenever possible, all members of the household were asked to participate actively in the project. The purpose for creating an inclusive process was to engage all members of the household in the discussion of sustainable waste habits.

The environmental discourse in the Latin American context offers little review on how food waste and individuals are connected. Assessment combining organic waste management, urban-spatial context and socio-cultural considerations are still largely absent in the literature.

Knowledge regarding the social context of waste is relatively recent compared to the expertise created in the engineering field. It was only at the end of the 20th Century that scholars like Colemann and Peterson in the European context, have brought forward the idea that solving waste problems would require more than solutions associated with infrastructure and technology. So what we know about society and waste is contained in a relatively small pool of knowledge spanning over only 25-30 years.

Based on this premise, defining and explaining waste issues at the social-spatial level requires us to add other layer of characteristics, to allow a holistic description of the problem of dealing with organic domestic waste at the source. By exploring the phenomenon through different fields, we can then speak of signs and symbols of domestic waste in addition to its volume, type and density. Figure 1 illustrates the overlapping fields that were integrated in this work.

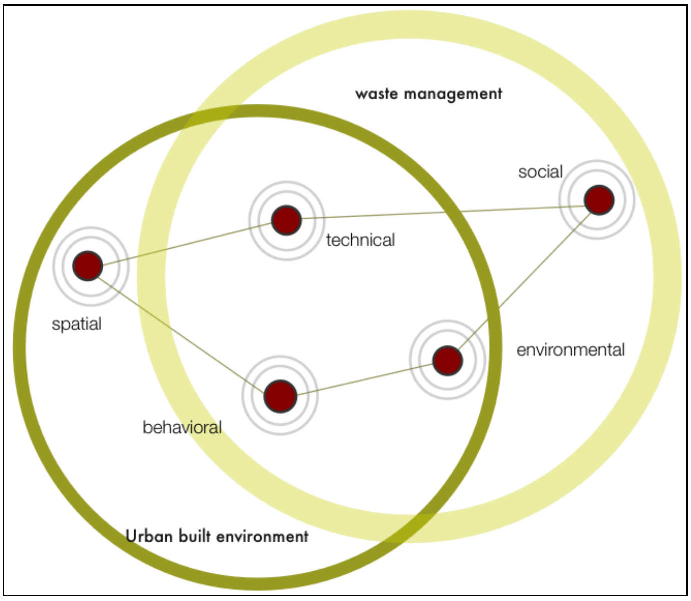

Figure 1 Socio-Spatial context of waste

Since the approach taken in this study is to situate people and organic waste in the center of household dynamics, a particular focus was given to how participants interacted with the waste they produce in their home. A diversified group of individuals were monitored. The practice of keeping records on everyday food waste production in the Mexican context takes into account endemic exo and endo socio-cultural determinants.

EXO AND ENDO SOCIO-CULTURAL DETERMINANTS

Endo Socio-cultural Determinants

Endo socio-cultural determinants are related to the daily routine in the household structure in relation with the physical characteristics of the place of residence. Drawing parallels between dynamics of daily life and dwelling characteristics helps better understand the micro context in which organic waste is produced. This approximation allows us to find out not just the structure of the built environment but also the timetable of organic waste production. The variables used to evaluate endo socio-cultural determinants take into account daily meal routines and food waste habits. They include:

1. Household type
2. Typical meal experience
3. Food purchase habits
4. Food waste separation behavior

The variables used to analyze building attributes are based on well-established mainstream housing indicators, which include:

1. Dwelling type
2. Water and energy supply
3. Sanitary features
4. House improvements

Exo Sociocultural Determinants

Exo sociocultural determinants are understood in the research as factors related to social contribution in relation with neighborhood characteristics. There is a connection between social contribution and neighborhood context. The rationale for focusing on social engagement and neighborhood life is based on observations made of improvements in the built environment, when community members take an active role in solving their problems, suggesting therefore a strong correlation between those two constructs.

The indicators used for determining the degree of social contribution are based on the literature review on social capital studies. They include:

- Time spent in the community
- Participation in community organization
- Willingness to help if necessary
- Level of trustworthiness

The indicators used to measure neighborhood dynamism in this research, emerge from the social science field in which elements of spatial activity and local interaction take a central role in filtering "micro neighborhood forces".

- Connectivity
- Street features
- Transportation and movement
- Urban greenery
- Neighborhood prosperity

PRELIMINARY DESCRIPTIVE ANALYSIS

Table 1 gives an overview on the household structure and urban context of the sample obtained in Mexico. The first column titled household structure illustrates the type of informant who participated in the study. Female informants provided most of the knowledge on daily habits and household composition. The study included 6 different age groups, most of them were represented in the study. The sample was divided into mostly undergraduate students, following by professional working full time. One unemployed male and one retired female also participated in the study. Each household received a non-sequential code number.

F indicates female informant,
M indicates male informant.
S studying
U unemployed
W working professional or skilled worker working part or full time
KH keeping house, raising children

Building type I: free standing house
Building type II: attached townhouse or enclosed multi-unit dwelling/condominium
Building type III: apartment building

Low: low income area
Medium: medium income are
High: high income area
PU: Peri-urban area
U: urban area

Table 1 Overview household structure, building type and urban context of the sample in the central region of Mexico

household structure					building type	urban context
code	informant login			No. residents		
51	F	18-24	S	4	Type I	Medium - PU
52	M	45-54	W	4	Type II	Medium - U
53	M	35-44	U	2	Type III	Medium - U
54	M	18-24	S	6	Type I	Medium - U
55	F	35-44	W	4	Type II	Medium - U
56	F	45-54	W	4	Type II	Medium - U
57	F	25-34	W	2	Type I	High - U
58	F	45-54	KH	4	Type II	High - U
59	F	35-44	KH	4	Type II	High - U
63	M	18-24	S	1	Type I	Low - U
65	M	18-24	S	4	Type I	Low - U
66	F	18-24	S	1	Type III	Low - U
67	F	18-24	S	6	Type I	Low - U
68	F	18-24	S	7	Type I	Low - U
70	F	18-24	S	4	Type I	Low - U
80	F	35-44	W	7	Type I	Medium - PU
81	M	25-34	W	2	Type I	Medium - PU
82	F	>65	R	2	Type I	Medium - U
83	F	45-54	KH	5	Type I	Medium - PU
84	F	18-24	S	3	Type I	Medium - U
85	F	18-24	S	4	Type II	High - U
90	F	18-24	S	4	Type I	Medium - PU
110	F	35-44	W	4	Type I	Low - PU
111	F	25-34	W	4	Type I	Low - PU
112	F	25-34	W	5	Type III	Low - PU

CONCLUSIONS

Preliminary analysis shows the type of organic waste produced in both urban and peri-urban context to be homogeneous. Observations made in each household show a high volume of organic residue with high moisture level. Fruits and vegetables appear more than excess cooked food. In peri-urban areas, the volume of waste was higher than the waste produced in urban areas. At this stage, there appears to be no significant difference between the type of food waste produced at medium and lower income level households. In the upcoming months, further in-depth analysis on the volume of waste produced and more details from the household structure will provide clearer insight on the differences and similarities of food waste production in the central region of Mexico.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.623-630

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Recycling of Solid Waste in Khulna City of Bangladesh

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ABSTRACT

Conventional recycling model of solid waste was investigated and analyzed in the Khulna city of Bangladesh. This study covered an extensive study of waste recycling with emphasis on the most important unit of the waste chain, the waste collectors. A systematic questionnaire survey was conducted on waste collectors, recycling dealers, factories, and municipal authorities. A complete hierarchy from waste collectors to factories of the recycled product was identified. The study revealed that 41.23 tons/day solid wastes of Khulna are recycled by the private sector in the city. This amount is 8.87% of total generated solid waste 465 tons/day as calculated from data presented in the literature. This amount is 65.88% of recyclable solid waste 62.77 tones/day or 82.11% of readily recyclable solid in Khulna. Private sector deals only with the readily recyclable solid wastes. The readily recyclable solid wastes including paper, glass, plastic, aluminum, iron, tin, bones and tyre are mainly recycled by private sector. These are used as raw materials for new products of the specific factories situated in Khulna. The other retrieved materials are transported to the factories located in Dhaka. The present situation and improvement of waste collectors are also discussed.

INTRODUCTION

Recycling is the process through which solid waste can be used over again. It is the reprocessing of wastes, either into the same material or to a different material. Solid waste recycling has found to be currently acceptable and a sustainable approach towards solid waste management. It is desirable from environmental, economic and social points of view. The solid waste recycling reduces environmental damage and is an import-substitution economic activities which also saves energy, conserves resources and saves waste collection and disposal costs (Kaseva and Gupta 1996). Recycling of Municipal Solid Maste (MSW) is now recognized as the most environmentally sound strategy for dealing with MSW following only the preventive strategy of source reduction and reuse (EPA 2004).

Bangladesh is generally faced with rapid environmental deterioration due to unmanaged generation of solid wastes. Urban solid waste management has become a major concern for the cities and towns of Bangladesh. The traditional recycling of solid waste has been carrying out in Bangladesh not designating those as waste but as resource and may provide positive impact. The poor waste collectors carry out the collection of recyclable solid waste (RSW). The waste finally goes to the recycling factories through a hierarchy of recycle dealers. Since no special support from the government has been forthcoming to encourage clean and organized recycling, it remains an activity within the private sector. Almost without exception, recycling activities take place in polluting and unhealthy environment. Therefore the aim of this paper is to investigate and analyze the potential of traditional recycling of solid waste in Bangladesh using data collected from Khulna city area. There are several advantages of solid waste recycling:

- Cutting down littering.
- Prolong life of the local landfill sites by reducing amounts of waste,
- Reduction of cost of solid waste management,
- Saving of energy in terms of electricity and fuel,
- Reducing import of new material,
- Generation of employment,

The municipal authorities of cities and towns are facing problems with higher generation of solid wastes similar to other cities of the world. It is well known that the recycling and reusing are important factors of 5R elements such as reduce, reuse, recycling, recover and residue. In Bangladesh, the recycling has been going on traditionally from times immemorial. There is no systematic technical publication so far. Therefore it will be a worthy work to see the traditional recycling pattern exists in the country. The waste characteristics and generation rate in the major cities are almost same with very few exceptions (Ahmed & Rahman 2000, Wastesafe 2005). The data collected in Khulna city can be taken as a representative for Bangladesh. The scenarios of Khulna can explain the traditional recycling pattern of Bangladesh.

METHODOLOGY

A set of questionnaires designed for waste collectors, recyclable dealers and workers of recycling factories were used to obtain information about the ongoing waste recycling pattern. Using the questionnaires a survey was conducted in selected areas of Khulna city to collect all important primary data regarding recycling of solid waste with the special objectives as (i) Composition of solid waste in different categories and their potential for recycling; (ii) The quantity of recyclable waste; (iii) The quantity waste originally recycled; and (iv) Impact of recycling on economy. The description of the area selected for the proposed questionnaire survey is given in Table 1. Total eight places among eight words are selected. Most of the recycling shops of Khulna city are situated in this selected area.

Table 1 Detailed description of selected areas in Khulna city

Location and Ward Number	Characteristics of the Ward	Number of House-holds	Population	Survey on Recycling Concern
Fulbarigate 2	Mainly low income households and some agricultural land	681	3,344	Recycling dealers & waste collectors
Daulatpur 6	Located in city periphery. Mainly pre urban but some agricultural land.	963	4,728	Collectors, recycling dealers &factory
Khalishpur 9 & 12	Industrial area located along the river. many factory workers live here and there are a few slums	2,961	23,924	Recycling dealers, collectors &factory
Sonadanga 17	Planned housing in built up area with higher income households	1,334	8,416	Recycling dealers & factory
Sheikhpara 20	It is mainly recyclable waste market area	1,077	5,708	Recycling dealers, waste collectors & factory
Gollahmari 24	Central area. Traditionally middle class and educated professionals live here	2,377	12,606	Recycling dealers
Lobanchora 31	Mainly low income Households with factories	2,998	14,721	Recycling Factory
Shiromoni & Other places -	Mainly middle class and educated households with factories	-	-	Recycling factory, dealers and collectors

Data on Waste Generation

Different studies showed that the waste generation rate in Khulna city is ranged between 0.22 to 0.50 kg per capita per day as given in Table 2. An average rate of generation of 0.31 kg per capita per day is selected for further analysis in the following sections. The total population in this city is taken as 1.5 million (KCC 2007). The calculated total daily average solid waste generation rate is found to be 465 tons/day.

Table 2 Waste generation of Khulna city according to different studies

Reference study	Per capita waste generation, kg/day	Total waste generation tons/ day
Waste Concern (2000)	0.22	201
New Age (2004)	0.23	300
Waste Safe (2005)	0.30	445
Ahmed & Rahman (2000)	0.50	750
Average	0.31	465

The physical composition of solid waste of Khulna and Dhaka are presented in Table 3. It can be seen from different studies that the physical composition of solid waste in both cities are similar with very few exceptions. The composition of Khulna can represent Bangladesh. Therefore, It will be worthy to see the recycling pattern of Bangladesh in light of Khulna.

Table 3 Physical composition of solid waste of Khulna and Dhaka City

Composition	A	B	C	D
Food & vegetable waste	78.9	70.0	70.12	67.00
Paper & paper products	9.5	4.0	4.16	8.50
polythene & plastic	3.1	5.0	4.17	4.00
Textile & woods	1.3	-	-	-
Metal component	1.1	0.13	0.13	-
Glass & ceramics	0.5	0.25	0.25	-
Rubber & leathers	0.5	-	0.70	-
Brick, concrete & stone	0.1	-	4.29	-
Green waste & Straw	-	0.27	10.76	7.00
Dust, ashes	3.7	-	-	3.50
Others	1.2	5.0	-	9.00

Source: Khulna A: WasteSafe (2005); Khulna B: Huda (2008); Dhaka C: Memon (2002); Dhaka D: Yousuf and Rahman (2007)

RESULT AND DISCUSSIONS

Waste Collectors

From field survey it was found that the waste collectors are the first link in the long chain of recycling. The collection of RSW using a tricycle is shown in Figure 1a. They are visible in every community of the city and come from nearby slums and squatter settlements. This group comprises of men, women and children. The role of the waste collector is to collect and classify various materials that have a recycling value and can be sold to a recyclable dealer as shown in Figure 1b. The wastes are placed nicely in a sorted form in a dealer shop according to their specific quality, quantity, type, size and the price.

The waste collection Pattern can be classified into two broad categories. The first category of classification is according to the mode of waste collection: (i) from house to house waste collectors are usually both men and women and their local name is Feriwala or Hokar. Most of the feriwalas carry a basket or large bag hold on their shoulder, while some own tricycles as shown in Figure 1b; and (ii) from bin waste collectors are usually children and both sexes with age below 14 years. Their local name is waste pickers. The waste pickers collect waste from streets, drains, municipal bins, open dumping sites and landfill sites. The waste pickers do not use any kind of protective gears, like gumboots or gloves, and are exposed to frequent injuries like cuts from glass pieces, metals, etc. The second category of classification is according to the mode of waste transportation such as manual transportation, or using a tricycle.

(a) Collection of RSW using a tricycle

(b) Recyclable dealer/shop

Figure 1 A traditional solid waste recycling process in Bangladesh

Estimation of Number of Waste Collectors

The number of waste collectors in Khulna was estimated by conducting surveys on waste collectors, recyclable dealers, and some slum areas in Khulna (Moniruzzaman 2007, Alhaz and Mostafiz 2006, Raihan and Hasan 2005). Assuming a similar distribution of waste collectors amongst the recyclable dealers in Shekpara, the survey results were projected for the total waste collectors. This yielded the presence of more than 2000 waste collectors in Khulna as shown in column (A+B+C) in Table 4.

Table 4 Estimation of number of people involved in recycling process

Location	Waste Collectors			Dealers	Employee of Factories (E)	Total (F)
	Feriwala		Waste picker			
	Men (A)	Women (B)	Children (C)	No. of Employee (D)		
Shiromoni	5	0	15	6	50	76
Fulbarigate	25	0	60	24	0	109
Dowlotpur	44	0	95	220	0	359
Khalishpur	65	10	120	120	20	335
Sheikhpara	450	20	850	600	200	2120
Sonadanga	11	0	35	50	45	141
Gollamari	10	3	50	60	45	168
Dakbangla	15	0	40	40	0	95
Munshipara	10	2	20	12	0	44
Lobon chora	8	2	15	8	350	383
Other places	15	0	12	110	40	177
Total	658	37	1312	1250	750	4007

Note: More than 500 brokers are also involved in different areas of Khulna

Working Conditions

The waste collectors tangible resource (i.e., waste) is not liable to damage, theft, and supply problems or due to unexpected changes in markets. Waste collectors mostly work alone, are solely responsible for the success of their work and each day is critical for them in the sense that each day's earnings are used to provide basic necessities for that day. Average income of the waste collectors was found to be range between Tk. 25 to 130 per day during 2006 to 2007. This compares well with the corresponding figures of incomes of waste collectors range between Tk 40 to Tk 200 per day as reported by Rouse and Ali (2001).

The waste pickers pick up waste from streets, drains, municipal bins, open dumping sites and landfill sites. None of these is hygienic enough, and yet the waste collectors do not use any kind of protective gears, like gumboots or gloves, and are exposed to frequent injuries like cuts from glass pieces, metals, etc. The work is unpleasant, and frequently the areas in which waste is found and assorted are used for public dumping point. The health and safety problems associated with the work are numerous and quite obvious.

Estimation of Waste Quantity Recycled

Estimation for quantity of waste recycled was done by using a method as described by Mittal et al. (2005). The average weight picked by man, woman and children was calculated by arithmetic mean of the collected data on quantity of waste in each category. The total quantities of recyclable solid waste (RSW) collected daily are divided into different categories (Table 5) depending on the quantity collected by men, women, and children through each of the transportation mode. Table 5 shows that of all RSW in the city, paper is recycled most by the waste collectors, while animal bones are recycled least. This can be explained by the fact that after food & vegetables (78.9% to 85.7%), the waste paper is the single highest RSW as by the weight 9.5% among the total solid waste components generated in the city. Therefore, the waste paper can be designated as easily accessible waste by collectors.

Table 5 Average daily collection of waste in weight by various categories of collectors

Category	Mode of transportation of recyclables	Average quantity (kg/day)					Total (kg/day)
		Glass	Paper	Plastic	Metal	Animal bone	
Waste picker (Children)	Manual	0.5	6	1.5	1	1	10
Feriwala (Men)	Manual	1	7	3	2	2	15
	Tricycle	4	11	8	10	2	35
Feriwala (Women)	Manual	2	6	3	1	0	12

Also the numbers of men, women, and children in terms of percentages was evaluated by field survey data (Moniruzzaman 2007, Alhaz and Mostafiz 2006, Raihan and Hasan 2005) and the summary is given in Table 6. From the data shown in Tables 4 and 5, the average weight collected by an average waste collector was evaluated as below:

Table 6 Percentage of waste collectors employing different modes of transportation

Category	Mode of transportation of recyclables	
	Manual (%)	Tricycle (%)
Children	65	None
Men	8	25
Women	2	None

Average daily weight picked up by an average waste collector
= [(65/100) (no. fraction for children-manual mode) ×10(kg/child-manual mode)
+ (8/100) (no. fraction for man-manual mode) × 15(kg/man-manual mode)
+ (25/100) (no. fraction for man-tricycle mode) × 35(kg/man-tricycle mode)
+ (2/100) (no. fraction for woman-manual mode) × I2 (kg/woman-manual mode)]
= 16.69 Kg ≈ 17 Kg
Hence, total quantity of waste collected daily by the waste collectors
= no. of waste collectors x average weight picked by each waste collector
= 2000 waste collectors x 17 kg = 34,000 Kg =34 tones
The average waste generated in Khulna = 465 tones/day
Hence, the percentage of waste recycled =34/465x 100 = 7.31% of total generated waste

Recyclable Dealers

Recyclable dealers are the second link in the chain of recycling. They are reported under three broad categories according to mode and quantity of collection and type of waste. There are three types of recycle dealers namely; small recyclable dealers (SRD), medium recyclable dealers (SRD), large recyclable dealers (SRD). The types of dealers depend on the quantity of Recyclable Solid Waste (RSW) collection and the specific nature of the waste.

1. Small Recyclable Dealers (SRD): Each SRD purchase all types of wastes from all types of collectors and their collection of RSW is below 250 kg/day per dealer on an average.
2. Medium Recyclable Dealers (MRD): Usually the MRD deal with two or three kinds of specific RSW. They purchase RSW from all the SRDs and occasionally from brokers. The amount of waste collected by MRD range between 250 kg/day to 600 kg/day per dealer.
3. Large Recyclable Dealers (LRD): The LRDs essentially specialize in specific type of wastes. They purchase RSW from the MRDs present in Khulna and from outside of Khulna. On an average the amount of RSW collection by each LRD is greater than 600 kg/day per dealer.
4. The recycling factories (RI): The RI is deals with specific RSW which includes the waste collected in Khulna as well as the waste imported from outside Khulna.

A proposed mass balance is shown in Figure 2. The estimated quantities of RSW recycled by waste collectors in Khulna are 34 tons/day. The amounts of RSW collected by SRD are 36.46 tones per day. The amounts of RSW collected by MRD are 41.23 tons/day. The amounts of RSW collected by LRD are 49.72 tons/day. Finally the amounts of RSW recycled by the RI are 64.19 tones/day is not shown in the figure. This can be explained by the fact that the SRDs collect waste only from Khulna and through waste collectors. The MRDs purchase RSW from all SRDs and occasionally from feriwalas and brokers of Khulna.

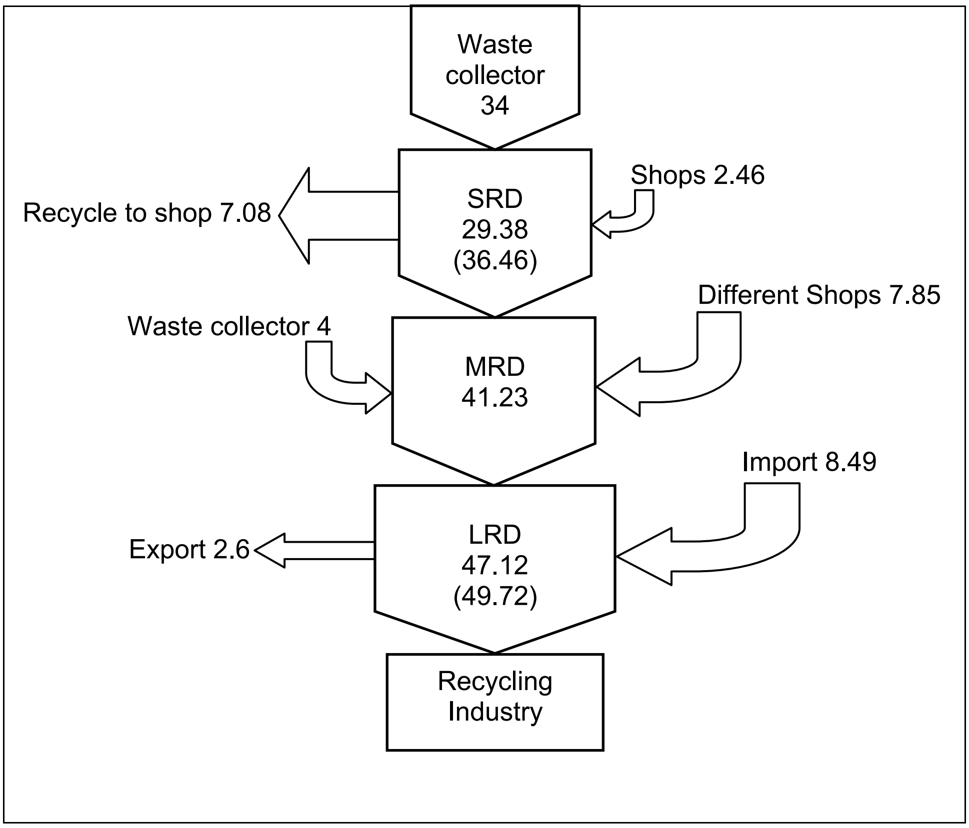

Figure 2 A mass balance of existing recycling activity in Khulna

The amounts of collection of MRDs are higher than that of SRDs. However, the LRDs collected the RSW from MRDs of all over the Khulna city and outside (mainly Chittagong) of Khulna by trucks. Their quantity is much higher than that of any other group. They also sell some sort of processed RSW (such as glass, iron) to factories and markets outside Khulna. They do so because all types of recycling industries or factories are not available in Khulna. For example, almost all collected glass can be used to produce new glass containers and bottles. As there is no glass recycling factory in Khulna city the total portion of collected glass are sent to Dhaka. Another reason for sending waste outside Khulna is for getting more benefit. The RIs on the other hand purchase RSW from LRDs sometimes through brokers and sometimes through the shopkeepers by using trucks. The mass balance for present recycling pattern is developed in this paper according to data collected during 2006 to 2007 (Moniruzzaman 2007, Alhaz and Mostafiz 2006, Raihan and Hasan 2005), is shown in Figure 2. From the mass balance it can be seen that at MRD almost all of the RSW are come from different sources of Khulna. Therefore it is reasonable to estimate the quantity (41.23 tons/day) of MRD as the total recycling of RSW of Khulna.

Estimation of Recyclable Solid Waste

The waste collectors generally collect paper, metal, tin, plastics, glass and broken glass, bottles from houses, dustbin or disposal site to sell. From the composition of solid waste it can be calculated that the percentage of these recyclable solid wastes such as paper, metal, glass, plastic, bone are vary between 12% to 15% (with average value of 13.5%) according to different studies as shown in Table 2. This data is very important, when one want to discuss regarding recycling. For the case of Khulna only 13.5% is recyclable. The other major part 87.5% can not be recycled. This part can be used as a raw material for composting. Therefore the quantity of recyclable solid waste can be estimated from total waste generation (465 tons/day) as (0.135×465) 62.77 tons/day.

Estimation of Readily Recyclable Solid Waste and Percentage of Recycling

It is not possible for waste collectors to collect all of the RSW found in the waste bin, dustbin and disposal site. They can collect only those recyclable solid wastes, which are clean and have some selling value. This portion of RSW which are clean and have some selling value can be designate as readily recyclable solid wastes. In absence of proper separation at the source some slowly biodegradable components such as paper, bone etc. tend to decompose and some other are spoiled as the mixed decomposable organic waste. Finally they lose their selling value as well as opportunity for recycling. Therefore it is necessary to calculate the quantity of readily recyclable solid wastes. The readily recyclable solid waste can be estimated 80% of RSW and the value is (0.80x62.77) 50.21 tons/day.

From the mass balance it can be seen that at medium recyclable dealers (SRD), almost all of the collected RSW come from different sources of Khulna. Therefore it is reasonable to estimate the quantity (41.23 tons/day) of MRD as the total recycling of RSW of Khulna. This quantity 41.23 tons/day is equal to 8.87% of daily total generated waste (465 tons/day), 65.68 % of RSW (62.77 tons/day) and 82.11% of readily RSW (50.21 tons/day). The data 8.87% of daily total generated waste compares well for Dhaka City Corporation as 9.10% (Memon 2002).

RECOMMENDATIONS

The recycling of solid waste is not included in the waste management policy of local authority, yet it has become a main source of income for several groups of the private sector as described above. The waste collectors should be formally incorporated in waste management systems, both at local level systems, as well as in the larger urban framework. For this, training would be required on personal hygiene as most waste collectors are presently unaware of the consequences of garbage sorting without adopting safety guidelines. The recycling sector can be private as traditional however, attention should be paid to improve the living conditions of the waste collectors.

CONCLUSIONS

Based on the evaluated results it can be concluded that:

- There are 450 recyclable dealers and most of the recycling dealers are situated at Shekhpara in Khulna. More than 4,500 people are involved in the recycling chain of the city.
- The composition of RSW are paper, plastic, iron, animal bone, tyre/rubber, glass, aluminum, tin are processed or recycled by the dealers. They deal with 49.72 tons/day of RSW as calculated for LRD, that come from all over Khulna city as well as from nearby districts.
- According to mass balance, about 41.23 tons/day recyclable solid wastes are recycled by the private sector in the Khulna city. This amount is 8.87% of total generated waste (465 tons/day) or 65.68% of recyclable solid waste (62.77 tones/day) or 82.11% of readily recyclable solid waste.
- Training would be required on personal hygiene as most waste collectors are presently unaware of the consequences of garbage sorting without adopting safety guidelines. Proper attention should be paid to improve the living conditions of the waste collectors.

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ISBN: 978-984-33-0761-3, Vol. 2, pp.631-639

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Emerging Uses and Issues of Biodegradable Plastics Waste Generation

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ABSTRACT

Biodegradable plastics are a new generation of plastics, emerging in the world market. They have expanding range of potential applications and driven by the growing use of plastics in packaging, agriculture, food, medical, etc. As an increasing number of countries are banning plastics bags and plastics packaging, responsible for white pollution, are replaced by the degradable plastics and hence plastics and particularly the degradable plastics is a small but a significant component of the municipal waste stream. However, issues are also emerging regarding the use of biodegradable plastics and their potential impacts on the environment, effects on established recycling systems and technologies. Some of these emerging issues were highlighted in this paper. Discussed here briefly, were the efforts in addressing the issue of degradable plastic wastes in particular. These efforts will lead to assist industries and the commonwealth to implement the rules and take initiative to address these issues effectively.

INTRODUCTION

It is rightly postulated by Mr. Scheer, a former investment banker who established the Biodegradable Plastics Institute in 1998 that “It doesn’t make sense, to use a disposable cup for 15 minutes, produced from petroleum oil that takes 70 million years to make and then send the cup to a landfill where it do not degrade for next 500 years” .

This non-biodegradable plastic thrown off in land, river, sea, mines etc. as garbage, stays right there since it is not degraded. It cannot be used for other purposes like biogas production, fertilizer etc. It reduces the porosity of the land where it is present as it is non-absorbing and non porous thus affects the percolation of ground water. Also, fish, turtles, cattle and other animals eat these plastic bags along with other garbage. Since these plastics bags are non-degradable, it gets accumulated in the poor creature/animal's body choking it to death eventually. Also, some kinds of plastics release toxins in the environment and also in the animal's body and killing them.

All these disadvantages have forced the world to go for the biodegradable plastics. Hence before knowing the biodegradable plastics it will be interesting to know certain facts about the plastics and its consumption.

The world's annual consumption of plastic materials has increased from about 5 million tones in the 1950s to nearly 100 million tones today. It is produced and used 20 times more today than it was used 50 years ago! Today the production of plastics in Asia alone is more than 25 million tones; i.e. one-quarter of world production. Considering China alone then its plastic products has been growing at an annual rate of over 20% since 1990. This is rare in case of any industry.

Hence, waste management problems are expected to worsen in all countries. In highly-industrialized countries plastics represent between 20 and 40% of municipal solid waste by volume. The time has therefore come to think of cooperation in developing strategies for bio-degradable.

Also it is realized that the use of long-lasting polymers for short-lived applications is not entirely justified, especially when increased concern exists about the preservation of living systems. The elimination of waste plastics is therefore of interest in surgery, hygiene, catering, packaging, agriculture, fishing, environmental protection, technical and other potential applications.

Biodegradable plastics, which will soon become competitive or necessity as the price of oil has/will soar. Because it requires less fuel and release less carbon dioxide than traditional plastics during manufacture and disposal. It also reduces annual landfill waste by thousands of tons. Plus, they're much safer than conventional plastic packaging, which may leech toxins into food. But again, looking to the various advantages and growth of biodegradable plastics, it seems that the biodegradable will also cause severe problems for the whole environment sooner or later.

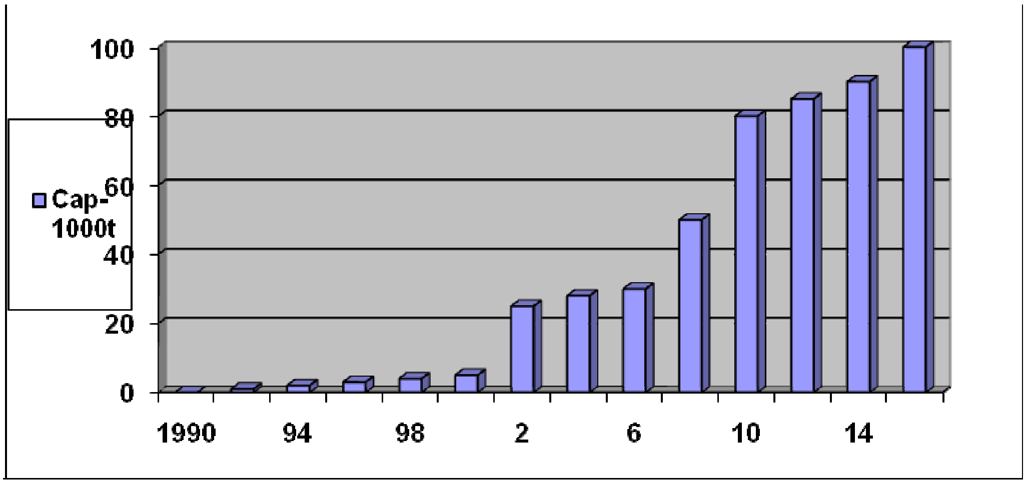

Figure 1 Global Production Capacity for Bio plastics in tons/year

THE GROWTH AND DEMAND OF BIO-DEGRADABLE PLASTICS

The demand of biodegradable plastics in US alone is to grow nearly 20% annually till 2012. In US, its demand is forecasted to nearly 16 percent per year to 720 million pounds (327 million kg) in 2012, valued at $845 million. Average prices will continue to decline as a result of higher capacity and greater production efficiencies, as well as price mixes reflecting fastest growth for the lower priced resins. Myriad opportunities are anticipated based on a more competitive pricing structure, increased competitiveness with petroleum-based polymers, and growing environmental, governmental and consumer initiatives for greater use of sustainable resources. Biodegradable plastic applications are also being expanded by developing testing and certification standards and enhanced performance properties brought about by more sophisticated polymerization and blending techniques.

Because of their above positive characteristics and benefits, biodegradable plastics and or bioplastics are often a viable alternative to conventional plastics made out of fossil resources. Since many conventional plastics can be substituted with bioplastics, features of and predictions within the conventional plastic market are also relevant for the bioplastics market. As an example, out of the 14 million tons of packaging material that are produced in Germany every year, about 40% consist of plastics. Around 1.8 million tons of that are perishable or single-use plastic packaging materials like foils, bags, containers, cutlery and crockery. These products could easily be substituted by starch or polylactide plastics. The production of about 500,000 tons of bioplastics in Germany is therefore realistic. Similarly, half of the six million tons of disposable plastic packaging in the European Union could be substituted by bioplastics.

The horticultural sector is another area where the use of bioplastics offers great advantages. There is a potential for a consumption of 12,000-20,000 tons of degradable plant pots and 1,500 tons of mulch foil per year in Europe alone. COPA (Committee of Agricultural Organisation in the European Union) and COGEGA (General Committee for the Agricultural Cooperation in the European Union) have made an assessment of the potential of bioplastics in different sectors of the European economy as shown in Figure 1.

WHAT IS BIODEGRADABLE PLASTICS?

The term "biodegradable plastic" is often also used by producers of specially modified petrochemical-based plastics which appear to biodegrade. Traditional plastics such as polyethylene are degraded by ultra-violet (UV) light and oxygen. To prevent this process manufacturers add stabilising chemicals. However with the addition of a degradation initiator to the plastic, it is possible to achieve a controlled

UV/oxidation disintegration process. This type of plastic may be referred to as degradable plastic or oxy-degradable plastic or photodegradable plastic because the process is not initiated by microbial action.

Where as many polymers that are claimed to be 'biodegradable' are in fact 'bio-erodable', 'hydro-biodegradable' or 'photo-biodegradable'. These different polymer classes all come under the broader category of 'environmentally degradable polymers'. For the purpose of this document the term 'biodegradable plastics' shall imply 'environmentally degradable plastics'. The classes of biodegradable plastics considered, in terms of the degradation mechanism, are: Biodegradable, Compostable, Hydro-biodegradable, Photo-bio-degradable and Bio-erodable. Two such products made from biodegradable plastics as shown in Figure 2.

Figure 2 Products made from biodegradable plastics

WHAT IS BIOPLASTICS?

Bio-plastics are based on the principle of the natural cycle of matter and allow an intelligent, cascading usage of natural resources without waste (zero waste) and without emissions of greenhouse gases (zero emission).

Worldwide, approximately 100 billion tons of organic material is generated every year by photo-synthesis and is in large part broken down by microbial degradation into the initial products of CO_2 and water. This natural model is followed by bio-plastics: renewable raw materials used for manufacturing. The used products can be composted. Two such products made from bioplastics as shown in Figure 3.

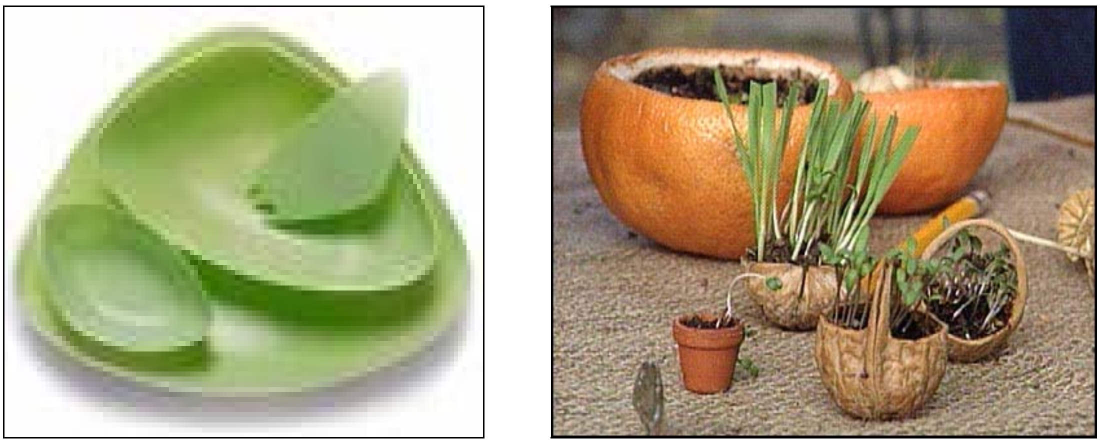

Figure 3 Products made from bio plastics

BENEFITS OF BIODEGRADABLE PLASTICS

The considerable growth in use of biodegradable plastic is due to the countless beneficial properties of plastics. Few of these include:

- extreme versatility and ability to be tailored to meet very specific technical needs.
- lighter weight than competing materials, reducing fuel consumption during transportation.
- extreme durability.
- resistance to chemicals, water and impact for defined time period
- good safety and hygiene properties for food packaging for limited time
- excellent thermal and electrical insulation properties.
- relatively inexpensive to produce.

RECENT DEVELOPMENTS IN TYPES OF BIODEGRADABLE PLASTICS

Thermoplastic Starch Polymers

The applications of thermoplastic starch polymers are generally film, such as shopping bags, bread bags, bait bags, over wrap, 'flushable' sanitary product packing material, and mulch film.

Foam loose fill packaging and injected molded products such as take-away containers are also potential applications. Foamed polystyrene can be substituted by starch foams that are readily biodegradable in some loose-fill packaging and foam tray applications.

Fiber Reinforced Composites

Natural fibers, such as those produced by hemp, flax, sisal, and jute are emerging as replacements for the glass fiber reinforcements, usually found in a conventional polymer matrix. The ecological and mechanical properties of the natural fibers are responsible for this opportunity. When natural fiber is incorporated into a polymer matrix, whether the matrix is based on natural or synthetic polymers, the final product is known as a biocomposite. Although the majority of composite materials include a plastic matrix and reinforcing fiber material, alternative matrix materials, such as concrete may also be used

Natural fiber-reinforced biocomposite materials have environmental and economic advantages over conventional composite materials. Glass fibers which are usually used to reinforce composite materials are formed through an energy intensive process detrimental to the environment. Natural fibers require decortications prior to use in composites, but much of this process can be completed in the field, or with chemical treatments, reducing the need for fossil fuel use as energy. In addition, particularly in the case of flax fibers, the biomass from which they are gathered has traditionally been burnt by producers, as a means of removing it from their fields. Therefore, the incorporation of it into biocomposites will provide an environmentally friendly way of disposing of the biomass.

Starch based Materials

Starch is a pure, natural biopolymer, found in the roots, seeds, and stems of plants such as corn, wheat, and potatoes. It is suitable for chemical modification into a thermoplastic material, available for use in a variety of applications. As starch is fully biodegradable and easily renewable, it will continue to be an important component of the biopolymer industry.

The primary application for this product is as filler for thermoplastics. In Europe, the industrial production volume of starch is almost 7million tones/year. Of this volume, approximately 50% of the starch is used for non-food applications, and approximately 30% of the starch is precipitated from industrial aqueous solutions.

The materials under consideration in their study included blends of starch with polypropylene (PP), polyethylene (PE), poly-capro-lactone (PCL), or poly-hydroxy-butyrate-co-hydroxy-valerate (PHB/V).

The methods are under development to obtain high mechanical properties of the biopolymers with desirable biodegradability of the end product

Plant Produced Polymers

Some of the most recent advances in biopolymer research have focused on the genetic engineering of conventional plants, in order to develop molecular processes by which the plants actually produce usable polymer materials within their cellular tissue. The polymer material which researchers are interested in incorporating in plant tissues is poly-hydroxy-butyrate (PHB), which has mechanical properties similar to those found in polypropylene (PP).

Corn, sugarcane, switch grass, mustard, and alfalfa have all been considered for genetic engineering toward PHB production. For reasons surrounding the ease of genetic modification and characterization, Monsanto has selected corn as their crop of focus in the area of PHB production. This breed of Monsanto corn is harvested by conventional means, and used as a regular variety of the crop. The stover is also collected, and extraction of the PHB from the leaves and stalk is completed using a two-step alcohol extraction process.

More recently, alfalfa has been chosen for genetic engineering toward PHB production due to its perennial growth, nitrogen-fixing capabilities, and the potential for multiple harvests in a single growing season. The organelles selected for PHB gene encoding in the alfalfa cells were the plastids.

Progress in the genetic engineering of plants has seen great successes in recent years. In addition, although PHB is a completely biodegradable material, it lacks the structural integrity required for its sole use in polymer materials. It has a high decomposition level prior to melting, and results in a brittle material.

This is an emerging technology, which will become more widely accepted as public education about it is expanded.

Microbially Produced Polymers

The common biopolymers which are able to be isolated from bacterial cells are poly-hydroxy-alkanoates (PHAs), polylactic acid (PLA), and PHBs, which have properties similar to those found in polyethylene and polypropylene. These biopolymers are found in nature, as intracellular deposits in bacteria, produced when bacteria must survive under unfavorable conditions. They act as an energy storage facility, and are developed when the bacteria's surroundings include excess carbon, and a deficiency of another nutrient. Bacterial production of PHAs and PHBs is based on fermentation processes using various materials as feedstock materials.

Polylactic acid (PLA) production is unique in its requirement of bacterial fermentation of a feedstock material (to produce lactic acid), followed by condensation of the lactic acid product. The feedstock material is often a polysaccharide such as starch or cellulose.

Japanese researchers have also developed a multi-component feedstock system for polymer production, but the polymer they have focused on is poly-l-lactate (PLLA); a bioplastic that gradually decomposes in average soil conditions. Their innovative process uses municipal food waste as a feedstock for the production of PLLA, thus reducing costs, and providing an environmentally conscious means of waste disposal. They consider their process to be the most practical one available, as there is no need to characterize the municipal waste prior to its use. The use of two types of bacteria (Propioni-bacterium freundenreichii and Lactobacillus rhamnosus) increases the efficiency of this process.

EMERGING APPLICATIONS OF BIODEGRADABLE PLASTICS

Synthetic Biodegradable Polymers as Medical Devices

Polymers prepared from glycolic acid and lactic acid has found a multitude of uses in the medical industry, beginning with the biodegradable sutures first approved in the 1960s. Since that time, diverse products based on lactic and glycolic acid-and on other materials, including poly(dioxanone), poly(trimethylene carbonate) copolymers, and poly caprolactone, homopolymers and copolymers-have been accepted for use as medical devices. In addition to these approved devices, a great deal of research continues on polyanhydrides, polyorthoesters, polyphosphazenes, and other biodegradable polymers.

There may be a variety of reasons that a medical practitioner want a material to degrade, but the most basic begins with the physician's simple desire to have a device that can be used as an implant and will not require a second surgical intervention for removal. Besides eliminating the need for a second surgery, the biodegradation may offer other advantages. For example, a fractured bone that has been fixed with a rigid, non biodegradable stainless implant has a tendency for refracture upon removal of the implant. Because the stress is borne by the rigid stainless steel, the bone has not been able to carry sufficient load during the healing process. However, an implant prepared from biodegradable polymer can be engineered to degrade at a rate that will slowly transfer load to the healing bone. Another exciting use for which biodegradable polymers offer tremendous potential is as the basis for drug delivery, either as a drug delivery system alone or in conjunction to functioning as a medical device.

Packaging

Accounting for one-third of demand, the production of packaging material is the largest sub sector of the plastics processing industry. The food industry constitutes the major end-user followed by the distribution and beverage industries. Despite environmental concerns, the European market for plastic packaging is rising by billions of Euro. every year. Pharmaceuticals, toiletries and cosmetics are large users of packaging. Hence, to keep abreast of future restrictive legislation aimed at reducing packaging weight and volume, these industries are very interested in seeing cheap biodegradable packaging available on the market.

The greatest growth rate has been predicted for polyester bottle resins, particularly in the carbonated drinks market, whose annual demand now stands at more than 500 million Euro. In response to this, Japanese companies have recently designed a substitute for polyester bottles with excellent physical properties by modifying, biodegradable polyester, using a technique known as stretch-blow molding.

Plastic Films

Plastic films are mostly based on poly ethylene with LDPE accounting for one-sixth of total EU plastics consumption. Major end-uses of plastic films are printed films for automatic packaging, shrink and stretch films for over packing, films for agriculture and horticulture (greenhouses, mulching), films for construction, shoppers, carrier bags, refuse bags, heavy duty sacks, and films for a wide range of technical applications such as magnetic tapes, credit cards, hot foil stamping, cables, motor insulation, furniture films and office films. Agriculture accounts for 3% of total plastic consumption in Europe. Plastic films for covering greenhouses have enjoyed both innovation and spectacular growth over the last twenty years.

ISSUES: BIODEGRADABILITY AND COMPOSTABILITY

Certain blends of polyethylene and starch can be degraded by physical agents (such as light). Indeed, a type of polyethylene is being marketed that includes a catalyst prompting the polymer's thermal degradation. Nevertheless, biodegradation is quite another thing.

ASTM standard D-5488-94d defines biodegradable as "capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds, or biomass in which the predominant mechanisms is the enzymatic action of micro-organisms, that can be measured by standard tests, in a specified period of time, reflecting available disposal conditions".

Composting is an accelerated biological decay process viewed by many to be a potential solution to the solid-waste management crisis existing in many parts of the world. Compostable is defined as "capable of undergoing biological decomposition in a compost site as part of an available program, such that the material is not visually distinguishable and breaks down to carbon dioxide, water, inorganic and biomass, at a rate consistent with known compostable materials."

To meet the compostability requirement, all of the blend components have to fully biodegrade under composting conditions and within the timeframe of the composting process. Draft national and European test standards for measuring biodegradability under composting conditions are currently under development.

The key issue is whether the biodegradation material i.e. the residue left by biodegradation is harmful to the environment. Testing the amount of mineralization alone does not take into account the nature of the residue left. Furthermore, biodegradation of blends of non-degradable synthetic polymers and starches, which can actually 'bio dis integrate', is doubtful.

Germany is dealing with the issue of plant health in its biodegradability/composting standards; 'a product must be fully biodegradable under composting conditions and the compost material cannot be phytotoxic or ecotoxic. It will support plant and microbial activity. In fact, the assumption that using natural ingredients always leads to harmless products is not true. Most important is the final destination of the biodegradable material.

One issue to be addressed is if current laboratory tests accurately reflect the biodegradability of a material in a real compost pile. The environment in which biodegradation takes place differed widely in terms of its microbial composition, pH, temperature and moisture. Also they are not readily reproduced in the laboratory.

Another issue for standards development is balancing the need for shelf life with the demand for rapid degradability. The development of more sophisticated distribution systems so as to avoid products sitting in warehouses, and the creation of more composting facilities directly related to the disposal or these products would be needed. In Japan, the Biodegradable Plastics Society (BPS) has proposed a standard for degradability that has been accepted there and is being considered by the International Standards Organization.

The OK Compost Conformity Mark is awarded jointly by the International Quality Inspection Bureau (A.I.B.).Vinçotte- Inter and “Organic Waste System”, a research institute in the field of biodegradability. Manufacturers can use this label on their material as a proof that it passes the biodegradability test and is appropriate to compost. So far, no internationally adopted standard laboratory method exists for investigating aerobic biodegradability in a composting environment.

It is predicted that soon issues of biodegradability will have solution and it will replace many materials ranging from chewing gum to automobile car. For example, the recently degradable chewing gum is completely environment friendly and does not stick to clothing or pavements. Once disposed off, it will crumble to dust in about six weeks, dissolving harmlessly in water or being absorbed into the soil. Where as, for the conventional chewing gum, “The Department for Environment, Food and Rural Affairs, London” has calculated that local authorities spend up to 200,000 pounds a year on clearing gum from the entire length of Oxford Street in London. In case of biodegradable car, the shell is made of hemp, wheels made of potatoes, and powered by fuel made from fermented wheat. When thrown into the compost heap and the only thing that will be left is the chassis. The chassis can be recycled, because it is made of steel and aluminum. Figure 4 represents the chewing gum and car made from biodegradable materials.

Figure 4 The chewing gum and car made from biodegradable materials.

CHALLENGES AHEAD

Acceptance of biodegradable polymers is likely to depend on four unknowns:

- Customer response to costs that today is generally 2 to 4 times higher than for conventional polymers;
- Possible legislation (particularly concerning water-soluble polymers);
- The achievement of total biodegradability; and
- The development of an infrastructure to collect, accepts, and process biodegradable polymers, as a general available option for waste disposal.

In a social context biodegradable plastics call for a re-examination of life-styles. They will require separate collection, involvement of the general public, greater community responsibility in installing recycling systems, etc. On the question of cost, awareness may often be lacking of the significance of both disposal and the environmental costs which are to be added to the processing cost.

Biodegradability is tied to a specific environment. For instance, the usual biodegradation time requirement for bioplastic to be composted is 1 to 6 months. In Europe, composting is on the increase, and the percentage of population with composting facilities available for their rubbish stands at about 80% in the Netherlands, 40% in Germany, and 30% in Belgium. Adequate regulation is still lacking however, and complaints have already appeared, for example in the Netherlands, where citizens must pay the same tax for plastics that go to composting as for those that go to incineration.

The development of starch-based biodegradable plastics looks very promising given the fact that starch is inexpensive, available annually, biodegradable in several environments and incinerable. The main drawbacks the industry is running into are bioplastics' low water-barrier and the migration of hydrophilic plasticizers with consequent ageing phenomena. The first problem together with the cost factor is common to all other biodegradable plastics.

As far as biological polyesters (PHA) are concerned, the recent purchase of Zeneca's Biopol business by Monsanto, who aims to expand it to include plant-derived polymers, does not suggest a bright future for microbial production of these polymers. Nevertheless, research on the production of the polymers by bacteria is worthwhile because it may be useful in helping us understand how to expand the range of polymers made by plants.

Packaging is a significant portion of the solid waste stream, and reducing the amount of waste generated from all sources, will require complex policy decisions and significant changes in solid waste management practices. Packagers are meeting the challenges of aiding solid waste management by incorporating those factors in the packaging design process.

Reducing the amount of materials in package; improving recyclability; incorporating recycled materials in new package production; making materials safe for incineration and land filling are important concepts which more package designers are taking into account.

Industry is also faced with making packages that fit modern lifestyles, packages that offer convenience and ease of use and protection of the products. Packagers are committed to balancing these economic and social considerations with environmental issues to produce packages which meet the use and disposal needs of society.

There is a need for better and improved communication among customers, retailers, suppliers and regulatory bodies to prevent over-reacting. This is to ensure that all are looking at the right target in a more rational and less emotional approach.

The packaging industry should not look at expedient solution to please interest groups; rather, look for environmentally and economically sound solutions. Moreover, the industries should not look into dissenting opinions with malice; rather, it should be looked at as needing sound technical information no matter how myopic such interest group may be. After all, it is always right to do right.

In view of these challenges, the packaging industry can either practice sound environmental strategy or reap competitive advantage in the process, or be forced into playing reactive or follower role, at a far greater cost. Indeed, the costs of inaction can no longer be seen from the individual corporate perspective; the costs and consequences or our actions have taken on a global dimension.

CONCLUSIONS

Biodegradable polymer technology can at present only offer a limited range of materials. This is the main reason why U.S. and Japan are now focusing on the technological development of biodegradable polymers, in order to expand the range of these polymers. So that it can fulfill processing and property requirements for many applications in which biodegradability would be an important materials property. The biochemical industry (food, grain, sugar) is therefore in an ideal position to build capacity for biodegradable plastics at the expense of the petrochemical industry or, conversely, the petrochemical industry could adapt its technology for processing renewable feed stocks, thereby profiting from a long-standing process experience.

Hence the degradation will be more difficult because of the higher competitive properties. This will further lead to more generation of waste and painful affair for the municipality to treat the same. Management of solid waste should include a critical understanding of the fate of synthetic polymers which may be disposed as solid waste in municipal landfills. Research, marketing and regulatory reviews of degradable polymers should take into account the characteristics of true landfills-not just lab tests of degradation.

Biodegradable plastics are starch-based and therefore, renewable. Any carbon dioxide released during their decomposition is thought to lead to net zero carbon emissions because the starch source, usually corn, needs carbon dioxide to grow. But the fact is that these bags actually emit more carbon dioxide than regular bags as they decompose and the large amounts of energy that go into growing the corn.

So what should be done? Just don't use either of them, regular plastic or biodegradable. Bring your own!

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Waste Pickers: Their Contribution to the Society and Environment as Informal Solid Waste Manager

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ABSTRACT

Dhaka, capital city of Bangladesh is one of the most densely populated cities of the world. So, the generation of solid waste in a small area is huge, but the authority of Dhaka City Corporation (DCC) has very little to contribute in solid waste management (SWM). And there is not a rule, or public interest in recycling the waste which is recycleable. So, the recycling of waste in Dhaka city is completely maintained by the informal sector, “waste pickers” are the part of this sector. It has been intended to discuss about who are these waste pickers, why they are involved in solid waste collection, what type waste they collect, what they do with that and where is the market. The main focus of this study is the contribution they make in SWM, and their indirect contribution to the society and environment.

INTRODUCTION

Dhaka city claimed as one of the densely populated megacity (according to UN estimates and projection) of the world. About 40,000 people living in every square kilometer of the city. The jurisdiction area of DCC is only 360 square kilometer consisting of 90 wards and it is the responsible authority to provide all kinds of services to the city dwellers such as street lighting, repairing of roads, SWM and many other important works. But as the estimates reveals that in 360 square kilometer with 1,44,00,000 people living in a small area, the production of waste per day is huge 4,634.52 ton/day (Iftekhar & Q. S. I. 2006) and the DCC has lack of labour and resource to manage these waste. The collection efficiency is about 50-60% of the whole generated waste. It is quite amazing that the remaining waste is any how managed whether by the community or the informal sector. Where the DCC is concentrating on management of waste, some informal sector has developed to use the waste as resource. In this sector one actor is playing a vital role and they are the waste pickers or better known as “Tokai”.

BACKGROUND

The developed countries of this world have already made different approaches to recycle, reuse and reduce their generated waste. But on the other hand the developing countries are not that much advanced with their waste management. Recently announced as least developed country Bangladesh and its capital Dhaka has very poor performance in managing solid waste. And the recycling is done by the informal sector. It is interesting to know that the concept of recycling, reuse is totally ignored by the public sector and there are not such rules or laws about recycling, reuse process in the country. The law is needed because recycling; reuse has impact on health, environment, economy and society. This is because the informal sectors those are involved with recycling, reuse include the waste pickers who are the major actor in the play of recycling in Dhaka city. So, it is important to know, who these waste pickers are, in which stage are they involved in the waste management and the recycling process.

METHODOLOGY

There is no specific number or published data on the waste pickers. The number was estimated in 2004 which was almost 1,20,000 (Nazrul & Salma 2004). But it has naturally extended to almost

2,00,000 with the comparison of the population of the city, which has increased from 2004 to in 2008. It is hard to identify them when they are not in work, because there are lots of urban poor livings in the city and involved with other works. So, without seeing those picking it was hard to identify them as 'waste pickers' they were then questionnaire survey. Total questionnaire survey was conducted on 156 no. waste pickers. Firstly, secondary data as internet, books, journal and the data of different organization working with solid waste management and recycling has been reviewed, before starting the work. Then based on the primary data as the questionnaire survey, has been analyzed using Microsoft Excel and SPSS software. Finally, the report was prepared based on the primary and secondary data with proper reference.

STUDY AREA AT A GLANCE

Dhaka is located in central Bangladesh at 23°42′0″N 90°22′30″E / 23.7°N 90.375°E, on the eastern banks of the Buriganga River. The city lies on the lower reaches of the Ganges Delta. The area covered in this study as depicted in Figure 1.

Figure 1 Map of Study Area

THE WASTE PICKERS IN DHAKA CITY

A waste picker is a person who picks out recyclable elements from mixed waste wherever it may be temporarily accessible or disposed of (en.wikipedia.org).

Christine Furedy described the works of these waste picker as “Waste picking refers to the process of picking out recyclable/reusable materials from mixed wastes, at gutters, street bins and piles, markets, transfer points, garbage trucks, and garbage dumps (legal and illegal) (Furedy 1997).
As per the definition prepared by “SWACHH: Alliance of Waste pickers in India”, the term "Waste-pickers" is defined as “Waste pickers are those workers whose livelihood depends on informal collection, segregation and sale of scrap. It does not include poor workers such as domestic workers, watchmen, doorstep waste collectors hired by contractors, municipal workers/ safai karmacharis, all of whom may be supplementing their incomes through sale of scrap. The latter category earns salary/wages while the waste pickers do not” (www.karmayog.org).

In Dhaka city about 40% of the people are poor, so to meet their daily need they have to do many kinds of work. Among many work, the ‘waste picking’ is a very simple work, need no education or skill. For this reason the waste picking has become somebody’s profession or source of income. They are seen with a bag hung with their hand on the shoulder on their back. They usually walk and their eyes are always searching for waste on the road, in the bin or at the dump site which is recycle able. They are the waste pickers of Dhaka city known as ‘tokai’ which is a bangla word means collecting. The ‘tokais’ are very familiar figure in the roads and bins of the city. According to our survey we could find three types of waste pickers or tokais; they are road side tokai, bin site tokai and the dumpsite tokai. The road side tokai follow the same route everyday and collects the waste which they need and can sell it. The bin and the dumpsite tokais are of same category, they have fixed bin or dumpsite to collect their waste. After their collection they sell these things to the vangari shop (the shop which buys the collected waste in cash) and here their work finishes.

Figure 2 Pictorial view of waste pickers in Dhaka city (source: field survey, 2009)

THE TYPE OF WASTE THEY COLLECT

Dhaka city generates about 4,634.52 ton of waste per day. The waste composition is shown in Figure 3.

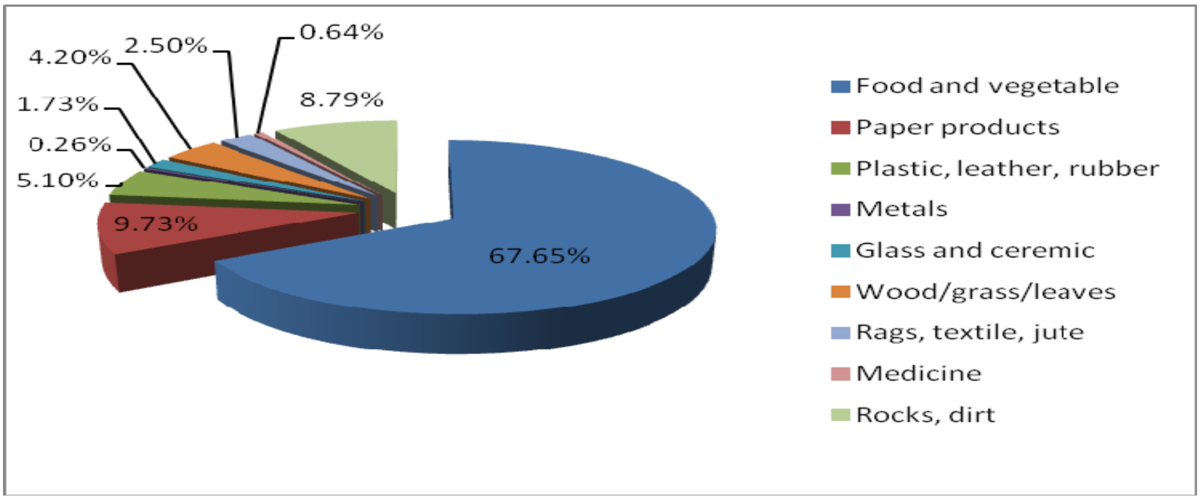

Figure 3 Average physical composition of urban solid waste (Source: Iftekhar & Q. S. I. 2006)

So, about 70% waste is organic which is compostable and can be used to generate fertilizer. But the main concern is towards the waste pickers, about what they collect. They collect the inorganic waste which has market value which means the materials they can sale easily and earn their livings. The wastes which are collected by the waste pickers and their prices are as presented in Table 1.

Table 1 Material collected and their Prices

Material name	Amount per kg (taka)	Amount per kg (US$) [1$=70tk]
Pet bottle	20 taka/kg	0.286 US$/kg
Paper	2-3 taka/kg	0.03-0.04 US$/kg
Plastic	20 taka/kg	0.286 US$/kg
Thick polythene	15 taka/kg	0.214 US$/kg
Tin can	20 taka/kg	0.286 US$/kg
Metal	20 taka/kg	0.286 US$/kg
Card board	5 taka/kg	0.07 US$/kg
Glass	5-15 taka/kg	0.07-0.214 US$/kg
Wire	10-20 taka/kg	0.7-0.214 US$/kg

Source: Field Survey, 2009.

These materials have market value, and value depends on the freshness of the material collected. The more the fresh material they collect the more money they earn.

WHAT THEY DO WITH THE COLLECTED MATERIALS?

The materials or waste they collect have a market value, so after finishing their work they try to segregate the product to earn a better value. Because when the products are in a mixed situation the vangari shopkeepers pay an average value of 5-10 taka per kg.

THE EARNING OF THE WASTE PICKERS

The waste pickers are the worker of their own; they are not anyone’s employee. So, they have a target of earning through waste collection. But they limitation of earning due to their age, collection efficiency, carrying capacity and the mostly luck of getting waste. The earning of the waste picker as depicted in Table 2.

Table 2 Range of Daily Earning of the Waste Pickers

Age	Weight of daily collected materials (kg)	Amount earned per day (taka)	Amount earned per day (US$)
4-8	2-3	20-30	0.29-0.43
9-16	4-15	40-80	0.57-1.14
17-35	15-30	100-200	1.43-2.86
35-70	10-20	60-100	0.86-1.43

Source: Field Survey, 2009.

THE REASONS BEHIND THE INVOLVEMENT WITH WASTE PICKING

There are definite some reasons behind getting involved with such work as it is not a comfortable job or work for any human being. The percentages of the involvement with this work due to parental pressure but most of them had different reasons as shown in Figure 4.

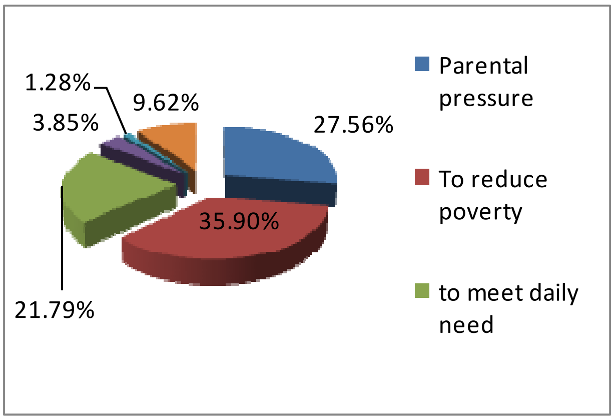

Figure 4 Reason behind the involvement (Source: Field Survey, 2009)

CASE STUDIES

Some case studies were carried out during field survey and three of them are mentioned below:

Case Study 01

His name is Riazul. He is 20 years old. He lives at Gopibagh. He has only one brother in his family. He was gone to primary school, so that he can write his name. From 3 years he involved with this work. Per day he collects waste about 12 hours. He is not trained by someone to collects waste. He involved this work through watching to others. He involved with work this work for taking drug. He collects plastic, glass, paper, metal, etc. He collects about 8-9 kg waste per day. His per day income is about 100tk.The selling price of plastic, glass, paper, metal are different. He sells those at motijhil in vangari shop. But he is not satisfied to price. Sometimes he is suffering skin diseases for collecting waste.

Case Study 02

Her name is Hafiza Khatun. She is 45 years old. She lives at Shahidnagar. She has 2 sons in her family. She is illiterate. From 10 years she involved with this work. She collects waste about 10-12 hours per day. She is not trained by someone this work. She involved with this work to meet daily need. She collects plastic, glass, paper, metal, rubber etc. She collects about 8-9 kg waste. Her per day income is 80-90tk. The price of plastic, glass, paper, metal, rubber is different such as; plastic is 15tk, glass 12tk, paper 3tk, metal 20tk. She sells that waste at Shahidnagar. Sometimes she is suffering diseases but it is not for collecting the waste. She said if DCC help them then they can collect more. And if DCC fix the rate of waste then it will be helpful to them to get the proper price.

Case Study 03

Her name is Sopna. She is 8 years old. She lives Nawabgang with her parents. She reads in a primary school and a student of class two. She goes to school at 8 am and after lunch she goes to collect waste. From one year she involved with this work. Her parents encourage her to involve with this work to extra income for family. She is trained by her mother. She collects plastic, glass, and paper, metal etc. Per day she works about 4-5 hours. She collects about 5-6 kg waste per day. She per day income is 50-60tk. The price of plastic, glass, paper, metal, rubber is different such as; plastic is 15tk, glass 12tk, paper 2-3tk, metal 20tk. She sells that waste at nawabgang. Her mother helps her to sell that waste.

THE LEVEL OF INVOLVEMENT IN SWM OF THE WASTEPICKERS

The level of involvement in SWM has been developed through a flow chart as mentioned in Figure 5

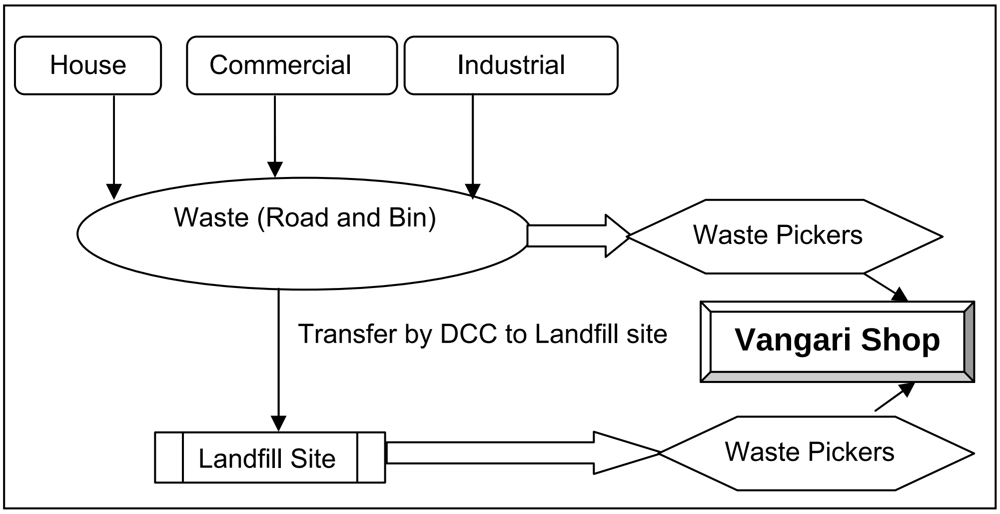

Figure 5 Waste Picker's level of involvement (Source: Author, 2009)

A WASTE PICKER, AN INFORMAL SOLID WASTE MANAGER

The waste pickers are in the Dhaka city is not seen in view of an informal solid waste manager. But they contribute in reducing the costing of SWM process as they takeout the recycle able waste almost about 4-15% (Iftekhar & Q. S. I. 2006) which saves the transfer cost of that waste which is reduced or picked out.

THEIR CONTRIBUTION TO THE SOCIETY AND ENVIRONMENT

As an informal solid waste manager their contribution to the society and environment is totally un-noticed by the government or other organization. It is astounding to know that the word 'recycling' is missing in the DCC Ordinance 1983. The public sector has never been concerned or convenient with the word recycle, reuse and reduce the solid waste, until some initiative taken by the private sector. But these waste pickers are totally informal who work for themselves, they are keeping the streets of Dhaka clean by picking up the waste thrown by the travelers. They also collect the waste from the drains which reduce some percentage of waster logging, keeping the society clean and healthy. The DCC takes off the solid waste to dispose it in the landfill site to compost. But if the waste is a mixer of organic and inorganic waste then composition of waste takes time and even the soil quality degrade. The soil mixed with plastic polythene is not suitable for any kind of development. As the 70% of solid waste is organic and 30% is inorganic which means 1390.2 ton per day out of which 695 ton per day is taken out for recycling. So, indirectly they are saving the soil quality, saving our environment.

PROBLEMS OF THE WASTE PICKERS

Their main problem is their poverty, for which they are involved with this work. Along with that they live in the slum, where the facilities for sanitation, health and living are almost very poor. They have health problem like backache (which is common for older waste pickers), cut and many others like breathing problem. They have no high equipped facility.

But the problem which was a common objection, which was that they have no fixed price to sell their waste, the vangari shopkeepers pay them as his wish or sometimes give the fewer prices.
The people also doesn't behave well towards them, everyone tries to neglect them.

GOVERNMENT RECENT INITIATIVE FOR THE WASTE PICKERS

The work under DCC entitles "Waste pickers health & livelihood issues through recycling". Livelihood as a "waste picker" is exposed of as most neglected, abused and exploited, which is the worst form of labour, vulnerable and risky.
Achieving MDGs through waste picking as a livelihood activity:

- Poverty reduction (Goal-1)
- Environmental sustainability (Goal-7)

Project: Livelihood improvement of at landfill site
Objective:

- To reduce vulnerability & risk to the livelihood of the poor waste pickers
- To ensure basic health & support oriented education ("learn & earn" approach) for achieving sustainable livelihood
- To facilitate to have better & justified income for the waste pickers
- To reduce child labour in scavenging

Four approaches for social & economic promotion of waste pickers

- Welfare based approach
- Development oriented approach
- Rights based approach
- System oriented approach

Waste pickers are unsung environmental heroes play a big part in resource conservation (www.dhakacity.org).

PROSPECTS OF WASTE PICKERS AND THEIR WAY OF LIVING

The waste picker can be seen one of the main actor of waste recycling. The have been trained by themselves, by their need for living, for survival. So, they can be mentioned as resource for our country in SWM. They can be well equipped or trained to improve the collection efficiency and protect their health from different diseases and illness.

RECOMMENDATION

In the developed countries of the world they have taken initiatives to improve the lifestyle of the waste pickers. They have been provided facilities by the government, their contribution has been acknowledged. So, we can make decision to improve the life style of our waste pickers and their position in the society. The following recommendation can be taken into consideration:

- to develop a waste pickers community where they live and maintain their community
- they should have to registered for free treatment for their work and to maintain government control over the recycling sector and provide the waste picker a better earning by fixing the selling prices of the material and even the vangari shop will also come under some rules and regulation
- the process of collecting and selling should be trained through different workshops for the waste pickers by different NGOs or CBOs.
- the wards of Dhaka city can be given some place to segregate the solid waste by the pickers and then taken to the dumpsite for proper sanitary landfill, which will also the pickers facility for collecting the waste they want but the access to this place should be limited through local authority
- the government should develop laws for the recycle sector to ensure the safety for the people

CONCLUSIONS

Based on the experimental results it can be concluded that we will try to remove the word waste pickers or 'tokai' from the society and make these people a part of the formal sector SWM. They should be an employee of the community of the SWM authority. So, to improve the life of the waste pickers in the government and its related authority should consider different ideas and concept and provide them facilities. The public private partnership can also be a good thinking to improve the life of these waste pickers.

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ISBN: 978-984-33-0761-3, Vol. 2, pp.649-656

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Solid Waste Management in Chittagong City Corporation for Electricity Generation

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ABSTRACT

This paper discusses the present solid waste management policy, its bottleneck and proposes an improve technique of solid waste management with focus on waste-to-electricity generation from solid waste in Chittagong City Corporation (CCC), Bangladesh. CCC's wastes contain suitable energy recoverable material as well as other materials, such as glass, metal, dangerous waste materials from hospital and industry. Present CCC's waste management needs to be modified and a new policy has to be adopted to separate these unsuitable materials to maximize electricity output from a proposed waste-to-electricity power plant. It is also found that installation of a 5 MW Waste-to Electricity Power Plant (WEPP) at Halishahar, Chittagong is feasible through the available solid wastes resources in CCC, which will not only ease the problem of load shedding in the city but also make the city cleaner.

INTRODUCTION

Now-a-days solid waste management has moved to the forefront of the environmental agenda in all countries. Actions to reduce the environmental risks of solid-waste treatment and disposal operations have reached unprecedented levels (Twardowwska et al. 2004). Waste-to energy facilities employ the controlled combustion of solid waste for the purposes of reducing its volume. City Corporation's waste-to-energy would facilities produce a number of benefits to a waste management system. Firstly, combustion can destroy bacteria and viruses in wastes as well as harmful organic compounds. Secondly, combustion can reduce the volume of solid-waste by up to 90% thereby conserving landfill space. Most importantly it offers the possibility of recovery of energy in the form of steam or electricity, (Wheatly and Hedgecock 1993 & Palanichamy et al. 2002).

Solid waste management has become a matter of major concern in Bangladesh. This is due to rapid urbanization taking place in an enormous scale in the cities and towns of the country. 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 (Rahaman and Castro 1995).

Disposing of the wastes in an environmentally acceptable manner is presenting a multitude of problems for local governments. These problems involve meeting air and water quality requirement, locating suitable landfill sites, and disposing of hazardous wastes while at the same time meeting the high costs of treatment, transportation and disposal, (Dicson 1974 and Henstock 1983). An alternative to land filling solid waste is recovering the energy contained in City Corporation's Solid Waste (CCSW). The disposal problem coupled with the energy shortage has an attractive alternative to land filling for virtually every community (Palanichamy and Nadarajan 1998 & Yokoyama 1996).

About 1200 tons of solid-wastes are generated per day in CCC area and new policy needs to be adopted for waste management for implementing the desire to construct a Waste-to-Electricity Power Plant (WEPP). Wastes generated in CCC area are from residential, commercial and industrial premises and also from street sweeping and all these wastes are presently dumped through container mover mainly in Halishashar Tensing Ground which is of 10 acres in area and 12 km away from the city center. This paper discusses the issues on solid waste management in CCC with an objective to possible electricity generation from the MSW.

BRIEF BACKGROUND OF CHITTAGONG CITY CORPORATION (CCC)

The Port City of the Chittagong City Corporation is the second largest city and the "Commercial Capital" City of Bangladesh. The City is surrounded by the beautiful natural features like Hilly Terrain, the Karnafully River and the Bay Bengal on the west. It is significant for the suitable geographical location in the regional map. So the city can be termed as the Gateway for the international Trade, Commerce and Tourism because of her significant role in the national economy.

The town is started to grow as a tiny Municipality 1963. Then afterwards it is re-constituted as a Municipal committee in 1964. After a long time span in 1982 it was upgraded as Chittagong Municipal Corporation (CMC) and finally as Chittagong City Corporation (CCC) in 1990. Organizational of chart of CCC is shown is Figure 1 and a brief overview of CCC is shown in Table 1.

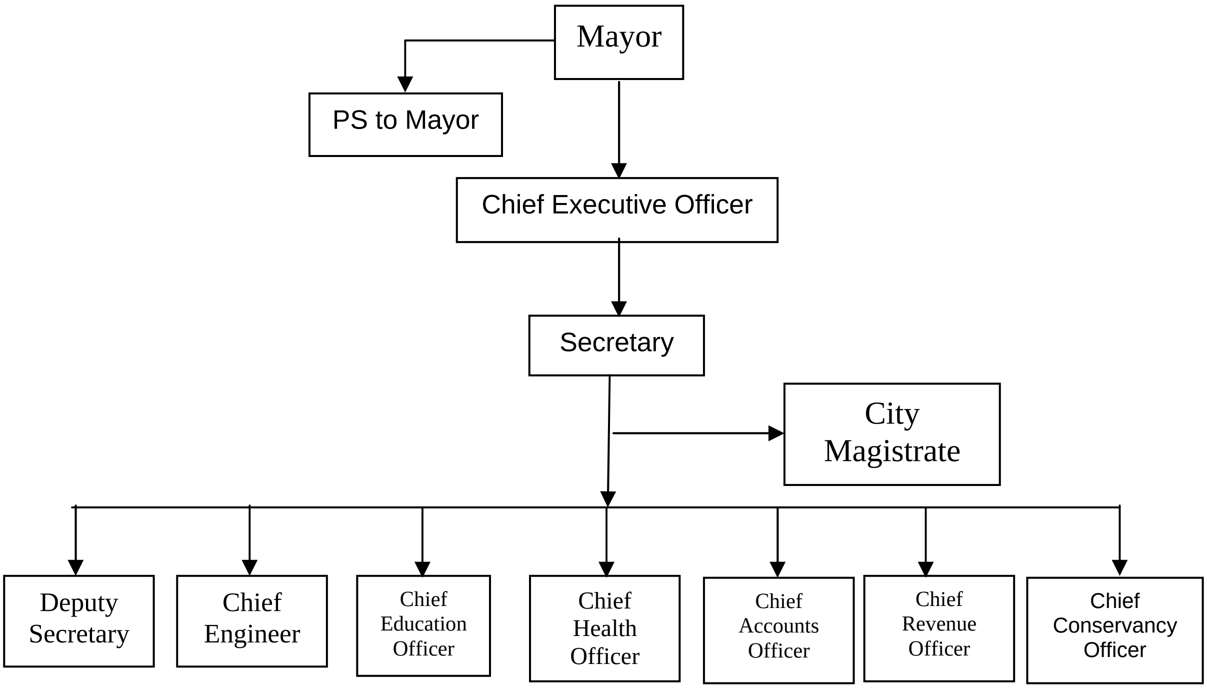

Figure 1 Organization chart of CCC

PRESENT SOLID WASTE MANAGEMENT IN CHITTAGONG CITY CORPORATION

Chittagong City Corporation is responsible for the operation and maintenance of city service, including solid waste management. It is made up of 7 functional departments, Education, Health, Accounts, Revenue, Engineering end Conservancy. The conservancy department is responsible for solid waste management.

Table 1 A brief overview of CCC

Area	155Sq km.
Total No. of Wards	41
Mayor	1
Commissioner	41
Female Commissioner (Reserved)	14
Total Population	35,64,580
Total No. of Roads	1,843
Total No. of Educational Institution	1,591
Total No. of Religious Center	1,079
Total Health Center	67
Population	40 Lac
Corporation Area	155.53 Sq km
Daily waste generation	1200 M.Ton
Per ton waste management cost	400/-
Urbanization rate (approximate)	80%

Solid waste collections from generation sources are done by NGOs. There are 1475 community bins and 37 metal container are located on roadsides throughout the city. Non-motorized vehicles of city authority are mainly used for transfer of wastes from community bins to SDS (Secondary Disposal Sites). There are total non-motorized rickshaw vans of NGOs to operate the collection system. One driver and one helper are assigned for each van and the collection generally occurs daily NGOs collect waste from generation sources by adoption door-to-door collection systems from residential sources as well as some offices.

Chittagong City Corporation has motorized and non-motorized vehicles for waste collection and transportation. Only motorized vehicles are used for transferring wastes from community bins and containers i.e. SDS (Secondary Disposal Sites) to UDS (Ultimate Disposal Sites). Table 2 shows the logistics support in CCC.

Conservancy officials, supervisors and inspectors who monitor the activities interchange information among themselves through wireless sets on a regular basis for achieving better result. A standing committee of garbage is formed in City Corporation. The Chairman of the standing committee looks after the whole management. Solid Waste Management (SWM) flow chart is shown in Figure 2.

Table 2 Logistic support in CCC

Serial	Type	Number
1	Track	107
2	Chain Dozer	1
3	Pay Loader	4
4	Dump Track	16
5	Tractor wagon	7
6	Excavator	5
7	Container Mover	6
8	Compactor	18

Functions of logistic supports are mentioned below.

- Excavator: It takes the garbage from one point and dumps at the other point in the tensing ground.
- Pay Loader:
    - ❖ takes the garbage and put on the truck.
    - ❖ Push the garbage and throw away .
- Chain Dozer: Throw away the garbage by pushing.
- Dump Track:
    - ❖ garbage are taken on it and carried to the tensing ground and dump
    - ❖ the garbage by opening the downside cover of the truck mechanically.

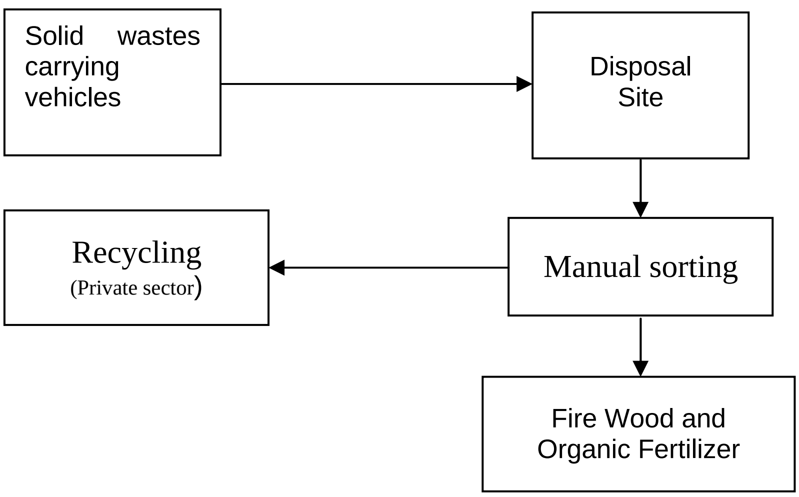

Figure 2 SWM flow chart

The quantity of solid waste Produced in the City is approx 1200 metric tons per day. These are transported by the above vehicles and finally open dump the collected wastes at UDS at Halishahar and Raufabad. About 800 Metric Tons of garbage are disposed at Halishahar and 400 Metric Tons at Raufabad which are of 8 and 6 km away from the city center respectively.

Manual sorting of wastes are done at SDS and UDS. At the UDS recyclable materials are recycled by the recycling plants installed by the private sector. Few very important issues on SWM in CCC with ultimate goal of producing electricity from waste in the near future is discussed below.

Garbage Treatment Plant

CCC has started to produce burning wood (solid fuel), organic fertilizer from waste vegetable particles with the help of local technology. This in return supports in the less privileged groups in terms of income generation as well as having low cost fuel for their domestic consumption at the present moment. A project named composting plant with the help of ADB grant in large scale has been taking in hand by CCC which will create a new horizon for creating business commerce contributing to the socio-economic of the city. These resources can be diverted towards electricity generation in the near future.

Medical/Clinical Waste Management

At present CCC is highly concerned with the Medical /Clinical Waste produced in the city every day. The hospitals and maternity clinics run under CCC are already aware enough and are destroying their own wastes by their own arrangements. At the same time CCC along with the related NGOs is trying to motivate the hospitals and clinics at the private ownership to take care of their harmful medical waste. This management will help to isolate the flow of medical/clinical waste from useful waste which will be beneficial for electricity generation as well.

Incineration Plant

Since Chittagong city is medium size city of 4.0million people only it is still at the manageable state in order to introduce an “Incineration Plant“ for the destruction of its Medical Wastes in an healthy manner. CCC authority is already afraid , with the growth of the city during the coming years-increase of different types of activities along with the rise of population density might cause severe health hazards in absence of an efficient Medical Waste Treatment Plant in the Port city of Chittagong .Therefore, an “Incineration Plant” is highly essential for Chittagong.

FEASIBILITY OF ELECTRICITY GENERATION FROM SOLID WASTE

Generation rate of waste of CCC is 0.25kg /capita/day. CCC is conducting motivational programs for awareness generation through related NGOs. Out sourcing of SWM is under processing in CCC. By involving NGOs in clinical waste management will play very vital role. To prepare policy guidelines and necessary reforms, prepare action plan for better service delivery, establish a network for exchanging knowledge, technology and experience will be helpful for improvement of the project at the same time this will be helpful for waste to electricity generation plant.

The initial study was on finding the resources for electricity generation from solid waste in CCC. To find out the components of the waste, 20kgs of waste from randomly selected 10 different places are weighed and percentages of the components of the wastes are shown in Table 3 and wastes from three different types of places- one residential, one commercial, an Industrial location are weighed and the percentages of the components are shown in Table 4. It may be mentioned that glasses are sorted out from the wastes and are not shown in the tables. From the information given in Table 3 and 4 it can be estimated that the average calorific value of waste is around 8 MJ / kg and sufficient solid wastes are available in CCC, which is suitable for installation of a power plant.

The trends in population growth and waste generation is shown in Table 5 and projected waste generation till the year 2015 is shown in Figure 3. The energy potential for electricity generation from solid wastes has been calculated and feasibility of installation of a 5 MW power plant has been agreed. Also from the trend of waste generation confirms long term availability of waste as raw material for a possible waste to electricity power plant in CCC.

Table 3 Screening and sorting of solid wastes of ten different types of places in CCC

Sample no. & name of sampling areas	Date of sampling	Vegetables matters & remaining of fruits %	News paper %	Tree trimmings & straw %	Stone ceramics & debris %	Plastics & polythene %	Clothes %	Rubber %	Clay %
Chawalk Bazar	20.1.04	50	05	15	10	10	05	05	
Alkaran	22.1.04	40	10	30	10	10	-	-	-
Jamal khan	25.1.04	35		30	05	05	-	-	25
Bagmoniram	28.1.04	50	03	20		12	15	-	-
Sholak Bahar	01.2.04	33	03	26	3.5	11	15	-	5.5
Anderkilla	04.2.04	25	05	25	25	10	05	05	-
East Madarbari	05.5.04	46	06	25	05	10	08	-	-
Enayet Bazar	08.2.04	30	05	22	20	08	15	-	-
West Madarbari	09.2.04	40	05	15	05	10	05	-	20
Pathan tooly	12.2.04	35		25	05	05	05	-	15

Table 4 Screening and sorting of solid wastes of three different types of places in CCC

Sample no. & name of sampling areas	Date of samplig	Vegetables matters & remaining of fruits %	News paper %	Tree trimming & straw %	Stone ceramics & debris %	Plastics & polythene %	Cloth %	Rubber %	Clay %
Sugandha Residential Area	15.2.04	17	20	40	03	10	-	-	10
Agrabad Commercial Area	16.2.04	15	05	10	05	15	40	10	-
West sholashahar Industrial Area	19.2.04	05	05		05	05	70	10	-

Table 5 Population and waste generation of CCC (projected for the year 2009)

Year	Population (in Lac)	Waste generation (Ton / day)	Per capita waste generation (kg/day)	Total waste generation (Ton / year)
1995	23	437	0.19	159505
1996	25	500	0.2	182500
1997	25.5	535.5	0.21	195457.5
1998	27	585.9	0.217	213853.5
1999	29	643.8	0.222	234978
2000	30	684	0.228	249660
2001	33	772.2	0.234	281853
2002	35	840	0.24	306600
2003	37	902.8	0.244	329522
2004	38.5	950.95	0.247	347096.75
2005	40	1000	0.25	365000
2006	41	1050	0.256	383250
2007	42	1100	0.262	401500
2008	43	1150	0.268	419750
2009	44	1200	0.273	438000

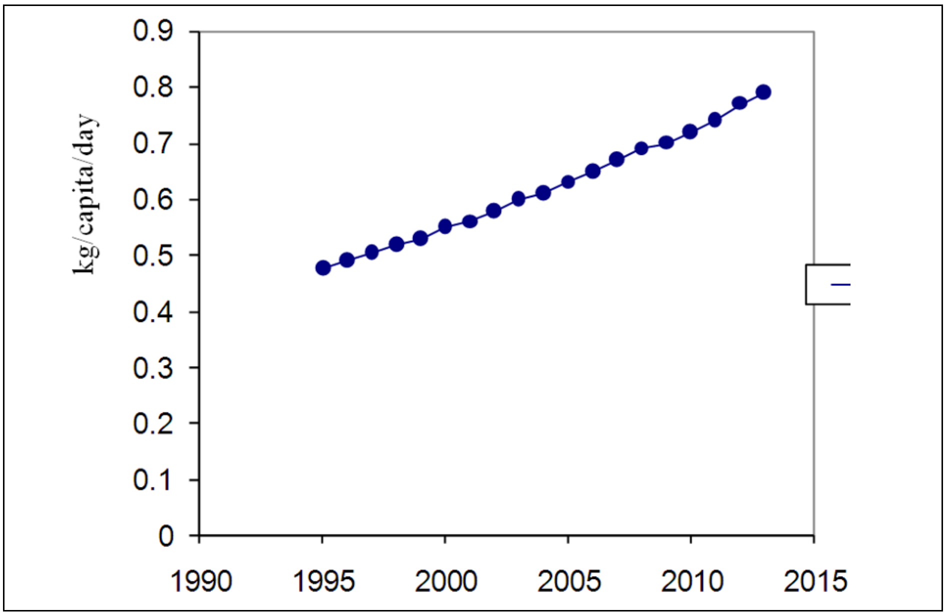

Figure 3 Trends in SW generation of CCC till the year of 2015

NEW POLICY OF SOLID WASTE MANAGEMENT FOR ELECTRICITY GENERATION

The waste hierarchy normally refers to "Reduce, Reuse and Recycle", Rahaman (2009), which in energy recovery terms can be stated as "Recycle after Sorting, Reduce through Using". In this regards present management policy can be modified slightly thorough adopting new technique beneficial for the proposed waste-to-electricity power plant. Few important policies are briefly discussed below.

Installation of a Waste-to-Electricity Power Plant (WEPP) and Management

Figure 4 shows the map of CCC with major routes for SW carriage. Presently there are two tensing ground one is at (A) Halishahar and the other at (B) Roufabad. The Roufabad tensing ground will be closed in the near future and if all the wastes are dumped in Halishahar, this ground will be filled up shortly and the CCC will face serious problem in finding new sites for tensing ground. Definitely the site will be far away from the town area and transportation cost will be excessive. To avoid this problem and alternative way of solving the problem is to installation a solid-waste power plant at Halishahar. Discussion in the previous section confirms the continuous supply of required waste for the proposed 5MW WEPP. However, the WEPP should be installed as early as possible all the wastes should then be diverted to Halishahar. The extra cost involvement to reroute the carriage from Roufabad area to Halishahar will be very much less as compared to the benefits obtained from WEPP. It is expected that WEPP will not only be economically viable but also solve the problem of land filling and play a very important role in making the city cleaner. Since the solid wastes is the raw material for WEPP, this waste will not be wasted in scattered areas in CCC. Moreover, the city dwellers will find less or no load shedding if such a power plant is installed and will co-operate in the waste management policy of CCC.

A separate management unit which may be under 'Chief WEPP Officer' may be added in the lower block beside Chief Conservancy Officer shown in Figure 1. This new unit will look into all the affairs at WEPP location and work together with Conservancy Unit for the benefit of WEPP.

Management on Sorting and Recycling

Instead of disposing all types of waste together in a dumping site, the city dwellers are encouraged to keep separately metallic parts and container, glass and other non fuel for WEPP from the useable waste for WEPP and dump in separate containers. Extensive awareness program may be needed in this regard.

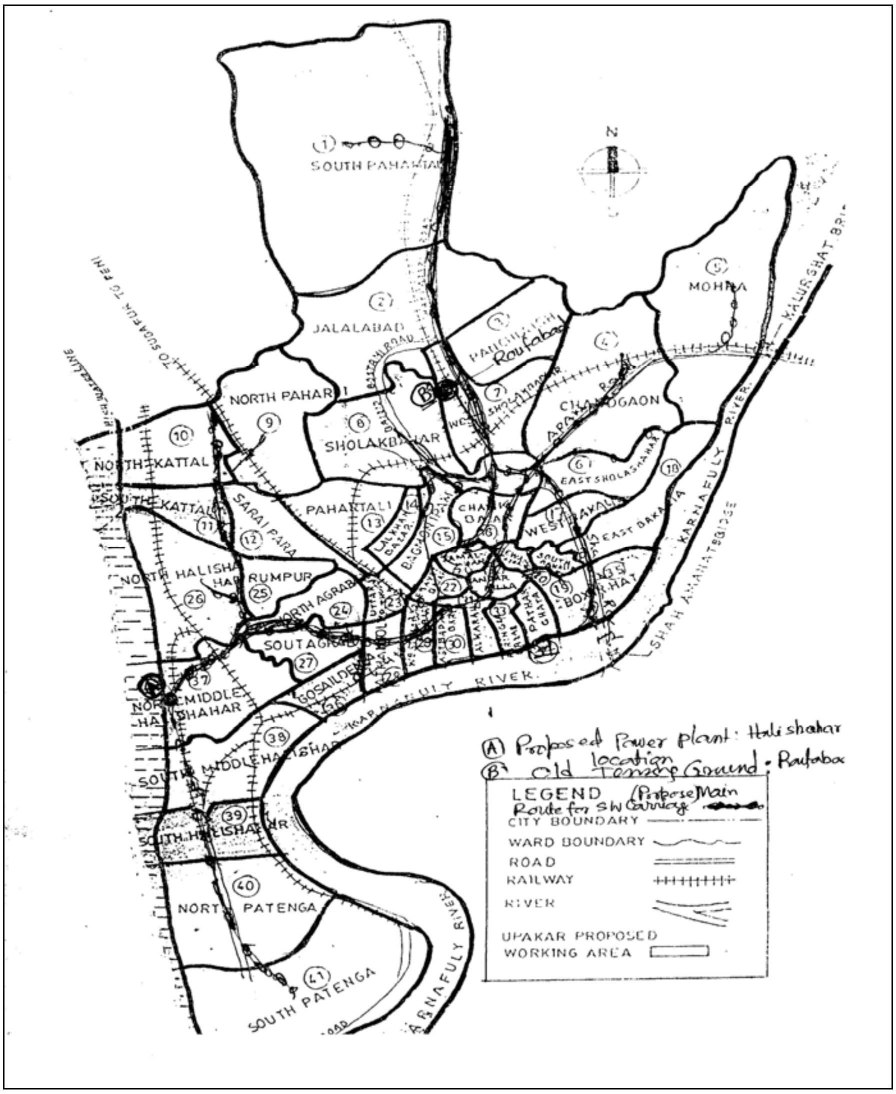

Figure 4 Map of Chittagong City Corporation with major routes for SW carriage

The non fuel parts can be bought from the dwellers by CCC separately under Conservancy unit shown in Figure 1. Alternatively, NGOs may also be permitted to look into this matter. Since the no fuel parts will be recycled it is hoped that this policy may be economically viable as well. This will reduce the burden on manual sorting as shown in Figure 2. However, another sorting will be need at the WEPP area and this should be under the management of Chief WEPP Officer.

Effective Management on Collection and Transportation of Solid Wastes

CCC is facing challenges of collection and transportation of the solid wastes to the tensing ground in the following area, Siraj (2009).

- Majority of the vehicles are not in working conditions
- Lack of transparency in duties of hired vehicles
- Lack of required number laborers

Through a list prepared by the vehicle/ mechanical department shows that more than 50%, in some types, 100% of the vehicles are in working condition due to which proper transportation of wastes is not possible. The Mechanical Engineering/Vehicle Department under the Chief Engineer's Office shown in Figure 1 needs to strengthen to tackle first two problems and the third one can be handled by the Conservancy Office. In this regards new management policy based on specific duty allocation strategy should be adopted. Alternatively only the collection and transportation part may be privatized and linked with the WEPP management unit. The focus will be not only to collect the wastes and non fuel part separately but maximize the collections. This will enable cleanness of the city as well.

CONCLUSIONS

This paper highlights present management scenario of SWM in CCC and gives proposal on improvement of the same. Present generation rate of solid wastes is around 1200 ton per day. It has been found out that installation of a 5 MW WEPP at the Halishahar tensing ground will be economically viable. If such a project undertaken a few addition and modification in existing lower level management units in the CCC organizational profile may be necessary, which is feasible to adopt. On the other hand load shedding problem in the city will be reduced and wastes will not be wasted in drain and scattered places, which will make the city cleaner. This study has identified the major characteristics of solid wastes and the salient features related to the environmental degradation caused by present solid waste management system. Generation of electricity depends upon the generation rate of the waste which is increasing yearly and a sound management solution for sustainable power continuity ahs been proposed in the paper. Generation of electricity from waste will also contribute towards general improvement of environment, human health and improves quality of human life. Reduction of Greenhouse Gas (Methane), contribution to poverty alleviation and sustainable development will be achieved by implementing installation of a proposed WEPP in CCC.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.657-662

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Recycling of Animal Bone in Khulna City

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ABSTRACT

In this study traditional recycling pattern of animal bone has investigated and analyzed in the Khulna city. A field interview has undertaken on waste collectors, dealers and industries involved in animal bone recycling. A complete hierarchy from waste collectors to industries of the recycled product has identified. This study reveals that about 432 kg of bone wastes are recovered daily in Khulna. The study also reveals that there are one hundred ninety three dealers and four small industries are involved in animal bone recycling in Khulna. The animal bone recycling industries of Khulna recycle about 19.33 tons animal bone per day into gelatin, comb, fertilizer, tiles, stick etc for local market and powder produced after grinding is sent to other industries in Dhaka and European countries as raw material. The flow diagrams and mass balance of existing recycling pattern for animal bone are also developed for Khulna city.

INTRODUCTION

The generation of municipal solid waste (MSW) is increasing day by day in Bangladesh as well as in Khulna. The total waste generated in Khulna city is about 520 tons/day. The environmental threats arise from open burning and uncontrolled dumping of solid wastes. Recycling of these wastes can be an essential and alternative option to minimize the environmental hazards, hence increase urban safety.

Of course, bones are consisting of both organic and inorganic parts. Organic part is infectious. After disinfecting the organic part, putting bones into landfills is not always the best disposal method, there is an alternative: recycling. This method recovers some of the value from the bone. Recycling recovers the raw material, which can then be used to make new products. Land filling animal bones does neither of these things. The value of land filled bone is buried forever. According to Diamadopolus et.al.(1995) if solid wastes are not recycled, the landfills will very fast exhausted and necessitate the construction of new ones. Kaseva and Gupta (1996) reported that solid waste recycling reduces environmental damage and is an import-substitution economic activity.

Bone is a versatile product. Generally, animal bone is hard and stiff and it is not transparent. Bone mainly consists of four basic constituents: Protein (60–65%), Lipid (23–25%), Ash (5-10%) and Moisture (4-6%). This paper looks in brief at the current bone waste recycling pattern in terms of collection, transportation and transformation in Khulna city.

RECYCLING PATTERN

A field interview has undertaken on waste collectors, dealers and industries involved in waste bone recycling. From the survey it is clear that it is the private sector that is responsible for recycling of bone waste in Khulna. The waste collectors groups from private sector are playing a prominent role in collection of recyclables as a main source of income. All of the buyers of bone waste are from private sector and only a few formal manufacturers are involved in using waste bone as raw material. There are several stages of bone waste recycling in Khulna city that are described below:

Source

Meat market and dustbins are the primary source of animal bone wastes in Khulna. People are eating meat more than ever before. Normally, people buy meat from meat markets and after taking the flesh they throw the bones as waste. Bone wastes have economic value. These are separated by some people at primary source for the purpose of sale. While the others of primary source throw it to dustbin as a waste instead of separation.

Waste bin Collectors

At the lowest stratum of the recycling chain are the waste bin collectors (tokai). They are visible in every community of the city and come from nearby slums. The collect old plastic bottles, basket, animal bones etc from dustbin, disposal site and from drain, road side (as shown in Figure 1).

Recyclable Dealers

Recyclable dealers are the second link in the chain of recycling (Figure 2). They are reported under three broad categories - small, medium and large according to mode and quantity of collection and type of waste. Each small recyclable dealer (SRD) purchases all types of wastes from the tokais and feriwalas in exchange of money and their collection is below 250 kg/day on an average. Most of the SRDs separate the recovered materials and sell to medium recyclable dealers (MRDs) (Figure 3).

The medium recyclable dealers (MRDs) then purchase particular kinds of waste from SRDs, different institutes and market. The medium dealers usually deal in two or three kinds of specific wastes such as animal bone, plastic, metal, paper .They sort , clean and sell some of the processed wastes (such as plastic bottles) to market. They sell rest of the processed waste to the large recyclable dealers (LRD) that essentially specialize in specific wastes such as animal bone (Figure 3).

Figure 1   Waste bin collectors are collecting mixed wastes from road side

Figure 2   A typical recycling dealers

Most of the Large Recycling Dealers (LRDs) buy their raw materials directly from the MRD. They receive their supply from not only all over Khulna but also Jessore, Kustia, Chuadanga, Jhenaidah etc. They sell plastic waste to recycling industries in Khulna (Figure 3).

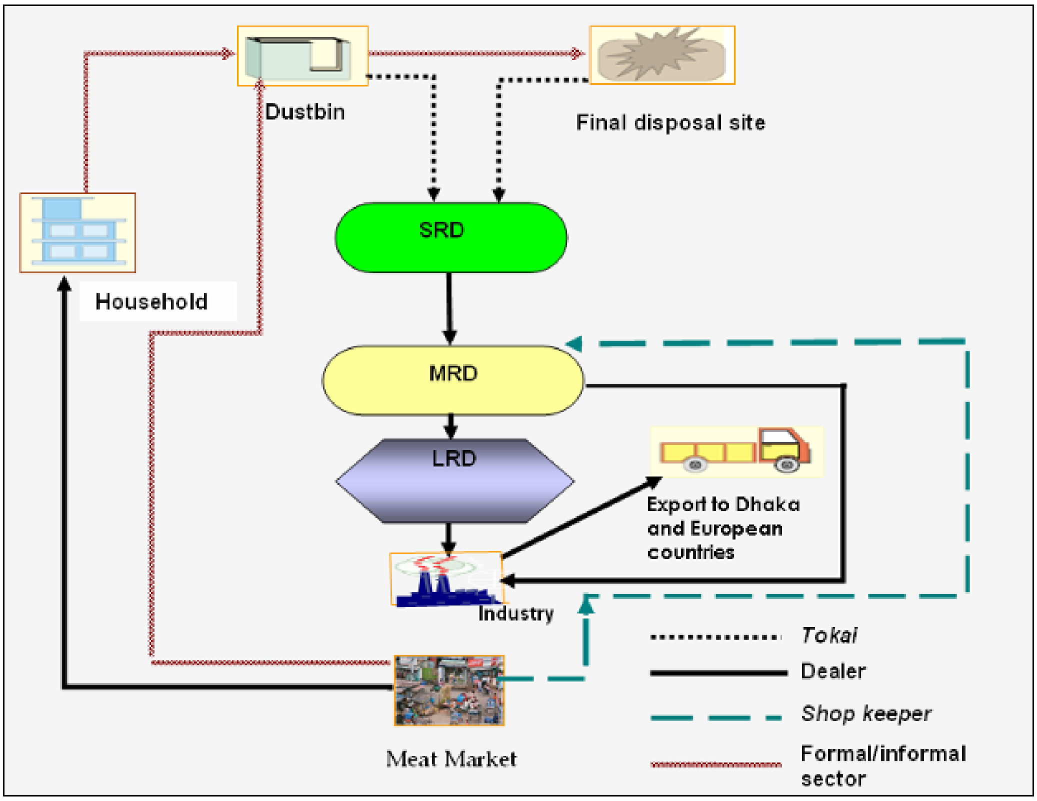

Figure 3 Animal bone recycling pattern in Khulna city

Final destination of the materials collected by different actors starting from tokais comes to recycling industries (RI) through a chain of dealers like SRD, MRD, LRD and formal (KCC crews) and informal sector (NGOs) as shown in Figure 3. Industries buy from LRDs and MRDs but not directly from the waste collectors. One of the important reasons for this is the variable quality and small quantity. Trade between LRDs and RIs is more formal than the existing relationship among the SRDs and tokais. Some time LRDs use their own transport (truck). The RIs sell their product to local market and industries of Dhaka also. The price of these materials varies with the supply and demand of the market.

RECYCLING PROCESS IN INDUSTRIES

There are four animal bone recycling industries in Khulna. Animal bone contains horns, teeth, bone, hoop etc. All these types of bones are collected not only from Khulna but also from Jessore, Kushtia, Chuadanga, Jhenaidah etc. The amount of bone varies from season to season. Highest quantity of bone is collected in winter season and lowest amount is collected in rainy season due to foul odor. The various steps of bone recycling are shown in Figure 4.The processes of bone recycling in steps are explained below

Sorting

The collected animal bones are sorted on the basis of items such as horns and heads, bones of legs etc.

Grinding

Then the sorted bones are grinded by machine.

Straining

After grinding powder is produced through straining and sent to other industries to Dhaka and European countries as raw material.

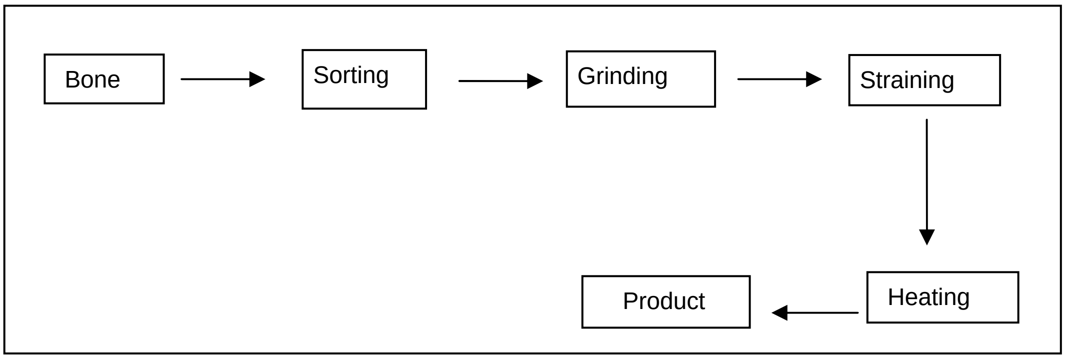

Figure 4 Typical flow diagram for the animal bone recycling industry

Heating

Some portions of grinded bone are used to produce gelatin by heating in a closed chamber. This gelatin is sent to Medicine Company in Dhaka to make cap of capsule, babies' food etc. The various steps of bone recycling are shown in Figure 4.

RESULTS

From field survey it is found that there are 102 SRDs, 87 MRDs, 4 LRDs and 4 RIs that are involved in bone recycling in Khulna. The waste bone recovered by SRDs is 230 kg, by MRDs 432 kg and by LRDs is 262 kg per day on an average as shown in Table 1. The collection of SRD is small because they buy only from Tokai. The MRDs collect animal bone wastes from all over Khulna city from all SRDs and different meat market places. The MRDs sell 262 kg/day of processed plastic to LRDs and 170 kg/day to RIs directly (Figure 6). But the RIs finally recycle 19333 kg/day of bone product. Because the bone recycling industries purchase bone from not only from all the LRDs but also from different meat markets of Khulna, Jessore, Kustia, Chuadanga and Jhenaidah. Hence, in the case of RIs the recycling percentage of bone (32%) and metal (48%) are higher than those of LRDs, MRDs and SRDs (Table 2).

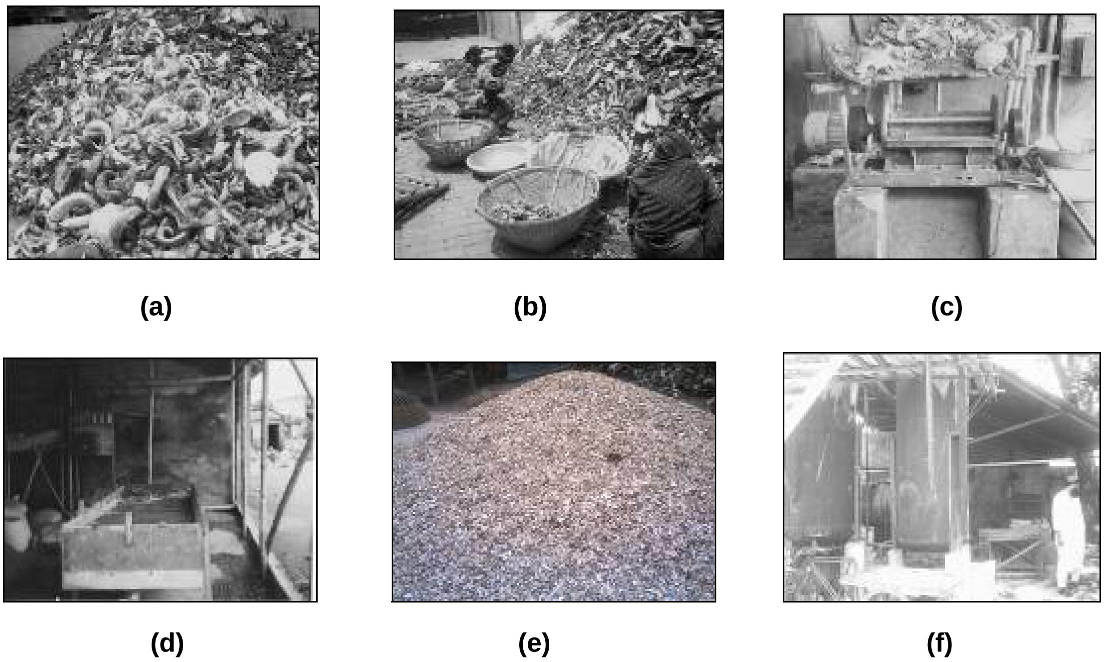

Figure 5 Animal Bone Recycling in Sattar Bone Mill (a) Animal Bone (b) Sorting (c) Grinding (d) Straining (e) Bone Powder after Straining (f) Heating Chamber

The RIs sell the grinding powder to other industries to Dhaka and European countries as raw material. The grinded bones are used to produce gelatin by heating in a closed chamber. This gelatin is sent to Medicine Company in Dhaka to make cap of capsule, babies' food etc. From animal bone varieties of products are produced such as button, comb, organic fertilizer etc.

Table 1 Average quantity of bone waste recovered / recycled by different actors in Khulna

Location	Amount of Bone Collected (Kg/day)			
	SRD	MRD	LRD	RI
Dakbangla	36	10	-	-
Khalishpur	-	56	72	262
Gollamari	20	42	-	170
Labonchara	100	-	-	-
Other places	74	324	190	18901
Total	**230**	**432**	**262**	**19333**

Table 2 Recycling Percentage by RIs

Type of Waste	SRDs (%)	MRDs (%)	LRDs (%)	Recycling by RIs (%)
Metal	32	41	71	48
Bone	1	1	1	32
Plastic	15	30	13	12
Paper	39	15	7	4
Others	13	13	8	4

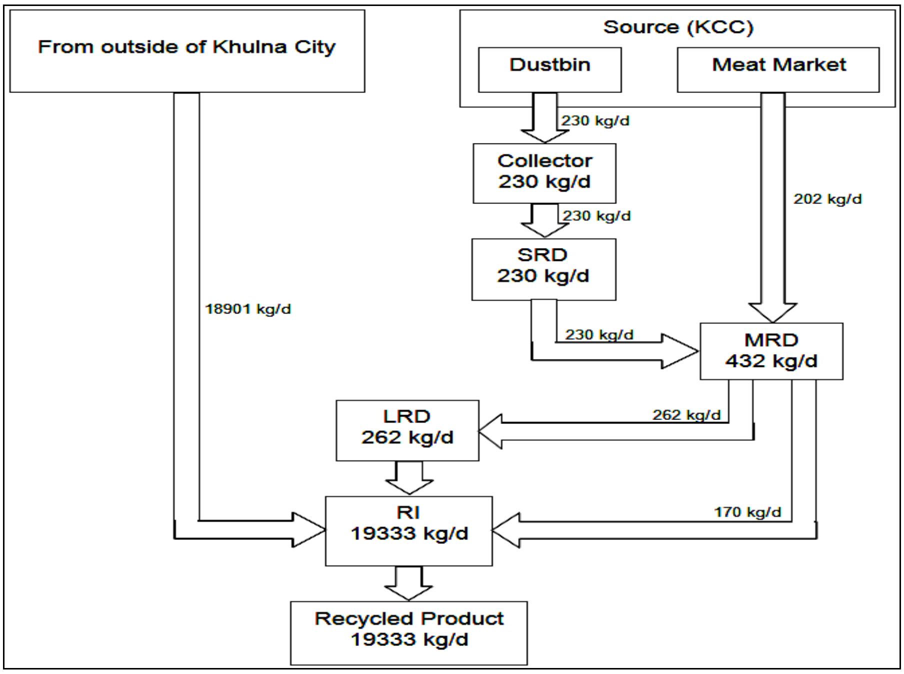

Figure 6 Mass balance of recovered animal bone waste in Khulna

CONCLUSIONS

The study shows that about (19.333 tons/day) of total generated bone wastes in Khulna are recovered by the private sector in the city. There are 193 recyclable dealers (109 SRDs, 80 MRDs and 4 LRDs) that are involved in bone recycling. Most of the recycling dealers are situated in Dakbangla, Khalispur and Gollamari. There are four plastic recycling industries in Khulna and their quantity of recycling is 19.33 tones/day that includes wastes from not only all over Khulna city but also from Jessore, Jhenaidah, Chuadanga and Kustia. They use locally available technology for recycling such as manual sorting and cleaning and mechanical heating/cooling, grinding and straining. The flow diagrams for plastic recycling industries are developed after extensive field survey.

In Khulna, the recycling of bone waste is currently carried out by a private sector comprising waste collectors at the lowest end and a succession of dealers and industries. The process creates a market of recyclable solid waste, and value addition occurs for the various recyclables in the recycle stream. The existence of waste, mainly non-bio degradable and slowly biodegradable has opened quite an extensive possibility for various groups of the community to utilize it. Although recycling of solid waste is not included in the waste management policy of local authority, yet it has become a main source of income for several groups of the private sector.

ACKNOWLEDGEMENT

The authors wish to convey special thanks to Mr. Alhazuddin and Mr. Mostafiz, Ex- students of Department of Civil Engineering, KUET for taking some field interview.

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ISBN: 978-984-33-0761-3, Vol. 2, pp.663-672

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Field Investigation on the Increase of Effectiveness in Primary Collection and Disposal of MSW in a Selected Area of Bangladesh

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ABSTRACT

The paper highlights the existing trends in solid waste management practices and related obstacles together with lack of public awareness and motivation at Ward No. 24 of Khulna City Corporation (KCC), which is considered as the case study area to illustrate the practical application of WasteSafe approach. More generally, the paper points to the practical difficulties devoted to these topics while conducting field investigations at this ward and also focus some important findings and perceptions on source storage, collection efficiencies, transfer system of Municipal Solid Waste (MSW) management at some other adjacent wards of 24. To explore possible implications for the sustainability of waste management practices several practical initiatives and some innovative approaches have been taken to improve the overall situation of MSW management. The study also reveals that the existing policies are mostly regulatory in nature focusing on transfer of waste from source to disposal sites and therefore, suggests some approaches that contribute to the generation of residential solid waste and finally to estimate the effectiveness of many of the options employed.

INTRODUCTION

The most exhibited consequence due to the growing level of urbanization in the developing countries with high population explosion is the solid waste management problem. The explosion in urban population is changing the nature of solid waste management in developing countries from mainly a low priority, localized issue to an internationally pervasive social problem. Bangladesh, the world's seventh highest populated country with population of 147.36 million (July 2006 est.) (Wikipedia 2007) and one of the fastest urbanizing countries, is a land of physical, climatic, geographic, ecological, social, cultural and linguistic diversity. At present there are 522 urban centers in the country including 309 municipalities and 6 City Corporations (BBS, 1997 and bdnews.com). With over 3.3% annual growth in urban population in Bangladesh during 1991-2001 census years, solid waste generation has also increased proportionately with the growth of urban population. This has been creating a higher per capita waste generation rendering the existing management system ineffective and has put on the risk of massive failure. According to a twelve month feasibility study in LDACs on MSW management done by

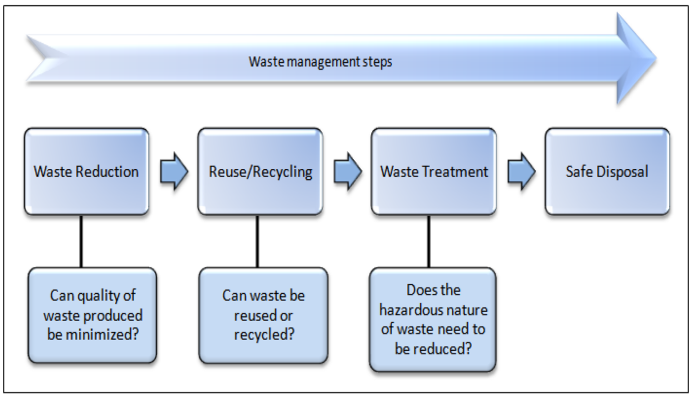


Figure 1 Hierarchy of waste management (suggested by WasteSafe, 2005)

WasteSafe (2005), the “waste management hierarchy” (reduce, reuse, recovery and disposal) should be socially adopted as well as environmentally and economically sound.

To implement the outcomes and suggestions comes from WasteSafe (2005), the further project of EC, WasteSafe II under Asia Pro Eco II Programme took some initiatives. The study utilizes the initial outcome of the performed initiatives and finally estimates the effectiveness of many of the options employed. To this attempt, Khulna - third largest city of Bangladesh - is considered as the main case study area. To have a clean, hygiene and environmental-friendly Khulna city, ward no. 24 is selected as pilot ward since it is one of largest ward of KCC (WasteSafe II 2007). Ward no. 24 is an important hub concerning the socio-economic potentialities. People of different categories, generally high level to mid level (in term of monthly income) and of different religion are living in this ward. Due to lack of financial resources, institutional weakness improper choice of technology and lack of public awareness that has rendered solid waste management services far from satisfactory, finally this research goes on describing the outlines and concepts for sustainable municipal solid waste management, highlights some important constraints and suggests possible solution.

OVERVIEW OF STUDY AREA

Khulna, the third largest city and one of six divisional cities of Bangladesh is located in south-west region, lies between 22^{o}49’ North Latitude and 89^{o}34’ East Longitudes and its elevation is 2.13 meters above mean sea level (BBS, 2004). The city extends from the south-east to north-west along the Rupsha-Bhairab River. Total area of Khulna City is about 45.65 sq. km and total population is about 1.5 million as roughly estimated by KCC. Gross population density of Khulna city is 18,000 persons per sq. km. The KCC consists in total of 31 wards of which ward no. 24 is one of largest and densely populated ward. It is situated at south-western side of city lengthened up to the Gollamari Bridge. It occupies an area of 0.53 sq. km. The layout plan of ward no. 24 is given in Figure 2, which is surrounded by the ward no. 19, 20, 23, 26 and 27.

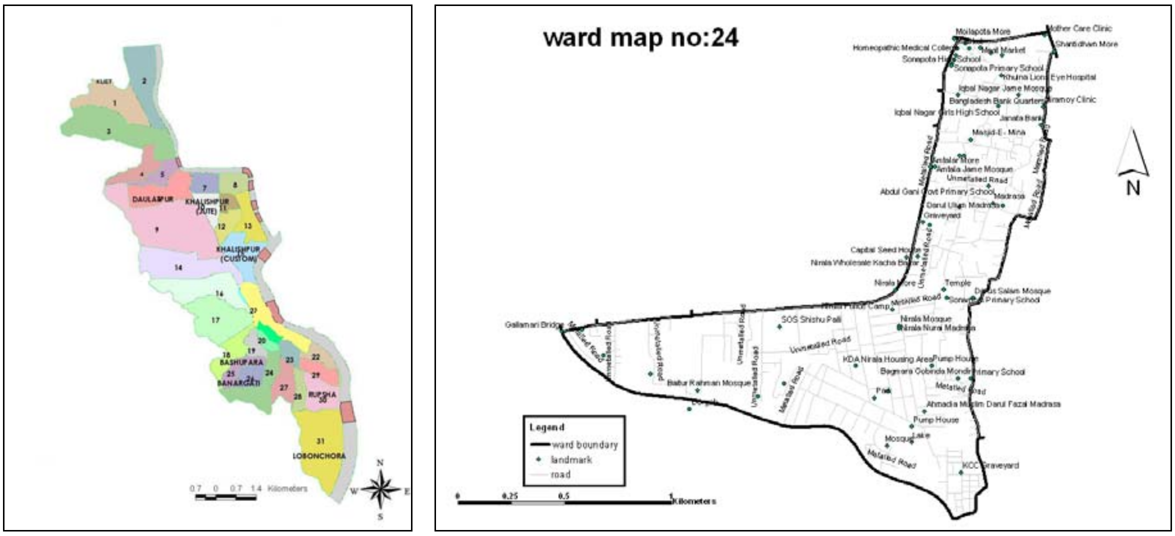


Figure 2 Map of Khulna city and the layout of ward no. 24

The total population of ward no. 24 is 52,624 of which the percentages of male, female and children are 34.8%, 30.6% and 34.6%, respectively and the total no. of family in this ward is 9,225.The average family size of this ward is 5 to 6. The population density in the ward is 99290 persons/sq.km. Some general information of this ward is given in Table 1. The land use pattern of ward 24 is shown in Figure 3, in which the land of the ward is divided into eight major categories. From this figure, it can be seen that the residential area occupies the major parts.

Due to the presence of higher number of educational institutes, cultural institutes, markets, restaurants, mosque, governmental & non-governmental office, NGO, CBO and other important features, the ward has turned to most well known ward of Khulna city.

Table 1 Population data at major zones of ward no. 24 (Akter et al. 2008)

Name of the Zones	No. of family	Male	Female	Children	Total Population
South Farazipara (SFP)	415	926	1096	589	2,611
South Gollamari (SG)	1398	2481	2588	2888	8,257
Ikbal Nagar (IN)	1400	3318	2653	2158	8,129
Muslim Para (MP)	1672	3247	2905	2778	8,930
Ray Para (RP)	1159	3051	2492	2349	7,892
West Bagmara (WB)	2956	5343	4693	5375	15,511
Total	9,225	18,624	16,427	18,573	52,624

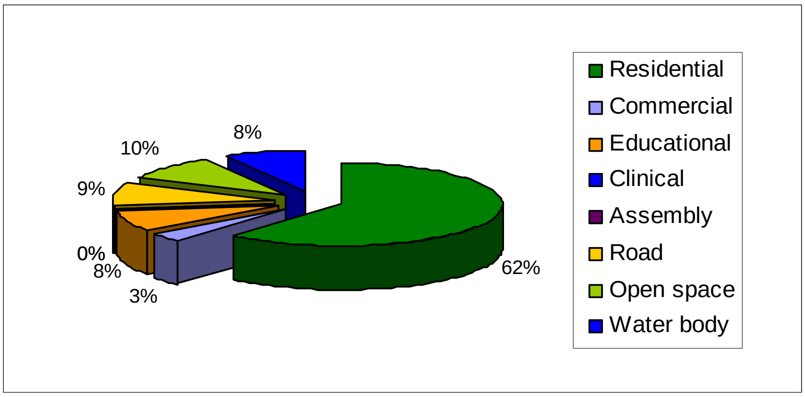


Figure 3 Area of different land use pattern

STATUS OF SOLID WASTE MANAGEMENT IN WARD NO. 24

Generally, waste generation is a part of every human activity, which occurs due to wrongly structured production and consumption patterns. Like other cities of Bangladesh, waste management system is not so well organized in Khulna city. Total daily waste generated in KCC areas is about 520 tons including residential, commercial and institutional wastes of which waste generation of ward no. 24 occupies a large portion. Present waste management system in ward no. 24 consists of several steps: a) storage at source, b) door to door collection of waste to the communal and secondary bin and c) collection and transfer of waste from the secondary disposal site (SDS) or bin to the ultimate disposal site (UDS). The entire system from source storage to ultimate disposal is shown in Figure 4 through a flow chart.

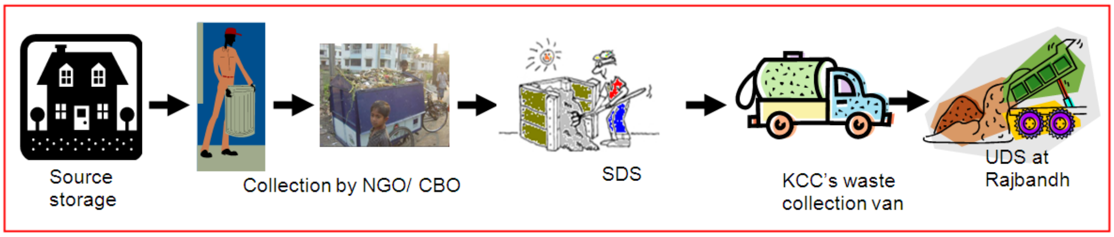


Figure 4 Typical waste collection system in ward no. 24

KCC is responsible for overall management of MSW in KCC area including ward no. 24. But collections of waste from sources are only dealing by Nabarun Sangsad (NGO) and Paribesh Unnayan Committee 24 No. Ward (CBO) in this ward against a very tinny payment. Waste generated in home is stored in a bin, basket or bag and collected mostly everyday basis by the concerned NGO/ CBO who transports the waste to the nearby Secondary Disposal Sites (SDS), transfer station and handover points. In ward no. 24, a major part of solid wastes are originated from residential houses but the other sources are street sweeping, commercial, industrial, construction and demolition, municipal services, treatment plant and agriculture. These includes dust, ash, vegetable and animal, bones, putrescible matter, paper and packing of all kinds, rags and many other non-combustible trash. In ward no. 24, a good portion of waste generated used for the filling of the surrounding low lying areas. People are not aware of the facilities provided, resulting in uncollected waste, which can exceed 25-40%. The collection system varies from one place to another and also from season to season and the systems are somewhat inadequate or inefficient. The transport systems include inadequate quantity of non-motorized rickshaw van. This hampers the overall collection process as the collection van might not be working due to lack of spare parts or continuous breakdown. Another point behind the inadequate MSW management is that, there are hardly any transfer stations, which can collect and handle the waste for systematic disposal in a regular basis with adequate capacity. Proper disposal of MSW is a necessity means to minimize environmental health impacts and degradation of land resources. In ward no. 24, MSW is collected from the SDS by KCC's motorized vehicle and is commonly disposed of by transporting and discharging in open dumps to the KCC's ultimate disposal site (Rajbandh), which are environmentally unsafe. Fifty percent (50%) of people is satisfied with the existing MSW practices where the rest 50% has expressed their dissatisfaction about the system (Akter et al., 2008).

METHODOLOGY

Both primary and secondary data have been used in conducting the study. Primary data have been collected by applying qualitative technique like in-depth interview by questionnaire survey and personal contact approach. Data have been collected purposively from different respondents group like city corporation employees, housewives, concerned ward commissioner and NGO/ CBO personnel. Their opinion has been collected to get an insight into existing waste management system. Their suggestion has also been considered in the study. Secondary data have been collected through pursuing different reports of City Corporation, web materials, BBS, and books. Following initiatives have been performed by the WasteSafe team to increase the effectiveness in primary collection and disposal of MSW in 24 no. ward.

Technical Issues

To get a very clear idea about the chief technical issues involved in MSW management, questionnaire survey were conducted several time in several way in ward no. 24 with close collaborations of Nabarun Sangsad (NGO) and Paribesh Unnayan Committee 24 No. Ward (CBO). In-depth data have been collected to identify present level of people's awareness and motivation, source storage, primary collection, on-site storage and secondary collection efficiency.

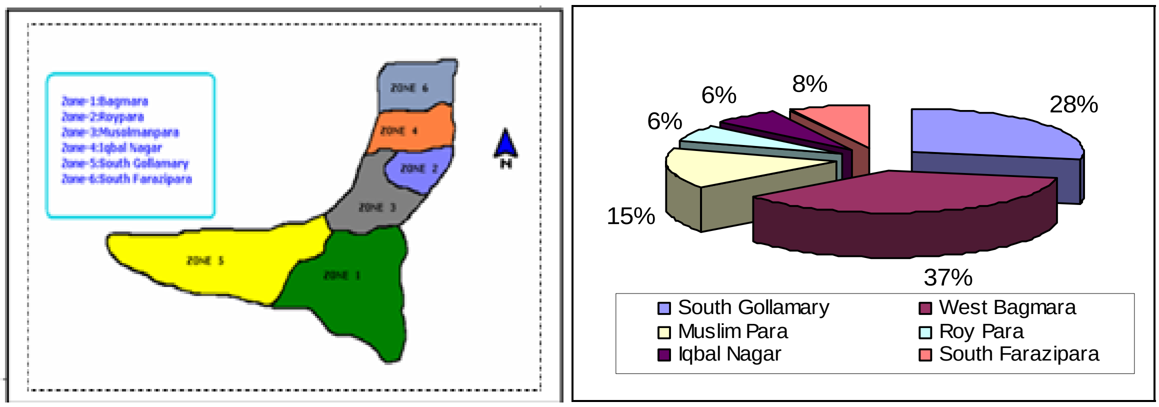
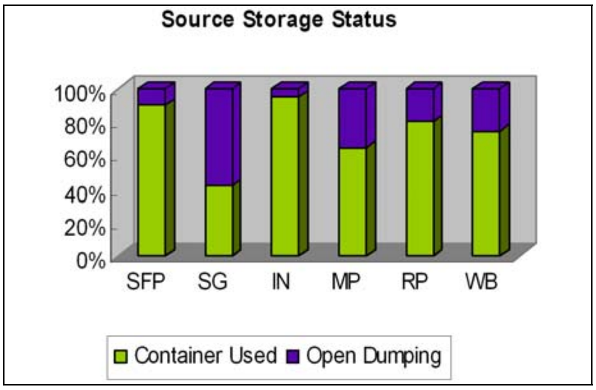
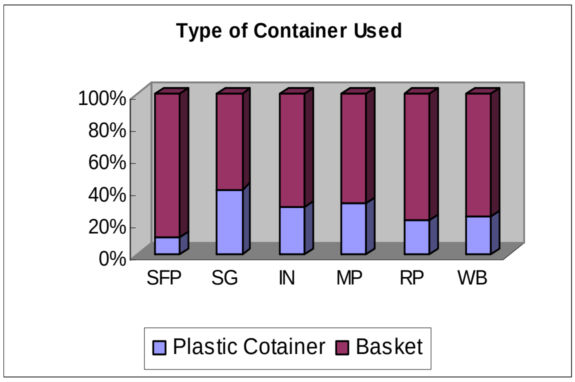


Figure 5 Zoning and area coverage in percentage by different zones of ward no. 24

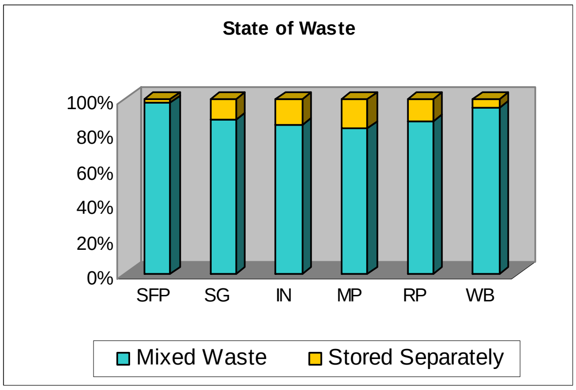
For convenience to perform all these activities, the total area of 24 no. ward was divided into six different zones as West Bagmara (WB), Roy Para (RP), Muslim Para (MP), Iqbal Nagar (IN), South Gollamari (SG) and South Farazi Para (SFP), which cover area of 37, 6, 15, 6, 28 and 8% respectively of total area of ward no. 24. From the Figure 5, it is clearly illustrated that out of these six zones, West Baqgmara and South Gollamary are the two largest zones. First time the survey was conducted by taking interviews at least one members of each family. Thus total 1548 families in ward no. 24 were surveyed. The waste management system is most acute in slums and low income group areas. Bins were supplied to these kinds of households in the surveyed zone. The family members were requested to store waste into the supplied bins. After collecting all these information, technical analyses were carried out in order to reach a good solution, which are given below in Tables 2 and 3 and Figures 6 and 7.



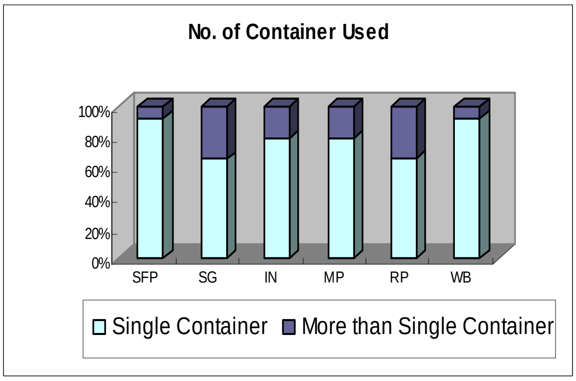
(a) Use of container



(b) Container type



(c) Storage type



(d) Number of Container

Figure 6 General information on the source storage at the residential areas of ward no. 24

Table 2 Generation of solid waste in ward no. 24 (Akter et al. 2008)

Zones	Surveyed families	Population	Waste generation (kg/day)	Waste generation (kg/cap/day)	Total population	Total projected generation (kg/day)
SFP	200	805	298	0.37	2,611	966
SG	328	1651	578	0.35	8,257	2890
IN	178	714	307	0.43	8,129	3495
MP	328	1631	587	0.36	8,930	3215
RP	144	572	269	0.47	7,892	3709
WB	370	1879	526	0.28	15,511	4343
Total	1548	7252	2565	0.35	52,624	18,618

Table 3 Door to door coverage in ward no. 24

	Based on direct survey			Based on secondary data		
Zone	Generated waste (kg/day)	Collection by door-to-door system (kg/day)	Coverage by door-to-door system (%)	Projected Generated Waste (kg/day)	Collection by door-to door system (kg/day)	Coverage by door-to-door system (%)
SFP	298	230	77.2	966	518	53.62
SG	578	300	52.0	2890	1334	46.17
IN	307	255	83.0	3495	2538	72.62
MP	587	215	36.63	3215	1144	35.58
RP	269	229	85.1	3709	3238	87.3
WB	526	158	30.0	4343	1103	25.40
Total	2565	1387	54.0	18618	9875	53.04

People living in the slum area throw their waste into drain or canals pass through the ward. Generally, single bin is practiced and collection van also has single compartment, so waste becomes mixed. But in some households use more than one bin. In the area of Kashem Nagar and Prantica of Gollamary zone some people dump their waste directly into the ponds to fill it and some people dump waste into low-lying adjacent land to their houses to raise the land level. Wastes are stored as 39, 55 and 7% at open spaces, dustbins and container, respectively. There is no transfer station and handover point in ward no. 24. The number of SDS available in this ward is 24. There are also no controlled/ engineered/ sanitary landfills in any ward of KCC.

Waste generation rate in study area varies from 0.28 kg/cap/day to 0.47 kg/cap/day. Generation rates also increase with the income level, as it should be due to more consumption. Different area may be covered by different collection time and frequency. Waste generation rate is higher in Iqbal Nagar zone, where as lower at West Bagmara zone. Average waste generation rate in ward no. 24 is 0.35 kg/capita/day. On this basis the solid waste generated in this ward is about 20 tons per day. Total collections of waste from these six zones are shown in Table 3.

It has been seen that actual generated solid waste from various source of study area is not properly collected. Moreover, due to lack of motivation, awareness and commitment, a considerable portion of waste, 30 - 35%, are not properly stored, collected or disposed in designated places for ultimate disposal. Present waste collection system of study area is inadequate and inefficient. By extensive data collection it has been observed that only 53-54% of total generation of waste is collected and disposed per day by KCC. Rests of wastes remain on roadside bins creating unhealthy environment all around such as bad odor, soiled street and aesthetically problem. To solve these problems KCC needs to find a proper solid waste management system in the Khulna city. More over NGOs/ CBOs may play a certain role by involving community in waste management.

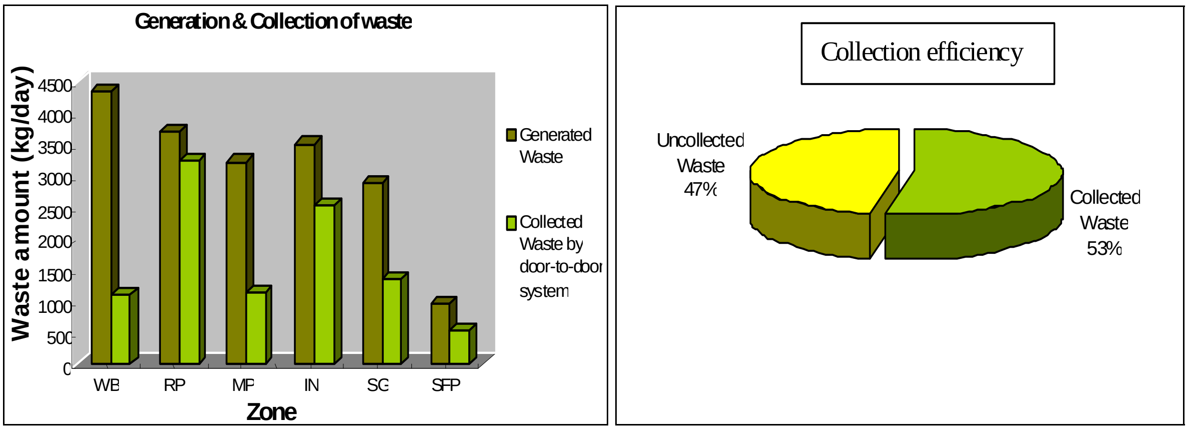


Figure 7 Generation versus collection amount and efficiency in six zones of ward no. 24

Stakeholders' Dialogue and Public Participation

There is a wide range of stakeholders - individuals, organizations and groups both in the formal and informal sector - involved and concerned with MSW management as generators, regulators and legislators. Waste management strategies can only be effective if all the stakeholders work in tandem for a successful venture. As generators of MSW, the public must be aware of the hazards posed by ineffective management of the refuse. Unless the public are involved throughout the management programs, awareness cannot be achieved. Once the public comprehend and acknowledge the main constraints and challenges in the system, no doubt, the actual scenario of waste management will be changed. Considering all these facts, several Stakeholders' dialogues and formal & informal discussions on solid waste management issues were arranged by the WasteSafe team in ward no. 24 to play a key role in bringing about this awareness through role play in the programs which in turn creates a sense of ownership among the individuals thus developing keen interest for shouldering responsibilities. Local residents, civic societies, NGOs, CBOs, local ward commissioner and local authority willingly participated in these Stakeholders' Dialogues, exchanged views, experiences, needs and gave their important opinions. From the discussion it was found that poorer section was sceptical on issue of paying service charges. City authorities charge conservancy taxes from city dwellers. So it is not unusual for city dwellers to expect that city authorities will provide a clean city. The WasteSafe team tried to convince them that they were contributing in this service by providing for the labour cost by physically delivering waste to rickshaw van by themselves as resources required to keep city clean, often far exceeds financial capacities of city authorities. Outcome of discussions have been tried to incorporate in the various initiatives of WasteSafe II. From these dialogues some important issues are identified:

I. Strong need of continuous awareness campaign
II. Need to increase efficiency and coverage of primary collection
III. Need to change situation of on-site storage
IV. Need to arrange workshop and training program

APPROACHES TAKEN BY WASTESAFE II

Leaflet Distribution

Considering the summarized outcome comes from the Stakeholders' dialogues, it is clear that no change in MSW management is possible until awareness get developed among the people of all level. To this endeavour, the first attempt taken by the WasteSafe team was to design a campaign leaflet, and then it was printed aiming for mass distribution among the city dwellers keeping provision for the commitment signature of individual to work for a clean, hygiene and environment-friendly Khulna city. The leaflets was designed at the middle of the year of 2007 and then printed and has been distributing among the city dweller since November 22, 2007.

Motivation and Awareness Campaign

Public awareness and attitudes to waste can affect population's willingness to co-operate and participate in adequate waste management practices. No comprehensive awareness campaign either from city authority or NGO/CBO was held in ward no. 24 before. To this attempt, mass awareness campaigns were held in two times on January 5, 2008 and November 25, 2008 with co-operation of large no. of students and teachers from KUET and WasteSafe team from KUET and KCC. They distribute Awareness Leaflet to the people, directly discuss with them and tried to convince their participation to build up a sound MSW management system.

Awareness through Art and Culture

To increase people's awareness especially among the children, attempts have been taken taken by the WasteSafe team was to arrange an Art and Culture program at Khulna Art School on July 2008. Theme of the program was waste management scenario of Khulna City. A good no. of students of Khulna Art School participated in that program. Their thought, idea and suggestion about waste management get reflection through their awesome colourful drawing. At the end of the program they were rewarded for further encouragement to follow the attempts which makes the city clean, hygiene and habitable.

Figure 8 Children's thoughts on clean city by solid waste management

Newly Designed Rickshaw Van

To enhance the primary collection efficiency and door-to-door coverage in ward no. 24, two covered Rickshaw Vans were designed and fabricated using materials available in local market (GI angle and stainless steel sheet) to overcome the limitations of present Rickshaw Van in Khulna city. Van size is 120 x 85 x 90 cm with the opening provisions at top and back. The rickshaw van has provision of compartment system in order to separate organic wastes from re-usable wastes. The top cover of van protects waste to be soaked by precipitation during rainy season. The idea and suggestions came out through stakeholders' dialogue and experiences of users were considered in design. The vans are using for primary collection of waste from source in ward no. 24 with satisfactory performance. In fact, this newly designed rickshaw van collects waste approximately two times more than that of carried by the existing vans.

Festoon Display

To attract public attention, a number of festoons have been designed and installed for display at the important public places for increasing public awareness on safe and sustainable management of MSW in Khulna city as shown in Figure 9(a). Different type of slogans like: "*Don't throw waste out, but store them in a designated place, by any means*" or "*Every house is a school and every mother is a teacher of her child. So parents can teach children about environment pollution and the necessity of a neat and clean environment*", etc. have been displayed on these festoon to modify people's attitudes and to enhance on sustainable MSW management.

(a) Displayed

(b) Proposed

Figure 9 Festoon and Billboard to develop awarness

Design of Transfer Station

To change the situation of on-site storage, reduce hauling cost and increase efficiency of solid waste management systems - need of transfer station is highly understood and WasteSafe II team has been designing an affordable one to increase the overall efficiency of existing MSW management. If some transfer station can be installed at some reliable points of the city, the double handling system of waste can be eliminated. The draft design of a proposed transfer station as shown in Figure 10 was handed over to authority of KCC for further discussion about its technical suitability and possible construction and management. If number of secondary collection points cannot be removed or reduced and remains unmanaged, scattered all over city, the city neighborhoods are bound to remain an eyesore; an environmentally unfriendly place for people to live in.

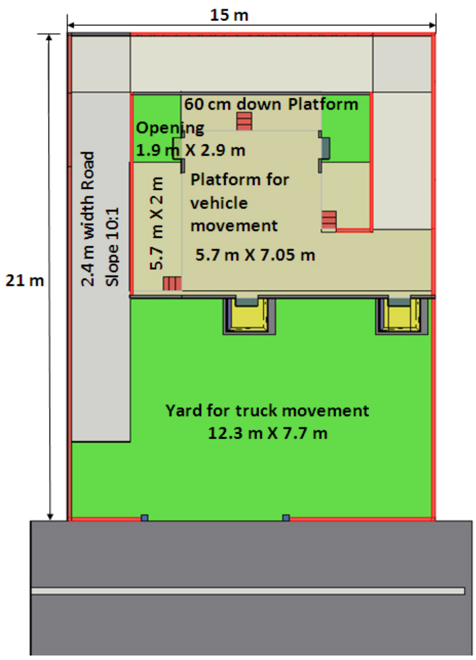


Figure 10 Plan of a proposed transfer station

PEOPLE PERCEPTIONS AND IMPACT ASSESMENT

After implementation of all the above mentioned approaches to increase the effectiveness in primary collection and disposal of MSW in ward no. 24, again a survey was conducted to investigate whether the taken initiatives has put any positive impact on the solid waste management system or not. This time the survey was conducted to obtain people perception not only in ward no. 24 but in some other surrounding wards of 24, just to compare the impact of the taken initiatives. Other surveyed wards are ward no. 20, 21, 22 and 29. The summarized comparisons are given in the Figure 11.

Survey result reveals that a significant percentage of general people want transfer station rather than dustbin as a secondary disposal site. The opinion of different groups of people about the existing solid waste management system in different ward of KCC is that more than 80% respondents think that this system is much satisfactory, 7% as quite good, while the rest think that this system should be improved by increasing the efficiency in collection, use covered vehicles for transportation of waste, and increase of house to house waste collection system.

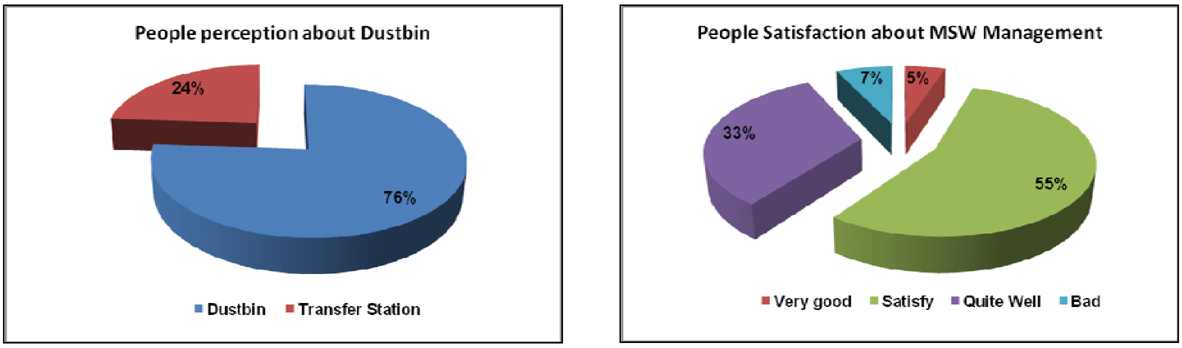


Figure 11 People's perception about the MSW management system

Due to continuous awareness build-up program together with other approaches taken by the WasteSafe team to change the overall MSW management scenario in ward no. 24, it is clear that people's perception and response about waste management practices is encouraging in ward no. 24 compared to other ward. Now they are pretty much conscious about the fact and at the same time become much cooperative than before which seems like sunlight after a long time of clouded day.

CONCLUSION

MSW management is a technical issue as well as socio-economic. A sustainable system can be obtained until people realized that they are the waste generator, so it is their responsibility to manage it properly for giving a clean, hygiene and environment-friendly city to their next generation. No change in waste management system is sighted until the people's attitude for changing their habit is changed, which is much more complex and difficult to achieve. The first survey result assured that 50% of people was quite satisfy with the existing MSW practices in ward no. 24, where the rest 50% expressed their dissatisfaction about the system (Akter et al., 2008). After conducting continuous awareness developing activities for about three years and implementing some other initiatives in the light of WasteSafe approach, the second survey result focuses that the percentage has changed to 67 and 33 respectively. The initiatives adopted for collection, transportation and disposal have already put positive impact on overall MSW management system in ward no. 24. This success is attributed through the involvement of informal sector, voluntary groups and the concerned NGO and CBO. The survey results depict that continuous monitoring, refinement of system, city authority's logistic support and social movement rather than pure technical issue are required. The present scenario of MSW management in ward no. 24 is undergoing changes towards the incorporation of the WasteSafe II could pave way for sustainable urban environment in Khulna city with effective inputs in economic, environmental and social aspects with adequate institutional arrangement.

ACKNOWLEDGEMENT

The authors greatly acknowledged the financial support provided by European Commission through projects of EU-Asia Pro Eco II Programme (ASIE/2006/122-432). The cooperation provided by

Nabarun Sangsad (NGO) and Paribesh Unnayan Committee 24 No. Ward (CBO) to this works are highly appreciated.

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Assessing the Viability of Solid Waste Management Projects for Carbon Financing in Nepal

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ABSTRACT

The haphazard open dumping of Municipal Solid Waste (MSW) at open place or poorly engineered landfill site in the municipalities is substantially contributing to the emission of greenhouse gases in Nepal. Recent estimates postulated that the total waste generation of 58 municipalities of Nepal was 1400 tons/day but municipal authorities are able to collect only about 42% of total generated MSW. Limited resources, low priority for the waste management and weak political will be the major factors leading to the absence of a comprehensive Municipal Solid Waste Management (MSWM) approach in these municipalities. Nepal being the signatory of Kyoto Protocol can be benefited through Clean Development Mechanism that provide the source of fund and contribute a local effort in the management of greenhouse gases. According to the survey conducted by this study in fifteen municipalities of Nepal, total methane emission was estimated to be 52 $GgCO_2eq$ per year in 2007. Further, Biratnagar sub-metropolitan city had the highest methane emission among all the municipalities studied. This study assessed the viability of reduction of methane emission through aerobic composting of the generated MSW. Although the composting technology was found to be a feasible solution, scale economy could be a barrier in implementing the CDM framework for majority of the municipalities in Nepal.

INTRODUCTION

Nearly 15% of the populations in Nepal reside in the 58 municipalities of the country with the population range from close to 10,000 to 700,000 (CBS, 2001). Despite such a high population pressure and rapid growth in the urban areas, MSWM is yet to be prioritized in development agenda and a comprehensive approach to SWM in all the municipalities has been almost absent. Current total waste generation of 58 municipalities of Nepal was found as1369 tons/day with the per capita waste generation of 0.25 kg/person/day. Further, the municipal authorities collect only 42% (average of 58 municipalities) of total solid waste generated in urban areas (IDI, 2004). However, the collected urban wastes in most of the cases are either haphazardly dumped in open space or disposed at a poorly engineered landfill site where it undergoes anaerobic decomposition and emits potential greenhouse gas methane into the atmosphere. In the existing landfill sites of Nepal, there is no provision for recovery and utilization of methane generated from MSW in landfill. Therefore, the fate of collected or uncollected solid waste is anaerobic decomposition which leads to emission of greenhouse gases (GHGs).

The organic matter under anaerobically decomposing condition produces mainly methane (CH_4) and carbon dioxide (CO_2) along with insignificant quantities of other gases. Emission of methane and carbon dioxide from the deposited MSW in landfill site are considered to be one of the several anthropogenic factors that causes greenhouse gas effect and lead to global climate change.

Disposal of MSW through composting in household level is a traditional practice in Nepal. However, there were not any large scales composting facilities used for the MSW management in Nepal. In contrast to the anaerobic decomposition of MSW, aerobic composting is a low GHG emitting process which reduces the release of GHGs and helps sequester carbon and other nutrients to the soil. During the aerobic composting process, CO_2, a lower global warming potential gas compared to the methane, is emitted into the atmosphere.

On the other hand, municipalities have very limited resources for MSW management, therefore comprehensive approach for MSW management is lacking.Hence, it is urgent to investigate non-traditional funding sources to tackle the problems of solid waste management in Nepal. Clean Development Mechanism (CDM) framework not only provides source of fund but also contributes to the global effort in managing the environment. CDM has emerged as project-based flexible mechanisms to stimulate the sustainable development in developing countries whereas for developed countries to achieve emission reduction commitment. Nepal, being signatory of Kyoto Protocol, can be benefited through CDM prospect in solid waste sector. This paper outlines an overview of initiative which addressed the opportunities of CDM and issues of solid waste management in the fifteen municipalities of Nepal. In these contexts, the paper provides an overview of the current status of solid waste generation, composition, disposal practices and inventory of greenhouse gas emission the selected municipalities.

WASTE GENERATION AND COLLECTION

A survey on per-capita household waste generation conducted in 20 households in each municipality gave an average per capita waste generation rate of 0.166 kg/person/day. The representative households in each municipality were selected mainly based on various socio-economic criteria and household size. As per survey results, the per-capita household waste generation rate ranged from 0.108 kg/day (Mahendranagar) to 0.325 kg/day (Biratnagar). Based on the per-capita waste generation rate and population figures, the 15 selected municipalities, generate 163 tons of solid waste per day on wet basis. However, there is large variation in waste generation rates among the municipalities as presented in Figure 1. Waste generation rate of Biratnagar municipality (65 tons/day) is comparatively high because of the higher population and per capita waste generation rate (0.325 kg/person/day).The current collection coverage achieved by municipal service in those municipalities has been represented using the same strategy. The average collection coverage was found to be low (42%) and varying from 16% (Gulariya) to 80% (Bharatpur).

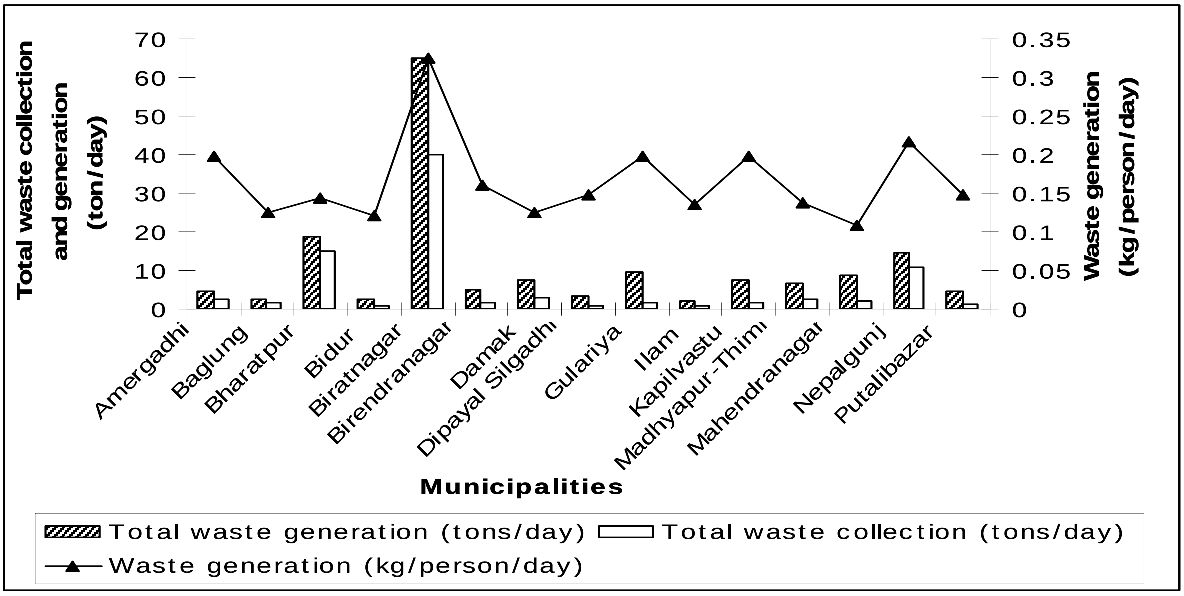

Figure 1 Waste generation and collection

HOUSEHOLD SOLID WASTE CHARACTERISTICS

Physical analysis of waste sample collected from the households during the survey was carried out to determine the composition of MSW. The average values for different waste fraction in terms of percentage composition by wet weight were obtained. Average physical composition in case study municipalities revealed three major waste components i.e. kitchen residues, recyclable and inert. Table 1 provides a summary of the physical composition and waste generation role in the municipalities.

Similar to other developing countries, the solid waste in the subject municipalities has high putrescible organic content and account of 72% of total waste in average as presented in Table 1. Further, recyclable materials like paper, glass, metal and plastic content account not more than 16% of the total waste. It is remarkable that the households surveyed in some of the municipalities such as Mahendranagar, Bidur, Damak and Baglung were found to reuse most of the kitchen waste generated for different purposes, e.g. feeding the pigs, pigeons and cattle thus resulting in lower waste generation rate compared to the average figure.

Table 1 Physical composition of household waste in the fifteen municipalities

Municipality	Kitchen waste (%)	Paper (%)	Plastic (%)	Metal (%)	Glass (%)	Inert materials and others (%)	Waste generation rate (kg/ person/ day)
Amargadhi	51	4	4	0	7	34	0.198
Baglung	62	15	14	0	2	7	0.125
Bharatpur	62	7	5	4	2	21	0.144
Bidur	64	5	6	2	13	11	0.12
Biratnagar	68	5	2	2	1	22	0.325
Birendranagar	81	4	2	1	3	9	0.161
Damak	69	4	3	0	2	21	0.125
Dipayal	77	10	7	1	4	1	0.147
Gulariya	76	4	5	0	7	7	0.198
Ilam	77	4	4	2	5	9	0.136
Kapilvastu	72	10	5	0	2	10	0.198
Madhyapur	76	3	2	1	3	14	0.137
Mahendranagar	77	7	4	1	3	8	0.108
Nepalgunj	87	3	4	1	2	4	0.216
Putalibazar	75	3	6	1	2	12	0.148
Average	**72**	**6**	**5**	**1**	**4**	**13**	**0.166**

WASTE RECYCLING

Materials in the solid waste like glass, paper, plastic and metals have high potential to be recycled. Reuse and recycling activities have a positive influence in reducing the amount of waste for disposal. Recyclable materials are 16% in comprising of the total waste on average. The content of recyclable materials (i.e. paper) varied from 3% (Nepalgunj, Putalibazar) to 15% (Baglung), with an average value of 6%. As far as the plastic waste is concerned, it has created a major waste disposal problem in each municipality studied. The content of plastic materials ranged from 2% (Biratnagar, Birendranagar and Madhyapur) to 14% (Baglung), with an average value of 5% and metal and glass had an average value of 1% and 4% respectively. Metals were the most recycled materials (31%) followed by plastic (24%) and paper (22%). This shows that endorsement of waste recycling activity may act as an important measure for the minimization of waste problems. The above finding was based on the finding from household questionnaire survey in the selected municipalities.

DISPOSAL OF MSW

Effective and efficient SWM approach was almost absent in case study municipalities. Current waste disposal practices included dumping at either open places or poorly engineered disposal sites. Due to the lack of human and financial resources, and political instability, it has been a challenging task to operate and maintain disposal sites at minimum sanitary standards. Slow burning and uncontrolled dumping on river, hillsides and forests or improperly planned and temporarily developed disposal sites were found as the common methods practiced for solid waste disposal.

It was observed that the Kapilbastu Municipality had the largest disposal area (1.35 hectare) followed by Putalibazar (1.3 hectare). The Biratnagar sub-metropolitan city, Damak and Kapilbastu municipality had their disposal sites at the bank of Shingiya, Ratuwa and Jamuhar rivers, respectively.

Ilam, Bidur, Madhyapur- Thimi, Bharatpur, Baglung, Putalibazar, Birendranagar, Nepalgunj, Gulariya, Dipayal-Silgadhi, Amarghadi and Mahendranagar municipalities use the temporary open pile system for the disposal of solid waste as shown in Table 2. It was interesting to note that collected waste was being dumped at the premises of Mahendranagar municipality office, itself.

It was found that the subject municipalities have neither appropriate landfill sites nor engineered incineration facilities. Open burning of MSW was found as a common practice in the centre of city at Mahendranagar and Madhyapur-Thimi municipalities. In most of the municipalities, a state of conflict on many SWM issues was noticed between local people and municipal authorities. In some cases political interference regarding the disposal of waste was also observed. This indicates a lack of appropriate waste management in the study area.

Table 2 Municipal solid waste disposals

Municipality	**Disposal site**
Amargadhi	Temporary open pile
Baglung	Public land
Bharatpur	Temporary open piles
Bidur	Temporary open piles
Biratnagar	River side
Birendranagar	Temporary open piles, riverside
Damak	River side
Dipayal Silgadhi	Temporary open piles, road/stream side
Gulariya	Temporary open piles
Ilam	Temporary open piles
Kapilvastu	River side
Madhyapur-Thimi	Temporary open piles
Mahendranagar	Temporary open piles
Nepaljung	Temporary open piles
Putalibazar	Temporary open piles

RESOURCE ALLOCATION FOR SWM

Increasing responsibilities on SWM dictate substantial requirement of human and financial resources. However, mostly because of financial constraints, municipalities are not able to provide adequate as well as efficient services. Furthermore, due to technical and managerial inefficiencies, the available resources are often utilized ineffectively. The quantity and type of financial as well as human resources allocated for SWM practices vary distinctly from municipality to municipality as presented in Table 3.

Table 3 Human resources in waste management

Municipality	SWM Staff	Person served per staff	Budget for SWM (NRs in million)
Amargadhi	8	2797	0.6
Baglung	14	1489	1.39
Bharatpur	62	2096	5
Bidur	16	1392	0.25
Biratnagar	114	1462	10
Birendranagar	14	2263	3.26
Damak	30	1953	1.1
Dipayal Silgadhi	11	2183	0.32
Gulariya	10	4887	0.6
Ilam	16	1015	15
Kapilvastu	16	2336	1
Madhyapur- Thimi	20	2387	1.6
Mahendranagar	27	2994	2
Nepalganj	103	659	2.75
Putalibazar	10	3000	8

For instance, municipalities such as Amargadhi, Gulariya, Putalibazar and Dipayal Silgadhi had only 8 to 11 personnel for SWM but large cities like Biratnagar and Nepalgunj had 114 and 103 personel were involved. In terms of resource intensity or number of people served per SWM staff, municipalities like Biratnagar and Nepalgunj had one SWM staff for serving 1,462 and 659 people respectively. However, Gulariya, Putalibazar and Amargadhi had one SWM staff serving 4,887; 3,000 and 2,800 people respectively. Similarly, there is large variation in the budget allocated for the SWM activity.

Table 4 Household waste generation and baseline emission of case study municipalities

Municipality	**Total population[1]**	**Total household waste generation (ton/day)**	**Collection efficiency %**	*** Baseline emission for year 2007 (tCO_{2e})**
Amergadhi	22378	4.43	56	1426
Baglung	20852	2.6	65	837
Bharatpur	130210	18.72	80	6026
Bidur	22273	2.67	30	860
Biratnagar	166674	65	61	20925
Birendranagar	31694	5.1	30	1642
Damak	58590	7.3	41	2350
Dipayal Silgadhi	24013	3.52	29	1133
Gulariya	48875	9.67	16	3113
Ilam	16246	2.2	46	708
Kapilvastu	37385	7.4	20	2382
Madhyapur-Thimi	47751	6.5	39	2092
Mahendranagar	80839	8.73	23	2810
Nepaljung	67891	14.6	75	4700
Putalibazar	30205	4.4	32	1416

*[1] Population as of 2001 census and * calculated using the IPCC recommended methane estimation method (IPCC, 2006 & Shrestha et al, 2005)*

EMISSION SCENARIO AND CDM DOCUMENTATION

After the implementation of the Kyoto protocol, CDM is becoming a key arrangement for limiting GHG and promoting sustainable development for both developing and developed countries. Any CDM projects should results in "measurable" reductions in GHG. The concept of "measurable" reduction is based on a comparison with some defined level of GHG emissions. This comparative level, against which the reduction of GHG emissions due to CDM project are measured, is termed a "baseline". The proposed CDM project will result in reduction of GHG emission only if the GHG emissions from the proposed CDM project are lower than the baseline. Human activities that causes the emission of GHG in to the atmosphere in the absence of a CDM project activity is commonly referred to as the baseline scenario. For example, disposal of MSW in landfills results in emission of methane, which is a GHG. In the absence of CDM project, no action is expected to be taken to reduce the methane from MSW landfill site. Therefore, the baseline scenario represents the quantity of methane generated from MSW in the landfill without any measures. The current waste management scenario discussed in the paper, indicated that majority of the municipalities are disposing their waste in non-engineered sites leading to anaerobic decomposition and generation of methane gas. The baseline scenario for existing SWM practices in the case study municipalities would indicate the emission of GHGs either with business as usual scenario or disposal in a planned /engineered landfill sites. The baseline emission, for the case study municipalities has been calculated using the IPCC recommended methane estimation method as presented in Table 4.

However, baseline emission was estimated as minimum value of 708 tCO_{2e} /year (Ilam Municipality) to a maximum value of 20,925 tCO_{2e} /year (Biratnagar Sub-Metropolitan City). It is expected that after implementation of biological treatment process such as composting, emission reduction from solid waste of Biratnagar Sub-Metropolitan City would be around 16, 000 tCO_{2e}. Thus, at the current market rate for trading of US$ 6 per ton of CO_2 for carbon trading, a rough estimate can be made for total revenue generation with the implementation of composting facilities. The figures for Biratnagar and Ilam would be NRs 6 million and 0.2 million only. Thus for majority of the municipalities, scale economy can be barrier in implementing CDM framework. So, this aspect needs to be considered in making a further strategy like preparation of the project documents such as project idea note (PIN) and project design document (PDD). Similarly, the institutional capability and political willingness were additional issues identified as major bottleneck. Bundling of the composting projects of two or more municipalities could still be considered for CDM funding.

CONCLUSIONS

Municipalities of Nepal is experiencing increasing trend in the MSW generation with the rapid urban growth. The haphazard open dumping of MSW at open place or poorly engineered landfill site is the common disposal trend in these municipalities. This study has assessed the GHG emission from the MSW disposal and associated CDM opportunities in fifteen municipalities. From the study, it was found that municipal per capita SW generation ranged from the highest 0.325 kg in Biratnagar to lowest 0.12 kg in Bidur. Similarly, MSW generation ranged from 65 ton /day in Biratnagar to 2.2 ton/day in Ilam. Further, the MSW shows that it is organic in nature in study area as its predominant fraction of kitchen waste of about 72%.

Emission of potential GHG from anaerobic decomposition of MSW into the atmospheres is responsible to increase global warming. Baseline CO_{2e} emission for SW disposal ranged from the highest in 20,925 ton in Biratnagar to the lowest of 708 ton in Ilam with the average emission of 3495 ton from 15 municipalities of Nepal for the base year 2007.

It is expected that after implementation of biological treatment process such as composting, emission reduction from SW of Biratnagar Sub-Metropolitan City would be around 16, 000 $tCO_{2e.}$ Thus, at the current market rate for trading of US$ 6 per ton of CO_2 for carbon trading, a rough estimate can be made for total revenue generation with the implementation of composting facilities. The figures for Biratnagar and Ilam would be NRs 6 million and 0.2 million only. Scale economy can be barrier in implementing CDM framework. Similarly, the institutional capability and political willingness were additional issues identified as major bottleneck. Bundling of the composting projects of two or more municipalities could still be considered for CDM funding.

ACKNOWLEDGEMENT

The authors are deeply acknowledged to the project "Using CDM Opportunities to mitigate the release of Greenhouse Gases by Improving the Waste Management Practices" funded by Asia Pacific Network (APN) for Global Change Research, Kobe, Japan.

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Climate-Relevant Emissions of Waste Management in the City of Puerto Princesa, Philippines

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ABSTRACT

Because of the rapid growth rates of smaller cities in many developing countries environmental consequences such as resulting amount of waste and local waste management systems come into focus. A special aspect is how it affects climate change and national Kyoto protocol regulations. Purpose of the study is to quantify greenhouse gas emissions of municipal solid waste management in a typical city in a developing country. The methodology is based on the 2006 IPPC Guidelines for National Greenhouse Gas Inventories. Potential emissions of waste management were assessed based on their global warming potential with respect to Kyoto gases CO_2, CH_4 and N_2O. The status quo serves as baseline scenario. Scenarios were established for higher composting quota and waste combustion. The results show lowest emissions for increased composting quota and waste combustion.

INTRODUCTION

Many cities in developing countries like the Philippines have to deal with consequences of growing population and higher population density, insufficient infrastructure and growing amounts of waste. Local administrations are under pressure to establish local waste management systems for growing waste amounts but limited land availability. Most common waste management systems in the Philippines are landfills and composting in few places. Mechanical-biological treatment of waste is not common. Waste combustion is actually prohibited by the Philippine Clean Air Act of 1999. National and local regulations regarding monitoring and reduction of emissions generally focus on emissions of the transportation sector but do not consider waste management. Towns and medium-sized cities may be able to adjust their waste management strategies to the growing needs of the city. Major cities however are facing bigger challenges to change current systems

Therefore, the objective of the paper is to quantify climate-relevant emissions of local waste management systems in Puerto Princesa City (PPC) which is a typical medium-sized city in the Philippines. The results are used to identify alternative ways of waste treatment to reduce greenhouse gas emissions. CO_2, CH_4 and N_2O were identified as relevant greenhouse gases. The current situation was used as baseline to be compared to scenarios with different waste management strategies like increased composting quota and combustion. To make results comparable with data of other studies the officially recognized 2006 IPPC Guidelines for National Greenhouse Gas Inventories were applied.

SHORT PROFILE OF PUERTO PRINCESA CITY

Puerto Princesa City (PPC) is the capital and the only urban agglomeration of Palawan, a tropical island in the southwest of the Philippines. PPC´s area covers about 2.500 km^2, and is divided into 66 so called barangays. Mountains surrounding the city are limiting its expansion. Nevertheless Puerto´s population recently is 300.000 at an annual growth rate of 7.5. Around 73% live in urban characterized barangays. Population density varies between 5 inhabitants per km^2 in rural barangays up to 200.000 inhabitants per km^2 in the city centre. PPC is not industrialized bus has some very small family-owned companies with only few employees. Most people work in commerce or service. Farming is confined to the outer barangays. Average waste production in PPC comes up with 80 to 100 tons per day. (Office of the City Planning and Development Coordinator (after 1998))

Responsible body for waste management is city government based on the Ecological Solid Waste Management Act of 2000. After that Act barangay administration is responsible for managing the compostable or recyclable municipal solid waste. Municipality which is the higher administrative level is responsible for management of residual or hazardous wastes. In 2005 a sanitary landfill was built at a former dumping site. The office of the City Solid Waste and Disposal Management is located there today and coordinates the collection and disposal of municipal solid waste. For collection two waste bins are allocated to the population from which one is provided for recyclable waste and the other one for residual and biogenic waste. The recyclable waste which consists of detail metals, glass bottles, hard plastic and cardboard can also be sold to junk shops or the city´s Materials Recovery Facilities (MRFs). The biogenic and residual waste is collected, transported to the transfer station, sorted and finally disposed on the landfill. There is no special waste collection or treatment for industrial waste, because the companies are so small, they dispose their waste in the waste bins for household waste.

WASTE CHARACTERISATION

83% of the waste is being disposed to the sanitary landfill and 17% are brought to junk shops or MRFs. In 2006 the City Solid Waste and Disposal Management Office organised a study to determine the detailed composition of the residual waste. For this aim collected residual waste was partially manually sorted and weighted in March and in June. The results of the study are shown in Table 1.

Table 1 Municipal solid waste composition of urban und suburban barangays in PPC, 2006 (City Solid Waste and Disposal Management Office 2006)

Waste fraction	Waste category	Waste of urban barangays in percent by weight	Waste of suburban barangays in percent by weight
Agricultural waste	biogenic	65.8	76.7
Cellophane	residual	12.2	10.2
Food leftovers	biogenic	6.3	3.4
Diapers	residual	5.0	3.4
Cardboard	recyclable	3.4	2.2
Glass bottles	recyclable	1.4	1.0
Plastics (hard plastics)	recyclable	2.6	0.4
Cans	recyclable	1.3	0.2
Textiles	residual	0.9	0.8
Others	residual	1.3	1.9

According to information of the City Solid Waste and Disposal Management Office and the table above, the composition of total waste in PPC can be estimated as follows:

- biogenic waste: 40% by weight
- residual waste: 28% by weight
- recyclable waste: 32 % by weight

There is no detailed information about the particle size of municipal solid waste in PPC, but it ranges between few millimetres for ash or dust to some decimetres for plastic bins or tires.

ESTIMATION OF RELEVANT GASES

CO_2 is produced by aerobic decomposition of biogenic materials in landfills, composting sites and combustion. Source of CH_4 is anaerobic decomposition of biogenic matter in landfills and waste water treatment plants. The greenhouse gas N_2O can be emitted by waste treatment facilities, mainly waste combustion, and waste water treatment. NO_x emissions are caused by waste combustion.

Local waste treatment techniques determine the amount of each greenhouse gas. Major emitter in PPC is the sanitary landfill. Composition of landfill gas was not actually monitored but consists generally of 45% CO_2 and 55% CH_4 due to predominant anaerobic decomposition. For composting CO_2 is considered since composting should be realised under aerobic conditions. But also N_2O is taken into account, since it is produced by the oxidation of ammonia during composting processes. Since waste water treatment is not implemented in PPC and waste combustion is prohibited in the Philippines, only illegal waste combustion can be a source for N_2O. Following this argument NO_x emissions are assumed to be even minor than those of N_2O.

One of the scenarios below deals with waste combustion. Therefore N_2O was taken into account although there is low importance for the current situation. Since there is no liable data available for emissions of CFCs or PFCs from Philippine waste management this study is limited to CO_2, CH_4 and N_2O.

BALACING METHODOLOGY

As a method for balancing greenhouse gas emissions the 2006 IPPC Guidelines for Greenhouse Gas Inventories (IPPC 2006) were chosen which are standardised, comparable, complete and transparent. Reporting of emissions according to national emission inventory is essential for monitoring total country emissions and to identify options for emission reductions. Therefore CO_2 emissions of fossil materials are mandatory to report, CO_2 emissions of biogenic materials are presumed climatically neutral. All other greenhouse gases have to be reported.

Basic mathematical approximation for estimation of emissions according to IPPC Guidelines is a mass balance which calculates emissions via activity data and a specific emission factor. This approach is the lowest possible level. Since there is more specific data available about local waste management, higher level was chosen. For composting and waste combustion, level 1 was chosen, since there is less information at hand. Decomposition of biogenic matter in a landfill body is estimated as a first order decay, since decay depends on time and detailed information is available.

CALCULATED SCENARIOS

Three scenarios were defined under following assumptions:

1. Different waste treatment techniques are used from 2005 to 2020. Only these 15 years of waste treatment generate data for calculating total emissions.
2. A 100 year period of emissions is used which is common practice in scientific calculations in case of time depending processes. Starting point is year 2000. Furthermore almost all emissions of waste, treated in 2020, are released.
3. Years 2000 to 2005 are considered to show emissions of former dumping site. Begin of different scenarios is set in 2005.
4. Average waste production is 113 kg per capita and year.
5. Population growth of PPC is 7.5% per annum, and is the same in all scenarios (and was extrapolated based on growth rates of social-economic profile (Office of the City Planning and Development Coordinator (after 1998)) of PPC.

Scenario 1: Current situation

Scenario 1 shows the current situation in PPC. Most important waste treatment technique is the disposal of waste at the sanitary landfill. Just around 15 weight percent of agricultural waste is composted. The waste composition is deduced from City Solid Waste and Disposal Management Office (2006) as shown in Table 1 and was transferred to urban and suburban barangays.

Scenario 2: Maximising composting quota

Currently just a few percentages of biogenic waste like garden or agricultural waste and food leftovers are composted. Optimising composting quota should be technical feasible if waste collection is changed to source separate collection of biogenic materials. Therefore scenario 2 shows the effects of maximum composting quota. Although raising composting quota to 75% for food leftovers and 90% for agricultural and garden waste is not realistic in short term, they can be set as benchmarks for upcoming development.

Scenario 3: Waste combustion

For this scenario the composting quota is frozen to the current situation (scenario 1). The remaining waste is assumed to be disposed by combustion.

RESULTS

Calculation of scenarios result in different greenhouse gas emissions, measured as CO_2 equivalents as shown in Figure 1 for the period from 2000 up to 2100. Table 2 represents summarises the accumulated CO_2 equivalents for the same period.

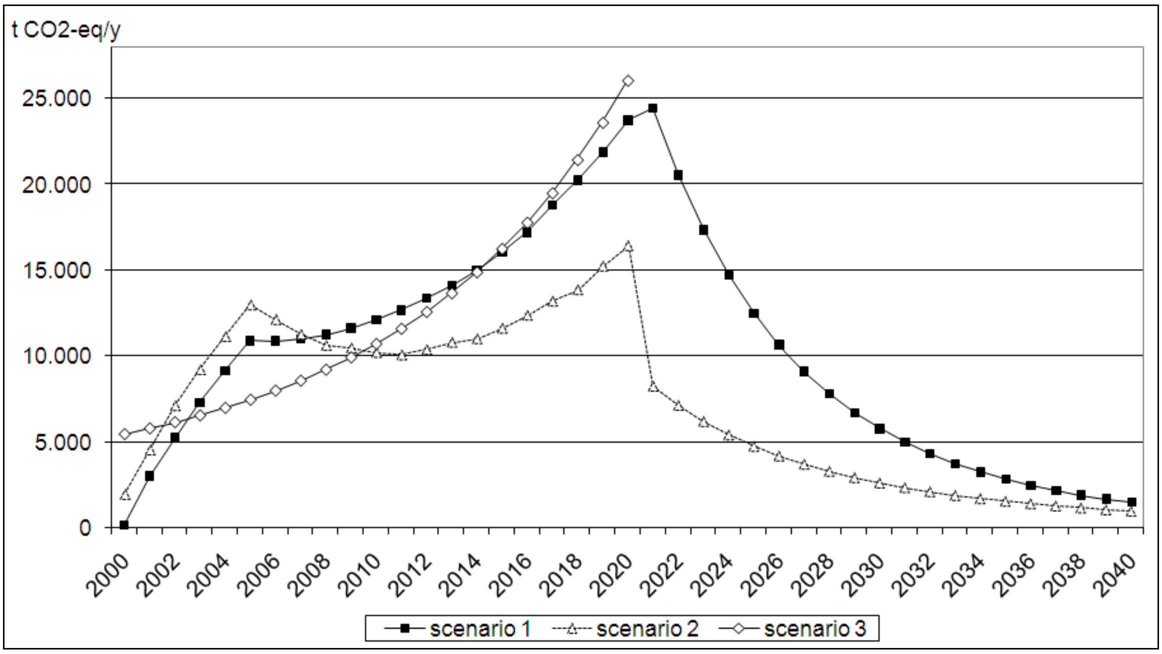

Figure 1 Annual total emission of all scenarios in CO_2 equivalents, 2000-2100

Table 2 Accumulated emissions of all scenarios in CO_2 equivalents, 2000-2100

Scenario	Emissions of waste treatment, 2000-2100 t CO_2 equivalents (rounded on 1,000 t)
Scenario 1: current situation	437,000
Scenario 2: maximised composting quota	302,000
Scenario 3: waste combustion	262,000

DISCUSSIONS

Comparing the results, waste combustion is the approach with the lowest emissions. Comparison of first 20-years period shows high emissions of waste combustion. But after combustion stops in 2020 there are no emissions any more, since residues of combustion which are slags and ashes are inert material and do not contain any putrescible components. On the contrary for current waste management situation (scenario 1) and maximised composting quota (scenario 2) emissions are still produced even after waste disposal stopped in 2020, since decay of biomass takes years. In summary, over a 100 year period, waste combustion produces the lowest emissions.

Scenario 1 and 2 only differ in composting quota. Effects of composting are twofold: On the one hand climate impacts result from N_2O emissions which have high impact factor (298 times CO2) (IPPC 2007). On the other hand CH_4 production which would occur if deposited on the landfill is omitted. For the first 10 years emissions of maximised composting scenario are therefore higher than those of the current situation. Reduction of CH_4 becomes more significant after 10 years of disposal. Despite the lower greenhouse gas potential of CH_4 (25) compared to N_2O (IPPC 2007), over 10 years time the higher load of Methane leads to higher total emissions in CO_2 equivalents than in scenario 2. Over the period of 100 years scenario 2 shows 135,000 tons CO_2 equivalents less than the current waste management situation.

Feasibility of scenarios

Regarding climate protection waste combustion shows high emission reduction potentials. Not only reduced emissions of greenhouse gases are a positive aspect of waste combustion. Further benefits are by reduced waste amounts to be disposed and reduction of organic pollutants. However, combustion is prohibited by the National Clean Air Act which considers a risk for air quality. In reality in high standard modern waste incineration plants this risk is minimised as compared with all other water treatment techniques. But because of prohibition by a Republic Act it seems not realistic for next years to implement waste combustion facilities in the Philippines.

Implementing large-scale composting sites however seems a realistic option. Since at least on a small scale the technique is already implemented the technical, financial and personnel effort is comparably low. PPC´s population obviously accepts waste separation, thus only lack of knowledge and practical experience is the limiting factor in composting. Higher composting quota will become more realistic if some incentives can be stimulated. Options are a composting program by the city government or reduced waste taxes for agricultural and garden waste. A composting quota of more than 70% for biogenic waste, as assumed in scenario 2, is rather to be seen as a potential or benchmark than a short time goal.

CONCLUSIONS

Waste combustion offers lowest emissions compared to current waste management situation and maximised composting quota. Hence combustion is prohibited by national law the implementation of waste combustion facilities is not feasible in the short term. But using modern technologies, negative consequences for air quality can be minimised. Economical and ecological benefits may increase the importance of waste combustion in the long term.

For next future it is recommended to use composting sites in order to reduce climate-relevant emissions as well as to lengthen the lifespan of the sanitary landfill in PPC. This also creates economic benefits for the city and has the advantage of using compost material as fertilizer. Incentives for this development can be given by the city itself or extern mechanisms, such as CDM, especially when taking into account the carbon credits of reduced methane emissions.

Balances of current state of waste management in Puerto Princesa City and scenarios for maximised composting quota and waste combustion depend on many assumptions. For more detailed scenarios more sophisticated information has to be collected and analysed which must include waste amount, composition, and physical and chemical qualities.

ACKNOWLEDGEMENTS

The paper was made possible through the great support of the City Solid Waste and Disposal Management Office in Puerto Princesa City. Members of staff provided information about the local waste management system and regulations and enabled contact to many local specialists. This support is much appreciated. Beyond this thanks to Prof. Dr. Susanne Rotter who was mentor for the basing diploma thesis. Furthermore the support of the German NGO Carpus e.V. is appreciated which is active in many fields in PPC and were among the first to stress that waste management is one of the most important challenges to future development in Puerto Princesa City.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.685-687

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

A Case Study on Impact of Solid Waste on Ambient Air Quality in Shivamogga City of South India

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ABSTRACT

Improper solid waste management is causing negative impacts in Shivamogga .To investigate the causes Shivamogga city was selected as a case study. The situation is becoming very complex in the city due to urbanization and improved living standards of urban areas, as these things are the cause of drastic increase in the quantity and complexity of generated waste. From this research, it is revealed that we have two major problems due to poor solid waste management, i.e. communicable diseases and unhygienic environment. Because of high growth rate, high waste generation rate, lack of efficient management and legislation, existing solid waste management systems in the city are not working properly. The main reasons for the failure of municipal solid waste management systems are unplanned annexation of the city, extreme weather conditions, lack of public awareness, community involvement, improper resources including improper equipment and lack of funds. Failure of the municipal solid waste management system has serious environmental impacts like infectious diseases, land and air pollution, blockage of drains and water pollution in natural streams.

INTRODUCTION

Rapid industrialization worldwide has triggered off a wave of economic development bringing prosperity and advancement for many nations. However, such activity has not been without degradation of the environment, through the depletion and contamination of existing natural resources and discharge of pollutants into air, water and dumping of solid waste on land. All of these have exerted an enormous load on the environment as a whole damaging the quality of resources available to all existent life forms. Solid waste exerted enormous load on the urban environment of Shivamogga, which is one of the important centrally located city of Karnataka state of India. Improper solid waste management is causing negative impacts in Shivamogga .To investigate the causes Shivamogga city was selected as a case study. The situation is becoming very complex in the city due to urbanization and improved living standards of urban areas, as these things are the cause of drastic increase in the quantity and complexity of generated waste. From this research, it is revealed that we have two major problems due to poor solid waste management, i.e. communicable diseases and unhygienic environment.

STUDY AREA

Shivamogga is one of the most important city of Karnataka State and is situated on the banks of river Tunga and spread over an area of 50 km² (19.31 square miles) with a total population of 474,105 (2007). The geographical location of the city is13°55′18″ N, 75°34′12″ E. Its height is 584 m above MSL (Mean Sea Level).It is a blend of history and tradition and a thriving commercial city. It is exposed to Southwest monsoon. Humidity is more during the month of July (78%). The annual rainfall is 200.97 mm. The average wind velocity is 9.7 km/h from the Southwest.

Fig1 Shivamogga city in map

MATERIAL AND METHODS

The ambient air quality survey was carried out by using a High volume Sampler APM 410, with a set of four midget impinger, for both particulate matter and gaseous sampling. The samples has be collected on 8 hourly basis for 24 hour a day Sampling done for eight hours in a spot which covers peak hour also at each spot (Sampling site) and average values are taken. The high volume sampler operated at ground level at an isolated spot away from abstractions like trees, walls etc. Sulphur dioxide and oxides of nitrogen concentration were measured by using Indian Standard Methods. The mass concentration of suspended particulate matter in ambient air expressed in micrograms per cubic meter was calculated by measuring the mass of collected particulate and the volume of air sampled. Apart from sampling a questionnaire was prepared and surrey was conducted in the city and colleted the data Table 3

RESULTS AND DISCUSSIONS

The present investigation was the preliminary survey conducted to determine the pollution concentration in Shivamogga city. As stated earlier the major air pollutants, which are usually generated from any industry include SPM, SO_2, NOx, Hence it very essential to record their concentration before implementing the control measures. The present study revels that the concentration of SPM varied fro362 – 393 $\mu g/m^3$ .Station wise SPM concentrations was highest in all the five sites and the reason attributed for this is vehicular density, and Small- Scale industries, widening the existing roads, diversion routes, construction flyovers at congested area, and also the particulates coming from the dumping yards.

Table 1 Quantity of waste in tons / day

Year	Population in lakh	Quantity of waste in tons / day
2001	274105	82.00
2004	295181	83.50
2009	333970	94.50
2011	350877	99.28
2014	377856	106.91

Data from primary source

The average SO_2 concentration varied from a 31.20 μg/m^3 to 25.23 μg/m^3 the concentration of SO_2 is well below the prescribed standard limits.

The NOx concentration varied from a minimum of 46.32 to 49.24 μg/m^3, are also well below the prescribed standard limits, our study also revels that the quantity of waste generated goes on increasing(Table 1) it is also shows that the population increasing rapidly due to urbanization, industrialization (Primary Data)

Table 2 Average concentrations of SPM, SO_2 and NOx (μg/m^3) at different sampling areas

Sampling Areas	SPM	SO_2	NOx
MRS	362	25.23	47.00
GANDHI BAZAR	393	29.6	46.32
AAMIR AHEAMAD CIRCLE	365	31.20	49.23
BUS STAND	370	30.23	49.24
MANDLI	367	29.3	48.12

Table 3 Diseases due to ambient air, solid waste in and around the city

Name of the disease	Total no of cases	Total no of persons
Asthma	30	29
Sneezing	29	19
Allergy	25	29
Hyperacidity	21	10

CONCLUSIONS

From the result it is concluded that solid waste is main problem in the city to cause various disease in and around the dumping stations and apart from this suspended particulate matter also play a vital role in causing some diseases. Hence to overcome this problem municipality authorities and polluter, we people should come forward to minimize and to manage the solid waste with advance eco-friendly techniques.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.689-698

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Recovery of Alternative Fuels and Raw Materials (AFR) and Its Socio-Economic Benefits for Waste Reclaimers at the Calahunan Dumpsite in Iloilo City of Philippines

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ABSTRACT

Iloilo City is a fast growing urban center and with more than a half million inhabitants the largest city in the Western Visayas. Currently, 160 tons of mixed household wastes are collected by a private contractor every day. The waste delivered to the local dumpsite is perceived to be residual, but still contains a significant fraction of valuable materials. Alternative Fuels and Raw materials (AFR) and other Secondary Raw Materials (SRM) could be recovered manually at the same facility with comparably low technological effort and with the help of people from the informal waste sector. To fulfill the legal requirements of the Republic Act 9003, also called Ecological Solid Waste Management Act of 2000, the local government of Iloilo City had decided to convert the local dumpsite into a landfill.

Beginning on September 3, 2008, a 100-days test for the recovery of Alternative Fuels and Raw Materials (AFR) was conducted at the central Material Recovery Facility (MRF) of the Calahunan disposal site of Iloilo City. The test took place as a joint effort between Iloilo City, the regional Department of Environment and Natural Resources (DENR-EMB6), the German Technical Cooperation Agency (GTZ) and Holcim Philippines Inc. The test aimed to determine the potential for waste diversion, its implications on the proposed new landfill and to identify options to integrate the informal sector into the municipal waste management project. Besides the technical and financial considerations the implications of the proposed changes to the socio-economic situation of the 220 local waste pickers were given equal attention.

During the test run more than 225 tons of AFR were recovered with 30 waste workers, which were hired from the local waste pickers. The waste recovery rate of AFR and SRM as accomplished during the test corresponds with a potential waste diversion rate of 20% or > 30 tons/day, if computed for the daily delivered 160 tons of solid waste at Calahunan.

The segregated AFR were utilized in co-processing for cement production by Holcim at their cement plant in Lugait, Mindanao. In addition 23 tons of SRM were recovered during the test such as metal cans, paper and cardboards and various types of bottles and hard plastics. The expertise of waste pickers in handling and sorting the mixed solid waste turned out to be essential for the success of the entire operation and for achieving an adequate output. During the conducted test, the informal sector benefited not only by receiving a regular income that was above the statistical poverty line of two dollars per day (UN Millennium Development Goals), but also availed of adequate, save and controlled working conditions for the involved waste reclaimers. The presented paper summarizes the set up, results and experiences encountered during the 100 days AFR recovery test from a technical and socio-economical point of view. It furthermore highlights potentials for a wider utilization of residual waste in the Philippines and formulates important lessons learned regarding the technical criteria and process of mechanized material recovery and its implications for the involved waste reclaimers.

INTRODUCTION

Iloilo City is the regional capital of the Western Visayas and with more than half a million inhabitants the largest urban center in Region 6. Presently, 160 tons of domestic type waste or around 90 truck loads are collected by a private contractor in Iloilo City every day. Due to the stressed traffic situation, the waste collection can only be conducted at night, whereby a significant portion of materials is already segregated and recovered prior and during waste collection. Nonetheless, around 220 waste pickers explore the local dumpsite and make their living by collecting reusable materials. Although they developed a certain working and life style to live from waste picking, their presence complicates the efforts of the Local Government Unit (LGU) for site improvement as it requires additional measures during the development and implementation of new waste management projects. To enhance the municipal waste management system, the LGU Iloilo City proposed to rehabilitate the existing dumpsite and to establish a new landfill with integrated material recovery and composting facilities and related support infrastructures. To reduce the waste volume prior to final disposal and to likewise integrate the local waste pickers into the project, a mechanized material recovery system was established in 2005. Through a development grant, a first mechanical recovery unit consisting of an input conveyor belt, trommel screen and a ring-belt system for manual segregation was acquired.

Prior to the AFR recovery project, delivered solid wastes at Calahunan were perceived to be residual waste. However, the incoming wastes still contain significant portion of valuable materials such as organic wastes, Alternative Fuels and Raw materials (AFR) and other Secondary Raw Materials.

AFR are defined as wasted materials, which could still be used to substitute other fuels and especially fossil fuels such as coal or oil derivates. To start with AFR recovery at the Calahunan site, various material recovery tests were initiated by the LGU Iloilo City, Holcim Inc., the Environmental Management Bureau Region 6 and the AHT GROUP AG as expert consultant on behalf of the German Technical Cooperation. A first test-run to recover AFR was already conducted in the time period July to August 2006 (Jaque, 2006; Paul et al, 2007). Based on the promising results of this test a second test was conducted from September 2008 to January 2009. Both tests aimed to clarify the amount of AFR that could be segregated out of delivered wastes by the local waste reclaimers and being utilized for cement production. The AFR recovery test was jointly financed by the City of Iloilo, Holcim Inc. and the German Technical Cooperation (GTZ). The produced AFR were test-wise utilized by co-processing them at the cement production plant of Holcim in Lugait, Mindanao.

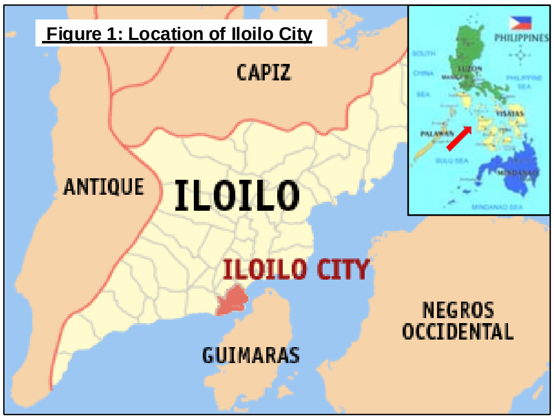

Figure 1 Location of Iloilo City

LEGAL CONTEXT FOR MATERIAL RECOVERY

The legal requirements for material recovery in the Philippines are provided by Republic Act 9003, also called Ecological Solid Waste Management Act of 2000, Chapter II, Section 20. This section states:

Establishing Mandatory Solid Waste Diversion – Each local government plan shall include an implementation schedule which shows that within five (5) years after the effectively of this Act, the LGU shall divert at least 25 % of solid waste from waste disposal sites through re-use, recycling, and composting activities and other resource recovery activities. Provided, that the waste diversion goal shall be increased every three years thereafter. It is noted here that nothing prohibits a local government unit from implementing reuse, recycling, composting activities designed to excel the goal.

Although RA 9003 sets clear waste diversion targets with section 20, there are no regulations regarding AFR recovery in the law. To overcome this gap, Holcim and GTZ initiated a corresponding guideline (GTZ-HOLCIM 2005 and CeMAP 2008). This guideline provides relevant information on technical, legal, environmental, safety and health concerns and especially proposes standards for permitting requirements, waste delivery control, waste acceptance criteria, co-processing, emission limits, monitoring and reporting formats.

OBJECTIVES, METHODS AND LIMITATIONS

Objectives

The conduct of the "*100-day AFR recovery test*" aimed primarily to assess the technical, social and financial viability to recover AFR as a routine operation of municipal waste management in Iloilo City. Based on the results and lessons learned from the prior conducted test in 2006, the following aspects and questions were raised:

- How much AFR could be recovered per day and work shift with the existing MRF unit?
- What AFR quality could be expected under routine work conditions and what are the main threats which would hinder a regular AFR recovery?
- What could be done to upgrade the material recovery rate and to address other bottlenecks which were identified during the test?
- What other materials could be gathered with the existing MRF simultaneously to AFR recovery?
- How can the involved management and waste reclaimers being capacitated to maintain the AFR recovery, to secure an efficient production and to work together as a team?
- What are the impacts on the operation of the proposed new landfill and the local environment?
- What are the socio-economic impacts on the local waste reclaimers?

Methods and Limitations

To obtain a representative sample of the waste generated within the City, five waste collection trucks with an approximate loading capacity of 7 m^3 each were designated to collect wastes from sources out of the city center during the daily routine waste collection. The sources included locations from central commercial and business districts.

The MRF test-run was conducted in two shifts. The first shift started at 8:00 PM until 4:00 AM and was followed by a second shift from 4:00 AM to 12:00 Noon. Each shift was run and managed by a team of 15 personnel who were selected among the local waste pickers. Each team was lead by a foreman, which the members of the shift selected themselves. Each team member was assigned to a specific work station with a specific task. Project coordinators from the Local Government and external observers from the AHT GROUP AG attended the test and documented important activities and events during the entire test run. Furthermore, selected waste reclaimers were interviewed individually prior, during and after the test run to identify changes in their perception related to the segregation test.

A major limitation of this study is the accuracy of volume and weight of the processed waste samples. The incoming waste could only be assessed by volume due to the lack of a weighing bridge. However, output materials could be measured on a per kg base in smaller units at the MRF and are more accurate. Comparing the results of input and output records, a significant discrepancy between the weight of the inputs and outputs became obvious. As a consequence, material balance equations could not be established and hence, the potential degree of material recovery has a low accuracy.

CONDUCT AND FINDINGS OF THE 100-DAY AFR RECOVERY TEST

Segregation Process and utilized Equipments

The material recovery test formulated the following main objectives and steps of treatment:

- Segregation of non-biodegradable, dry materials, mostly mixed plastics, garments, packages to be segregated manually and stuffed into bags provided by Holcim ("*Tonner-Bags*"),
- Segregation of organic materials to be utilized for composting,
- Segregation of sellable materials such as cardboards, paper, glasses, metals, hard-plastics,
- Mechanized segregation of mixed fine materials (under-flow from trommel screen) which are a mix of sweepings, ashes, fine organic materials, soil-like components, broken glass, small metals, stones etc for waste disposal.

The process followed a so-called positive sorting scheme, meaning desired materials were sorted out, while undesired materials were left on the conveyor belt to be finally disposed. The test aimed to process up to five truck loads from the routine public waste collection per shift with an expected total throughput per shift of up to 25 tons. Based on the prior conducted recovery test from 2006 it was expected that up to 5 tons AFR could be recovered per workday (Paul et al. 2007). The central material recovery facility provided the following technical components to conduct the test:

- A bay area for unloading incoming mixed waste as inter storage prior to the entrance conveyor belt,
- A small wheel-loader to bring waste materials from the loading bay to the entrance conveyor belt, also used to transfer segregated or residual wastes to their storage or disposal facilities,
- A conveyor belt with the dimension 5 m x 0.5 m for loading and pre-sorting incoming waste,
- A rotating drum or trommel screen for sieving out a fraction < 4 cm,
- A loop of four conveyor belts of approximately 4 m x 0.5 m length each, which allow manual sorting of materials along the loop,
- A truck (7.5 tons loading capacity) used to transport residual materials from the MRF to the waste disposal site.

The following Figure 2 illustrates the process flow of the AFR recovery at the Calahunan MRF.

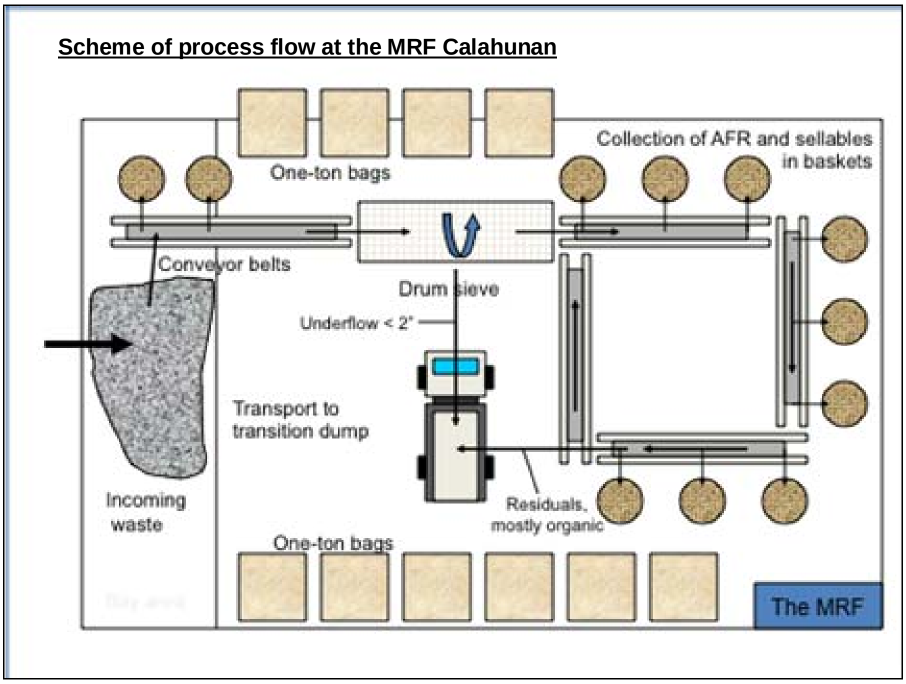

Figure 2 Scheme of process flow at the MRF Calahuan in Iloilo City (Lange 2009)

Incoming wastes were unloaded at the bay station and taken over by the small wheel loader. Plastic bags or other cardboard boxes were manually opened at the entrance conveyor belt and disturbances such as glass bottles, larger metals, woody components etc were segregated. A significant amount of sellable materials were already segregated at this work station. The remaining, pre-sorted materials then entered the trommel screen, where fine materials < 4 cm were removed (under-flow). This fraction of mixed waste was directly forwarded to the waste disposal site.

Materials which passed the trommel screen (over-flow) were forwarded to the loop conveyor system (4 belts) and underwent manual sorting. The waste workers were assigned to gather all materials which were sellable from their point of view, all materials which could be utilized as AFR as instructed by Holcim and all organic materials, which could be forwarded for composting. Remaining materials on the conveyor belt were considered as residual waste and were either loaded manually or with the small wheel loader on the provided truck and forwarded to the dumpsite. Recovered AFR and recyclables were collected in baskets. The filled baskets were weighed and recorded.

The objective of the segregation process was not to segregate out all potential AFR entirely but to achieve the highest possible material output in time. Hence, some of high-calorific materials ended up in the residual waste fraction and were forwarded to disposal.

Figure 3 Waste workers segregate materials which passed the trommel screen at Calahunan MRF

Recovered AFR were finally stored in the provided "*Tonner-Bags*", wherein the materials were compacted by stepping on them after bag loading. Sellable materials were stored separately and sold on a daily basis to local scrap dealers. During the test the following data were monitored and recorded:

- Input of waste material for treatment per shift (in kg),
- Output of recovered AFR and output of secondary raw materials per shift (in kg),
- Attendance of recyclers at the MRF per shift,
- Output of sellable materials,
- Payment per person and week (in Peso) and income development per person and time,
- Development of waste diversion over time.

Findings

The test itself covered a time span of 15 weeks and resulted in a total production of 228.5 tons of AFR for cement production. This correlates with an average output of 15 tons AFR per week. The average work efficiency reached 7 shifts per week, whereas 30 waste reclaimers worked in two 8-hour-shifts with 15 members per shift. The average output per shift was approximately 2 tons. This means an average output per person/shift of around 130 kg. The reduced work efficiency was mainly caused by changing weather conditions, in particular rain events, as well as by technical problems such as the break down of the wheel loader or the conveyor belts. Further delays were due to problems related to storage and transport logistics, especially delayed AFR packaging or lack of place for AFR storage.

Based on the Holcim feedback, the quality of the recovered AFR was very good throughout the entire test. Additionally, a total of 23 tons of various Secondary Raw Materials (SRM; mainly sellable materials) were recovered during the test period. The average output of SRM per week was 2 tons. On average, each shift recovered approximately 300 kg sellable SRM per day. The recovery of SRM took place at the same time as the segregation of AFR for co-processing in cement production.

Prior to the test, it was agreed that all recovered SRM should be owned and sold by the recyclers after each shift. On average, each recycler collected 20 kg of secondary raw materials together with the mentioned 130 kg of AFR per shift. Moreover, during the test it became obvious that the recyclers had recovered literally all of the sellable SRM that were contained in the incoming waste. The price level thereby had no significant impact on the recovery rate. The following Figure 3 shows the development of the material recovery during the test for AFR and SRM.

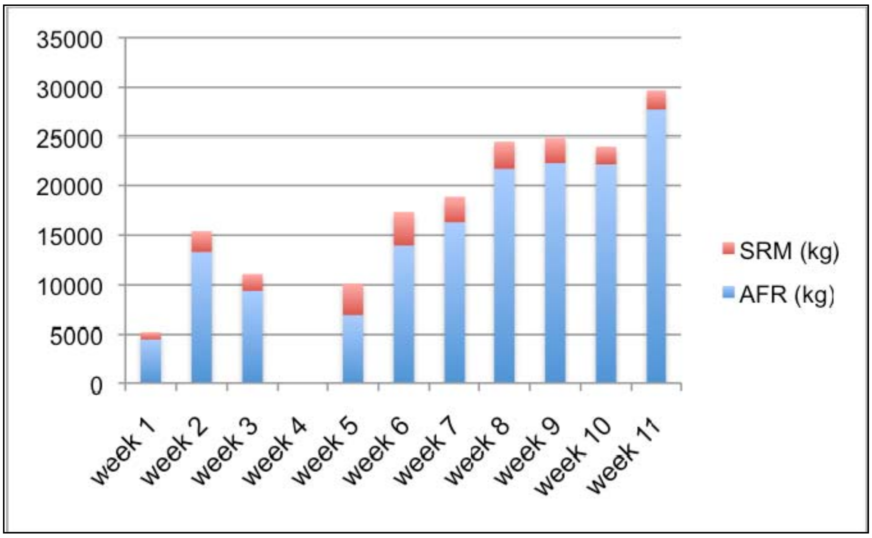

Figure 4 Weekly material recovery rates during the 100 day AFR test (Lange 2009)

Figure 4 reveals that the recovery rate for AFR could almost be doubled during the 100-Day test, whereas the recovered SRM quantity remained comparatively stable. The recovery of AFR was basically a new activity for all team members, meaning certain skills and routine procedures were only established during the test and resulted in increasing efficiency over time. However, during the last four weeks of the AFR test, the recovery rate surpassed > 22 tons/week respectively or > 4 tons/day.

During the 100 Day recovery test, 228.5 tons of AFR and 23 tons of sellable SRM were recovered. This means a total amount of 251.5 tons of valuable materials that were recovered from the incoming wastes instead of being disposed.

If the conducted test, which tackled roughly 15 % of the daily delivered waste volume at Calahunan, would be extended to the total delivered 160 tons per day, a material recovery in the magnitude of up to 20 % could be achieved. However, the presently installed capacity for material recovery is not sufficient to treat all of the the incoming waste. In order to efficiently segregate AFR from the incoming waste at Calahunan, a capacity five times bigger as presently installed would be needed.

Challenges and Shortcomings

During the four month time span of the AFR recovery test various shortcomings and challenges became visible. Weather conditions and particularly heavy typhoon rains were problematic for the work process and material storage. Although the MRF is protected by a rooftop, the bay entrance area, where the incoming wastes were stored, is in the open and site drainage of the building is not completed yet. Consequently, the moisture content increased drastically during rainfalls, which reduced the AFR quality. Moreover, heavy rains hindered material segregation and resulted several times in clogging of materials on the conveyor belts and in the trommel screen. In addition, the lack of storage places hindered the AFR packing especially during rainy days and consequently reduced the recovery efficiency. Furthermore, handling space and takeover points for segregated materials were insufficiently developed and reduced the work output. Lastly, the "*Tonner-Bags*", which were provided by Holcim, were not always on stock in the needed number and hence limited the AFR material packaging and work process. Besides, the packing and handling of AFR into "*Tonner Bags*" turned out to be too time consuming. The test revealed that the packing and storing aspect of the bulky AFR materials will be of paramount importance to establish sound logistics and to enhance efficiency.

As observed during the prior test in 2006, the utilized, small wheel loader remains a bottleneck of operation because of regular puncturing of tires due to metal components contained in the delivered waste (Paul et al, 2007). Due to the lack of a fence surrounding the MRF, straying animals such as goats, dogs and cattle which occupy the storage places hinder the material transfer.

Cost aspects of the conducted AFR recovery test

External funding was a prerequisite to conduct the AFR test as agreed upon by the main involved stakeholders prior to the test. The main cost factors to conduct the test were as follows:

- Cost for purchasing the AFR from the recyclers (artificial set at 21 US-$/ton),
- Cost for supervising staff, project coordination, monitoring, documentation and evaluation,

- Cost to run MRF operation (electricity, fuel, maintenance, cost for spare parts etc),
- Cost for providing protection gear (e.g. robber boots, goggles, gloves, air protection masks), mobile toilet and fresh water,
- Transportation cost for public waste collection and for material transportation from MRF Calahunan to the Holcim pier in Iloilo City,
- Shipment from the Holcim pier in Iloilo to the cement production plant Lugait, Mindano.

The following Table 1 summarizes the various cost aspects of the conducted AFR recovery test.

Table 1 Summary of expenses of the 100-Day AFR recovery test at the Calahunan MRF

Aspect [1)]	Unit	Cost in Peso	Cost in US-$[2)]
MRF operation	228,445 kg AFR output	228,445	4,860.50
	MRF conveyor and mechanized screen	10,500	223.40
	Small wheel loader	40,428	860.20
AFR transport MRF to pier	Mini dumptruck	32,444	690.30
AFR transport MRF to pier	Dumptruck	51,926	1,104.80
Labor cost LGU Iloilo City	2 permanent and 6 casual workers	179,039	3,809.30
Cost work protection gear	For 30 workers	90,000	1,914.90
Cost for entrance, mid-term and final workshops	3 workshops	55,000	1,170.20
Cost for “*Tonner Bags*” AFR packing		Not established	-
Cost shipment Iloilo-Lugait by Holcim		Not established	-
TOTAL		> 687,792	14,633.60

1) cost for planning, coordination, monitoring, documentation and public waste collection provided by Iloilo City, GTZ, EMB-6 and HOLCIM and cost for depreciation of MRF not included, 2) based on an average exchange rate of 47 Peso = 1 US-$

The total cost of the AFR test are estimated to be > 14,633 US-$ for the recovery of 228 tons AFR or > 64 US-$/ton recovered AFR. This cost estimation does not include the depreciation costs for the MRF facility, cost for provided consultancy works, cost for the public waste collection and cost for AFR shipment from Iloilo City to the Holcim cement production plant Lugait, Mindanao. However, the cost estimation does not consider potential cost reductions of recovered SRM and organic waste. If the latter materials would be included in the cost estimation, the cost per ton recovered AFR would be significantly lower. The latter potential cost benefits still need to be established at a later stage of project development.

It is of course hoped that the started approach can be enhanced in various aspects. For instance by switching to AFR baling instead of manual packing into “*Tonner Bags*” as discussed during the final workshop.

DISCUSSION

Technical and environmental benefits

Although, waste segregation and the establishment of a composting component is mandated by RA 9003, so far a large fraction of municipal waste disposed in the Philippines is composed of organic residues (Paul et al. 2008). Hence, the conducted AFR recovery test also aimed to establish better data on recoverable organic materials besides the SRM and AFR recovery. During the 100-Day AFR recovery test the following average distribution of main waste fractions was identified:

- AFR for co-processing in cement production with a diversion potential of up to 20 %,
- SRM as group of sellable materials under local market conditions with a diversion potential in the magnitude of 3-5 %,
- Organic materials > 4 cm particle size for composting with a diversion potential of 20-30 %,
- Residuals, mainly mixed components such as sweepings, soil-like components, rocks, ashes, broken glasses and fine organic materials with 35-45 %.

Recovery of AFR, SRM and organic waste actively contributes to resource protection and energy efficiency and contributes to avoid environmental problems related to resources extraction (mining) and burning of fossil fuels.

Related to the local context, the complete recovery of AFR, SRM and organic waste materials at Calahunan could at least double the lifespan of the proposed new landfill and significantly contribute to lessen organic waste disposal, whereas the potential for methane and leachate generation would be far reduced and likewise the landfill stability increased. In total > 80 tons/day of AFR, SRM and organic waste could be recovered instead of being disposed, provided the needed segregation and treatment facilities would be established. Besides, this approach would further contribute to offer additional livelihood options for local waste reclaimers.

Socio-economic Impacts for the Informal Sector

In terms of socio-economic development, the most important impact of the test was the generation of a steady income for the 30 waste reclaimers. This income was generated from the regular sale of AFR to Holcim, whereas for the test an artificial price of roughly 21 US-$/ton were proposed by the development project. Further income for the waste reclaimers was generated by selling SRM based on the price level of the local market. The recovered 228.5 tons of AFR provided an income of roughly 4,800 US-$ (price of 1 Peso/kg AFR) whereas the additional recovered 23 tons of SRM had an economic value of roughly 2,400 US-$ at the start of the test. However, at the end of the test the value decreased to only 880 US-$ due to declined market prices. Each participating recycler was able to gain a daily income in the magnitude of 3.3 to 5.3 US-$ per workday, an income higher then their prior income from waste picking at the dumpsite. This means that the test participants could be elevated over the statistical poverty line of 2 US-$/day as formulated with the Millennium Development Goals of the United Nations (UN-MDG). However, the price level for SRM dropped significantly in the course of the latest world financial crisis in the second half of 2008, which also affected the income of the waste reclaimers for SRM starting in November 2008. Compared to the average income for SRM recovery of 3.3 US-$/worker/day, the income for SRM dropped down to 0.7 US-$/worker/day for the same quantity of SRM.

Besides the income, other important effects were observed during the test. Working conditions were set and achieved at the MRF as similarly found in a formal employment. The recyclers benefited from team work, regular work hours, weather protected work places, work protection gear and access to fresh water and basic sanitation. The pre-condition that they would be paid during the test based on performance as a group demonstrated to be the "*right choice*". Prior to the test they were used to pick waste individually at the dumpsite or to work in very small groups. Although team work was not forced upon the workers during the test, the joint interest to gain a better income gradually motivated them to perform tasked jointly and more efficiently. This aspect also contributed greatly to enhance work related communication and skills development. The project coordination team gave special attention to gender related aspects prior and during the test.

Although women and men were equally invited to join the test, it turned out that > 60 % of the finally recruited workers were women in the age bracket 31-50 years, who are married with children. It is assumed that married women with children are more restricted to perform waste picking at the dumpsite and hence preferred to get involved into the AFR recovery test. The work at the MRF was clearly perceived as the better work choice by the involved recyclers, if compared to the waste picking at the open dump as expressed during the final workshop by most of the test workers in December 2008 by the reclaimers themselves.

After the MRF test run, the involved workers were asked which system they would prefer in recovering materials from the wastes. Almost all answered, that they prefer the MRF system if compared to the open system at the dumpsite. When asked why they prefer to recover materials using the MRF system rather than to collect at the open dump, they stated that the MRF system is more systematic and makes material recovery easier. They further mentioned that working in the MRF protects them against sun and rain. Potentials for accidents with garbage trucks and other incidents like puncturing or stepping on unwanted wastes are also minimized based on their experience.

In terms of their working relationship, the waste reclaimers appreciated the value of teamwork. The MRF system offers individual roles and work places for each team member. As a result they do not need to compete or struggle over the materials to be recovered. However, a significant advantage of the former system over the MRF operation - as mentioned by the waste reclaimers - is their freedom to work anytime they like compared to the ordered 8 hours continuous work at the MRF. Furthermore, in the former system, they only collect what they want to collect whereas in the MRF system, they have to collect and process nearly everything including non-sellable materials and residuals.

CONCLUSIONS

Iloilo City is the first Local Government in the Philippines which started to test if the recovery of AFR out of the municipal solid waste stream is a feasible option for waste reduction. The chosen approach is well supported by the general potentials of AFR recovery on a global scale and especially for the context of developing countries, which so far hardly utilize "*waste-to-energy*" technologies to enhance their solid waste management systems (Lechtenberg 2008). The experiences made during the "*100-Day AFR recovery test*" are very promising. Hence, the establishment of a routine operation for AFR recovery is welcomed by all involved parties. This statement is underlined by the establishment of a corresponding Memorandum of Agreement between the Local Government Iloilo City, Holcim Inc., the Environmental Management Bureau Region 6, and the German Technical Cooperation, which was signed recently on May 25, 2009. The reached development progress is further manifested by the formalization of the involved waste reclaimers as a legal business entity. They availed of an official registration as "*USWAG Calahunan Livelihood Association, Inc*." by the Securities and Exchange Commission of the Philippines on May 12, 2009. This is considered as an important milestone to strengthen their role as private partner and to take on a more active role in the routine material recovery process. This development will also assist to reach out for new livelihood options by supporting the local municipal waste management program.

The envisioned AFR recovery offers substantial cost savings for the Local Government whereas especially the cost for the future landfill operation may be decreased due to reduced waste disposal rates. This would also assist to lengthen the life span of the proposed new landfill. The latter is significant since a new suited site to establish a landfill in Metro Iloilo could not be identified so far. Furthermore, the project offers to contribute to poverty alleviation, especially for the involved waste reclaimers who may obtain a more stable income and enabled to change their daily work place from the open dumpsite to a more organized and protected material recovery facility. The latter offers a weather protected work place, team work, work protection measures and access to sanitation and water facilities.

Lastly, Holcim Inc. may receive AFR on a regular basis, which would allow reducing imports and utilization of coal for cement production. The utilization of AFR through Holcim would also reduce the extend of the landfill operation and hence lessen the generation of harmful Green House Gases emissions, which are considered as the main reason for climate changes and related environmental problems. However, to establish a sustainable MRF operation at Calahunan, various measures for process enhancement such as establishment of additional MRF units, equipments and storage facilities, enhanced AFR packing with baling technology, integrated recovery of organic materials with subsequent composting within the daily MRF operation and others need to be explored.

With regards to socio-economic impacts, the most significant contribution of the AFR test was the provision of a steady income for the involved waste reclaimers. During the test period an income in the magnitude of 3.3 – 5.3 US-$/worker/day was realized. However, due to the volatile prices for sellable materials it seems of paramount importance to increase the efficiency of AFR recovery and to integrate the recovery and composting of organic wastes into the MRF operation. This may further assist to establish a more independent MRF operation in relation to changing prices for SRM and local market fluctuations.

To further enhance material recovery at the Calahunan site, many efforts are needed, especially to capacitate the involved waste workers. Although they are already formalized as a legal entity their current capacity to act as a formal business partner is still unstable. Further development assistance is needed to upgrade their skills and to strengthen them as an official project partner of the Local Government Iloilo City and Holcim Inc.

Finally, it should be kept in mind that by recovering and utilizing AFR for cement production, by producing compost and by utilizing other recyclable materials, new opportunities were created for the social and economic development of local waste reclaimers. The envisioned transformation of Calahunan from an ordinary dumpsite into a modern Waste Management Center would be a significant contribution to enhance the work and living conditions of waste pickers at Calahunan. However, this can not be accomplished without transforming the present waste pickers into a capacitated labor force for waste management. The latter would be a significant contribution to enhance the work and living conditions of waste pickers at Calahunan. Besides, the United Nations Millennium Development Goals specifically mention this marginalized group of people to be addressed by poverty alleviation measures.

ACKNOWLEDGEMENT

The Authors wish to thank Mayor Jerry P. Treñas, Engr. Raul Gallo, the City Council as well the employees from the General Service Department for their continuous support to prepare and conduct the AFR recovery test. Furthermore, the authors would like to acknowledge the generous financial assistance provided by the German Technical Cooperation. Last not least, the authors like to express their sincere gratitude to all involved waste reclaimers from the Calahunan site, for their willingness to participate in the test and to perform new and often less attractive duties by segregating mixed solid waste and by packing and baling AFR materials.

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Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Community Participation in Municipal Solid Waste Management

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ABSTRACT

Substantial increases in Municipal Solid Waste (MSW) generation in the urban areas of Bangladesh create negative environmental impacts in the urban life of the country. Household solid waste currently constitutes about two thirds of MSW and most receives no processing after it has been generated. Proper management of the household solid waste stream has considerable potential to enhance the performance of MSW management systems as a whole. Improvement in MSW management will occur gradually through institutional strengthening, legislation enforcement and community involvement. These can significantly reduce the amount of domestic solid waste entering MSW streams before going to landfills. Reduce, reuse and recycle system of household waste can be established through community participation. Private-public partnership program may be established in MSW management system. Through community participation, community members especially the younger generation will aware of the benefits of MSW management and environmental issues. Therefore community participation can play an important role in the development of MSW management program. This paper describes some issues of community participation in the management of MSW in the major cities of Bangladesh.

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. But protection of environment is a burning and global issue. Urbanization, industrialization, construction of infrastructure all is good source of wastes. Due to lack of financial, human and technical resources in the municipalities of Bangladesh are not able to provide these basic services adequately (WasteSafe 2005 and Alamgir 2009a). Municipality is obligated to manage its solid waste and keep their environment healthy. But solid waste management is a complex system. Broadly it has two dimensions. One is municipal initiative and other is producer responsibility. So community participation has a great impact in MSW management.

Community participation is a sociological process by which community people organize themselves and become involved at the community level to improve the condition of daily life. By this the community members assume responsibility for their welfare, develop capacity for contribution. In this process they come to know their own situation better off and are motivated to solve their common problems. It comprises various degree of individual or collective involvement at different stages. Such as: financial or physical contribution and social commitment. Through community participation, community people can raise their needs in the activities. Furthermore, community participation can increase capabilities of community members. Due to resource limitation, city authority cannot manage solid waste in a proper manner (Rahman 2009). So city authority is training to find out a new strategy to solve the problem. Currently many cities of Bangladesh are managing their wastes through community participation. A public private partnership has already been developed in the field of waste management. This partnership program should more effective and sustainable. Community participation is the only way to achieve it (UNDP 1993).

COMMUNITY PARTICIPATION IN SOLID WASTE MANAGEMENT (SWM)

Local government body like City Corporation or municipality is obligated to manage the solid waste, which is produced in their area. If one thinks in depth, the mind reminds that waste is produced by human activity. So citizen involvement is necessary in any stage of SWM. Accordingly, to keep any SWM systems running, participation of the human community is required in putting the waste at the definite place at a proper way at the right time. At the individual level, residents have the responsibility as a waste producer. This involves actions like storing of waste in a proper way at producing point, separate recyclable or reusable materials from the waste and cleaning the area around the house. For greater interest people should perform organized activities, like meetings, clean-up campaigns, and awareness raising works. Furthermore, community participation may involve financial or physical contributions to the activities of waste management, for example, supporting the city program of waste management abiding by the city laws and paying fees for waste management.

For more involvement people can organized and participate in field level activity of waste management, express opinion and ideas about further improvement of existing methods and can jointly supervise, monitor its activities. To achieve this they should organized as forum and make link between community and local government authority. They can arrange house-to-house waste collection. The highest level of community participation in solid waste management will achievable when community members will form community-based organization and go under the same umbrella; consists of NGO, local government authority and development partner.

BENEFITS OF COMMUNITY PARTICIPATION

City Corporation or Municipality of Bangladesh suffer from a lack of financial, technical and human resources and are therefore not capable to deliver and maintain waste management service adequately. So city authority wants community support in waste management activity. Community participation has great impact in solid waste management. Possible benefits of community participation in waste management are:

Improvement of Waste Management System

SWM is a complicated task. Residents produce wastes. City authority has obligation to manage. There is a close relationship between city authority and people in case of solid waste management. City authority and community people both expect that their waste will be managed and city environment remain clean and healthy. To meat the need city authority should have to improve waste management system. Due to resource limitation city authority need external support for improvement. It may be financial or participatory. When community involve in waste management activity, community can able to integrate their needs in waste management system and contribute in operation system and with the community support city authority perform solid waste management works effectively.

Community Empowerment

Community participation may increase awareness, knowledge and capacity of community members and also may improve their ability to negotiate with authorities and other stakeholders to promote community welfare and increase individual responsibility within the community. Community participation can ensure different needs and opportunity to solve community problems. It also may give people the opportunity to devise and initiate strategies to improve their situation. Through increased knowledge and awareness regarding waste and environment most of the people become conscious about their environment, health and sanitation. Community people are encouraged and their capacity is built up. Community people can raise their voices wherever and whenever necessary. They can bargain with the Government and Non Government Organizations. Municipality, the residents and community forum may provide a good solution in dealing with the technical and commercial aspects which communities find difficult. Provided that community get necessary support from concerned agencies community people can move forward in any type of community-based programs.

Established of 3R Concept

Every moment's waste production is increasing. But waste management facility is not increasing as needed. Waste disposing land is shorting day by day. In future city authority will have in a great problem with wastes. So reduction of waste quantity and type is very necessary to conserve our environment. Accordingly Reduce, Reuse and Recycle of waste are a golden concept in the field of waste management. Bangladesh is a poor and developing country. So implementation of modern technology in waste management is very difficult. If we can establish house-to-house waste collection through community participation we can implement the 3R concept. In case of house-to-house waste collection community committee can impose charge for waste collection on the basis of waste volume. So to save the money residents will try to decrease their waste production. Community people can motivate residents to separate their waste into three categories; organic, reusable and recyclable and should store in separately. If residents separate household waste, city authority can arrange the following steps of reuse and recycle system.

Economic Gain

Any method of waste management, though it is energy converting or recycling or composting, it is not cost effective, but it has great impact on environment. So any type of activity, which can bring waste management to economic gain, has a great value. When household waste can separate in generation point, income of each household will increase by selling reusable or recyclable wastes. The residents will have some money for selling the recyclable and reusable wastes. Residents are required to separate their waste into three categories; organic, reusable and recyclable and should store in separately. Community ensures to collect the waste separately. Thus final disposable wastes may reduce and cost of waste management will decrease. Community forum or city authority should purchase recyclable and reusable wastes. The residents will have some money for selling the recyclable and reusable wastes.

Sustainable Environment Conservation

Environment protection is a global issue. Waste management has important impact on environment. But local body of under developed country is less capable to conservation of environment by proper management of solid waste. If community participation will establish in waste management system of all cities of Bangladesh existing waste management will be improved. Community can mobilize local resources and maximum utilization of existing resources can be possible through people's participation. Community can realistically play in management of their own waste depends on local context. Through community participation community members especially the younger generation will aware of the benefits of waste management and environmental issues. Individual motivation can successful setup and manage waste collection system that lead to overall environmental improvement. Women members of community can take part in hygiene, cleanliness and waste management. When general people come to participate and contribute in waste management, city authority can able to adopt an environment friendly waste management system and sustainable environment protection will establish.

Establishment of Public Private Partnership Program

Currently community people are very conscious about their environment. Many communities of different cities of Bangladesh are willingly participating in MSW management activities. They contribute by physical labour or financial support. City authority is providing awareness building training to the community members and doing motivation works. Community members are participating in planning, organizing and supervising the activities of waste management system of city authority. Now a strong mutual trust has been established between CBOs and municipality through waste management system.

PRESENT SCENARIOS OF WASTE MANAGEMENT

Present solid waste management system of almost all cities of Bangladesh consists of three components-collection, transportation and disposal. The collection of waste and cleaning of streets are done manually. Daily a large amount of wastes have uncollected and that create much negative impact on health and environment. But City Corporation or Municipality has the obligation to manage their wastes. Due to lack of resources, proper regulatory law enforcement mechanism and local government commitment- they cannot manage their wastes properly. But since few years, the attitude of local government of waste management has been changed. Now, local government is trying to improve solid waste management system. People are more concern and more aware about their living environment and started working with local government. Many Non Government Organizations (NGOs), Community Based Organizations (CBOs) and private sectors have been started to work with city authority. Prodipon, Prism Bangladesh, Waste Concern are prominent of them. Bangladesh Environmental Lawyers Association (BELA) is an especial type of voluntary organization. Their main function is to protect the environment through application of environment related laws. Currently, few cities of Bangladesh have taken initiatives for better management of their wastes. Dhaka and Khulna City Corporation have started to disposal their waste into sanitary landfill. But they cannot dispose their all wastes in their sanitary landfill. Many cities of Bangladesh have no land for construction of sanitary landfill. Traditionally waste management department of local government authority collect waste from dustbins and streets. They deposit it in dumping ground in an open condition. Domestic servants or owners themselves deposit household waste into the secondary collection points (dustbin). But all the residents do not deposit their waste into the bin. Generally they throw wastes over streets or near to the dustbin or comfortable places. These wastes create unhealthy environment and make blockage of drains.

Figure 1 Open dumping of wastes

Figure 2 Waste transportation

The ultimate waste disposal sites are generally situated in and around the city areas of low -lying open places, unclaimed land, riverbanks and roadsides. Even in some cities do not have any specific place for disposal. All the ultimate MSW disposal sites of Bangladesh do not have minimum infrastructure requirements and environmental protections. Considering controlling parameters such as contents of waste types, rainfall control facilities, distance to drinking water aquifer, site drainage, potential to create leachate at site, distance to domestic water source, site accessibility, frequency of burning, site materials exposure to public and vector and degree of public concern, it is evident that all ultimate disposal sites are posed to high threat to health and environment .On the other hand city authority has not sufficient transportation tracks, compactors and others logistics. Daily average generation of MSW at Chittagong City Corporation areas is 1500tons. Conservancy trucks and hired trucks operating in two shifts and are collecting about 800 to 1000 tons of solid wastes per day. About 500 tons of solid wastes are remaining uncollected. This situation is almost same in case of other city. So environment of all cities of Bangladesh are now under threat of hazardous impact of wastes. It is the responsibility of city authority to improve their waste management system. Current status of MSW in Bangladesh can be obtained in WasteSafe (2005, 2008 and 2009), Ahsan (2005), Ahmad and Rahman (2000) and Enayetullah and Sinha (2003).

PRESENT SCENARIOS OF COMMUNITY PARTICIPATION

In Bangladesh waste management is running in an old manner. Few cities are trying to adopt modern methods. But to keep the city clean, hygiene and environment-friendly, generated solid waste should be managed in a scientific way. But solid waste management is a complex system. Broadly it has two dimensions. One is municipal initiative and other is producer responsibility. Traditionally residents deposit their household wastes in the bin of municipality generally at night. They pay conservancy tax. These are their routine participation or contribution. For the improvement of the system, community participation in solid waste management should be increased. Now-a-days, few communities of the city have come forward and taken initiative for better waste management. They are contributing in many ways. Followings are the examples of community participation in solid waste management. More on community participation can be obtained in Bidlingmaier (2009), Alamgir (2009b) and Haedrich (2009).

In Dhaka city many communities are participating in solid waste management by an organized way. Kalabagan community is the pioneer one. Kalabagan is a densely populated area in Dhaka City. Interior streets of kalabagan are very narrow. City conservancy track could not enter there. Wastes collection of Kalabagan was insufficient. Environment of Kalabagan was deteriorated. Local people were united to solve the problem. They made a committee. They decided their activity. Accordingly they purchased two rickshaws and modified into rickshaw van and started collecting waste from house to house in 1987 and disposing the wastes in the bin of city at a far distance on the mirpur road. Community collects waste collection fees from residents and they provided rickshaw van puller. Impact of Kalabagan community participation was appreciable. Within short time nearby community followed it and formed form to do the same. Now many communities are joined to participate in solid waste management in Dhaka city.

Figure 3 Rickshaw can collecting household waste

In1994, Chittagong City Corporation declared Jamalkhan ward as healthy ward. World Health Organization supported Chittagong City Corporation in the activities of Jamalkhan healthy ward. Initially community people organized and searched out the problems of solid waste management. The community people raised the issues that people live in the community were of different behaviour and different level of awareness and attitude. They also all raised that all the family of the community was not of equal income and all residents were not produced same amount of waste. So in case of participation their contribution should be different. With the community people opinion they started waste collection from house gate rather than house-to-house collection.

Figure 4 Rally within the community for awareness rising

Because this type of waste collection all people of community had the same contribution. City authority divided Jamalkhan ward into nine zones and provided Rickshaw van with driver for each zones. The residents were required to contribute physically by delivering the wastes to the rickshaw van when the van driver announced his presence by blowing a whistle twice in a day. It was the responsibility of Chittagong City Corporation to provide the rickshaw van and pay the salary of the van driver. Gradually this type of waste collection system spreads in many wards of the city.

In Barisal City Corporation waste collection by rickshaw van started in 1993. Barisal City Corporation selected five residential areas; named Boydapara, Jordan compound, Brown compound, Alekanda and Fakirbari. There were narrow roads, conservancy trucks did not enter, and waste collection was difficult. Two rickshaw vans were engaged for each area. Van driver was appointed from City Corporation. The residents delivered their wastes to the rickshaw van when the van driver announced his presence by blowing a whistle once in a day. Some residents managed van drivers to collect their waste from their house and they pay to the van driver 30.00 to 50.00 taka per month as an incentive. The incentive makes the rickshaw puller more attentive in his daily work. Due to the demand of city dwellers city authority increased rickshaw vans into 40 for new areas. In 2007 with the support of UNDP under Local Partnership for Poverty Elimination Project a new initiative was taken by Barisal City Corporation. Four poor communities of Barisal city were selected for their wastes management through community participation named charbadna-2, BDS Christian colony, and Shawsan Ghate and Eshakhati Christian colony. There were 200-300 families in each community. The communities were deprived of city waste management facility. Waste management committee was formed in each community. Women members were 60%. Training was providing to the community people about waste management. Community meeting and rally were done for awareness building. One rickshaw van was given for each community. Tubs were provided for each family to deposit their wastes. When the van driver announces his presence by blowing a whistle, resident deposits their waste into the rickshaw van. The community committee fixed 10/-taka waste collection fees for each family per month. The committee paid the salary of van driver and committee members monitored van driver's sincerity and efficiency. It is observed that people's participation was satisfactory. All decisions were taken in the community meeting and the community people made a good relation with the city authority. Here community participation was more effective and environment of the community improved much.

CHALLENGES OF COMMUNITY PARTICIPATION

The success of community participation in waste management depends on multiple factors. It depends on the attitude of community people, commitment of public representatives, cooperative attitude of municipality's officials and involvement of local leaders. For example, if City Corporation does not collect waste separately, it has no value of in-house separation of wastes. There are many challenges for strengthening the existing system; hence the city authority should take initiative for further improvement. Major challenges can be listed as:

- Community motivation.
- Community participation.

- Introducing service charge for house-to-house waste collection.
- Arrangement of financial resource.
- Availability of logistics.
- Voluntary or contributory service generally does not last long.
- Different types of people live in a community and they have religious barriers, social hierarchy, different level of literacy and these impede their participation.
- Support, commitment and participation of City authority.
- Sustainability.

WAY TO OVERCOME THE CHALLENGES

Local leaders can play important role in community participation. They can encourage the residents for in-house separation of their wastes and to collect the waste separately by the community forum and take steps that people pay the waste collection charge. Furthermore, they should act as a negotiator for local authorities; supervise the performance of local authorities and act as a pressure group to obtain services from the local authorities. Comprehensive initiatives should be taken for changing the community attitude and to obtain public representatives' commitment. Following are the initiatives that can enhance the successful and sustainable community participation:

- Awareness building activities Such as; Community meeting, Rally, Campaign, Advocacy.
- City authority should play main role to develop an effective public private partnership program in municipal solid waste management.
- In private public partnership program City authority can contribute 50% of solid waste management cost.
- City Corporation and community committee jointly can fix the house-to-house waste collection charge.
- Rickshaw van used for household waste collection should have three components. One for organic, one for reuseable and one for recyclable waste for enhancing the economic value of waste.
- Community committee should the responsible for the controlling the activities of waste collector.
- Encouraging a sense of responsibility of family members.
- Ensuring the people that all are doing for their benefit.
- Involvement of whole community.
- Community committee should form with the representative of all stakeholders.
- All decisions should take through participatory method.
- Concern local leaders can stimulate community participation and ensure that community needs are taken into account.
- Women can play a determining role in waste management and they form important channels of communication.
- Establishment of income generation activity; compost fertilizer, Biogas plants, reuse and recyclable waste based small industry.
- Prioritization of waste management activity in city development program.
- Build-up private public partnership system.
- Policy and Law should reform for waste management.

CONCLUSIONS

Due to inherent constraints of resources of local authorities in Bangladesh, implementation of modern waste management system is difficult and even the sustainability of the existing system is in question. But City Corporation or municipality is obligated to keep the city clean and habitable. Community participation is essential to meet the city dwellers demand by overcoming the constraints. Community members can participate in different stages of waste management in different ways, such as paying collection fees, disposing waste at appropriate time, and separating reusable and recyclable materials in the house, dispose it separately and city authority collect it separately for final management. Furthermore community members may be involved in awareness raising activities, participate in meeting to influence the process of the City Corporation activities. Effective coordination between NGOs/CBOs and City Corporation is very important for community participation in solid waste management. Introduction of public private partnership system can improve the quality of waste management.

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ISBN: 978-984-33-0761-3, Vol. 2, pp.707-716

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Study on the Traditional Practices for Solid Waste Recycling in Rural Homes

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ABSTRACT

Solid wastes are important components for recycling biomass to return the nutrients to their origin. Traditionally, the people of the Ganges and the Brahmaputra basins have been recycling solid wastes for centuries. The practices which are followed here have scientific merit but in most of the cases, the people are ignorant about those facts. The present study was conducted in 90 rural homes of Ishwarganj and Nandail Upazillas under the district of Mymensingh. The objectives of the work were to find out the scientific explanations of the recycling practices. The study showed that the traditional procedures which are being applied on trial-and-error basis got the effective result of supplementing organic materials to the soil. Although these effective practices have been used generation after generation, in-depth studies were not carried out. This study has uncovered the scientific reasons behind many of the traditional practices of solid waste management. Chemical analyses revealed that most of the macro-nutrients, namely potassium, phosphorus, nitrogen, calcium, sulphur, magnesium, iron and total organic matter contents were not depleted; rather, the total organic matter contents increased significantly after the recycling. This kind of rural home-based and short-cycled solid waste management ensures zero depletion of organic soil content.

INTRODUCTION

Civilization began when nomads first took shelter in permanent homes and started cultivating the earth. Home became their centre of all activities. They used to collect their livelihoods from the surroundings, learnt to process and store them for their use in their homes. During the processing and utilization, the un-utilized remaining, called the ‘wastes’ were left, thrown away or stored for degradation and recycling. From the experience, people acquired knowledge for easy and safe recycling methods for better utilization of wastes in favor of natural environment. Home is a microenvironment and fulfils an ecosystem.

Traditionally, the inhabitants of the Ganges and Brahmaputra Plains were more conscious about hygiene, natural resources and agricultural practices and they were used to practice simple methods in their homesteads knowingly on unknowingly, which are really important and scientifically rich even during this advanced technological era.

However, with the advancement of mechanization and industrialization and the influences of western culture many of the traditional cultural practices have lost their importance and are not in use by the common people. Therefore, it is essential to collect the age-old practices used by the common people for waste management and biomass recycling. These should be studied to investigate their scientific merit and re-establish their positive roles in the present complicated situation aroused by the modern cultures, specially, by the chemicals and shortcut cultures. With this aim, Centre for Global Environmental Culture (CGEC) of IUBAT—International University of Business Agriculture and Technology along with Homestead Cropping and Ecoagriculture Research Center for Sustainable Rural Development (HCERCSRD) conducted the present study in a few villages of Mymensingh in the Brahmaputra Basin.

MATERIALS AND METHODS

During the study, the sources of waste, previous and present practices of waste and residue management were investigated; relevant information and data were collected from the fields and villagers. Fact-finding works were done through physical observation, analysing data and comparison with present practices. Traditional practices are supported by figures and question-answer methods with the villagers. Chemical analysis of soil was done in the laboratory of the Bangladesh Tea Research Institute, Srimangal. The present study carried out in-depth analysis of the major crops and activities are focused.

OBSERVATION

The following major sources of wastes in the rural homes are found, in most cases the biological products come from the fields, homestead forests, ponds, rivers, Haors, Bheels, and the markets, are utilized and processed and the residues are recycled through some traditional practices. The main sources of solid wastes are:

- Agricultural crops
- Foods
- Pets and domestics
- Litter and sweepings
- Fuels
- Clothing
- Building materials
- Utensils
- Corpses, faeces and excreta

Agricultural Crops

Major crops

- Food crops: Rice, wheat, millets, sugarcane, lentil, pulses, potato, vegetables, onion, garlic, ginger, turmeric and chilies etc.
- Fruits and nuts: Mango, jackfruit, litchi, banana, carambola, papaya, pineapple, lemons and oranges, black berry, Bullock's heart, coconut, betel nut, Palmyra palm and dates etc.
- Meats and Fishes: Beef, mutton, chicken and fresh water fishes and prawn etc.
- Fibres: Jute, hemp, silk cotton, coir and silk etc.
- Oilseeds: Mustard, linseed, peanuts, sesame and castor oil etc.
- Corms and tubers: Arums (*Colocasia spp.*), Elephant foot yam, Kham-aloo (*Dioscorea atata*)

Rice

Rice is the major crop produced by the farmers of the villages. After harvesting this field crop, the grains are separated from the panicles, are cleaned by sieving or blowing out the debris, Chittas etc. Husks and bran are also removed manually by traditional Dheki and or power operated husking machine. Residues viz. straws, Chittas, husks and bran have the secondary uses and then undergo decomposition or burnt to ashes. The common practices are:

Table 1 Traditional uses and recycling of rice residues

Residues	Primary Use	Secondary Use	Dispersal, decomposition and recycling
Straws	Fodder, Thatch, Packing materials, Fuel	Mulch	Cow-dung, Ash, Compost
Chittas	Fuel	Mulch	Ash, Compost
Husks	Fuel, Smoking, Mud-wall cladding	Mulch	Ash, Compost
Bran	Fodder, Poultry feed		Excreta, Compost

Jute

Jute is the second most important crop produced by the farmers of the selected villages. After maturity, jute is harvested from the field, rotten in water; fibres are separated from the sticks, dried and bundled for sale. Fiber is the primary product used for weaving, ropes and threads etc. Sticks are also dried and used as fuel, thatch, wall cladding and also for making pulp. The common practices are:

Table 2 Traditional uses and recycling of jute residues

Residues	Primary Use	Secondary Use	Dispersal, decomposition and recycling
Sticks	Fuel, Fence, Cladding, Thatch, Chips, Paper pulp, Support for creepers and climbers	Mulch	Ash, Compost
Leaves	Vegetable, Fuel, Fodder,	Mulch	Ash, Compost
Pods/Capsules	Fuel	Ticca (carbon), Mulch	Ash, Compost
Roots	Fuel	Ticca (carbon)	Ash, Compost

Sugarcane

Sugarcane is another important crop produces in this area. After maturity, the canes are harvested and sent to the mills or brought to the homes for traditional roller driven juice squeezer. The bagassee, leaves, leaf sheaths and twigs are the major residues which are utilized and recycled.The common practices are:

Table 3 Traditional uses and recycling of sugarcane residues

Residues	Primary Use	Secondary Use	Dispersal, decomposition and recycling
Bagassee	Fuel, Paper pulp, Packing materials	Mulch	Ash, Compost
Leaves and leaf sheaths	Fuel, Fodder, Cladding, Thatch	Mulch	Ash, Compost
Twigs	Propagation	Fodder and fuel	Ash, Compost
Roots	Fuel		Ash, Compost

Vegetables

Vegetables are also important crops produced in this area. The common vegetables are egg plants, tomatoes, amaranths (Danta, Lalsak), arums, beans, cucumbers, pumpkin, gourds, Pui, cinopodium, radish, cauliflower, cabbage and drumsticks etc. The common practices are:

Table 4 Traditional uses and recycling of vegetables residues

Residues	Primary Use	Secondary Use	Dispersal, decomposition and recycling
Whole plant	Fodder		Ash, Compost
Leaves and leaf sheaths	Fodder		Ash, Compost
Twigs	Propagation		Ash, Compost
Roots/bulbs	Fodder, propagation		Ash, Compost

Disposal of Solid Wastes

Solid wastes are disposed and recycled traditionally for hundreds of years. The people of the experimental area informed that they did not know when these systems were started. They also do not know the reasons for such accumulation of the refuses separately with distinct groups. They might have used trial and error method to establish best process for recycling. One thing is clear from the interrogation that, they know the need and benefits of the wastes for their crop production. During the study, it was also found that people followed some specific methods for specific purpose of

conducting the simplest ways of decomposition and recycling. A utilization and decomposition chart of household refuses is shown below.
Usually the green garbage and dungs of cow and horse are disposed in a pit of 2-3 meter

- Compost Pit: Cow-dung, goat droppings, fodder residues, waste green vegetables,
- Sweepings: Fallen dry leaves, chicken and duck droppings,
- Ash Heap: Fuel wood ash from the kitchen, burnt dry leaves and straws, etc.
- Human faeces: Latrine

Figure 1 Heap and rice straw

Figure 2 Cows eating straw

Figure 3 Cow-dung

Figure 4 Drinking water

Figure 5 Compost heap

Figure 6 Compost

Figure 7 Compost in the field

Figure 8 Fuel wood

Figure 9 Withered thatch

Figure 10 Sugarcane Bagassee.

Figure 11 Ash collection

Figure 12 Cow-dung sticks

Figure 13 Kitchen

Figure 14 .Large stove

Figure 15 Ash application

Figure 16 Cleaning utensil with ash

Figure 17 Jute hanger

Figure 18 Bamboo crafts

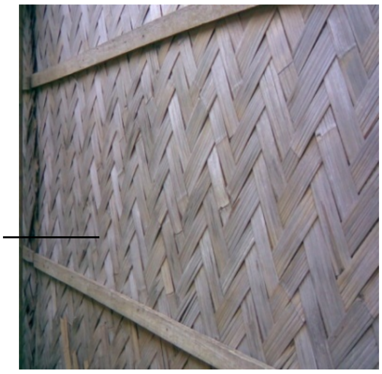


Figure 19 Bamboo cladding

Fig. 20 Floor cladding with Dung & Husk

Figure 21 Pitcher/Coconut shell

Figure 22 Goats eating banana sheath

Figure 23 Goat droppings

Figure 24 Chill

Figure 25 Chicken room

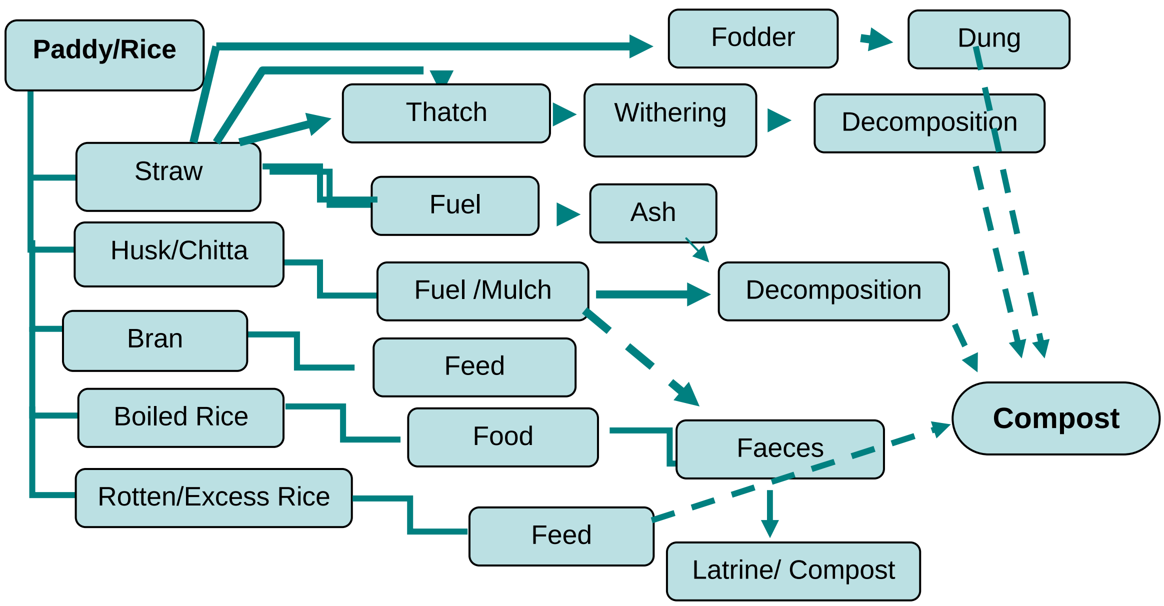
Figure 26 Mulched Bamboo

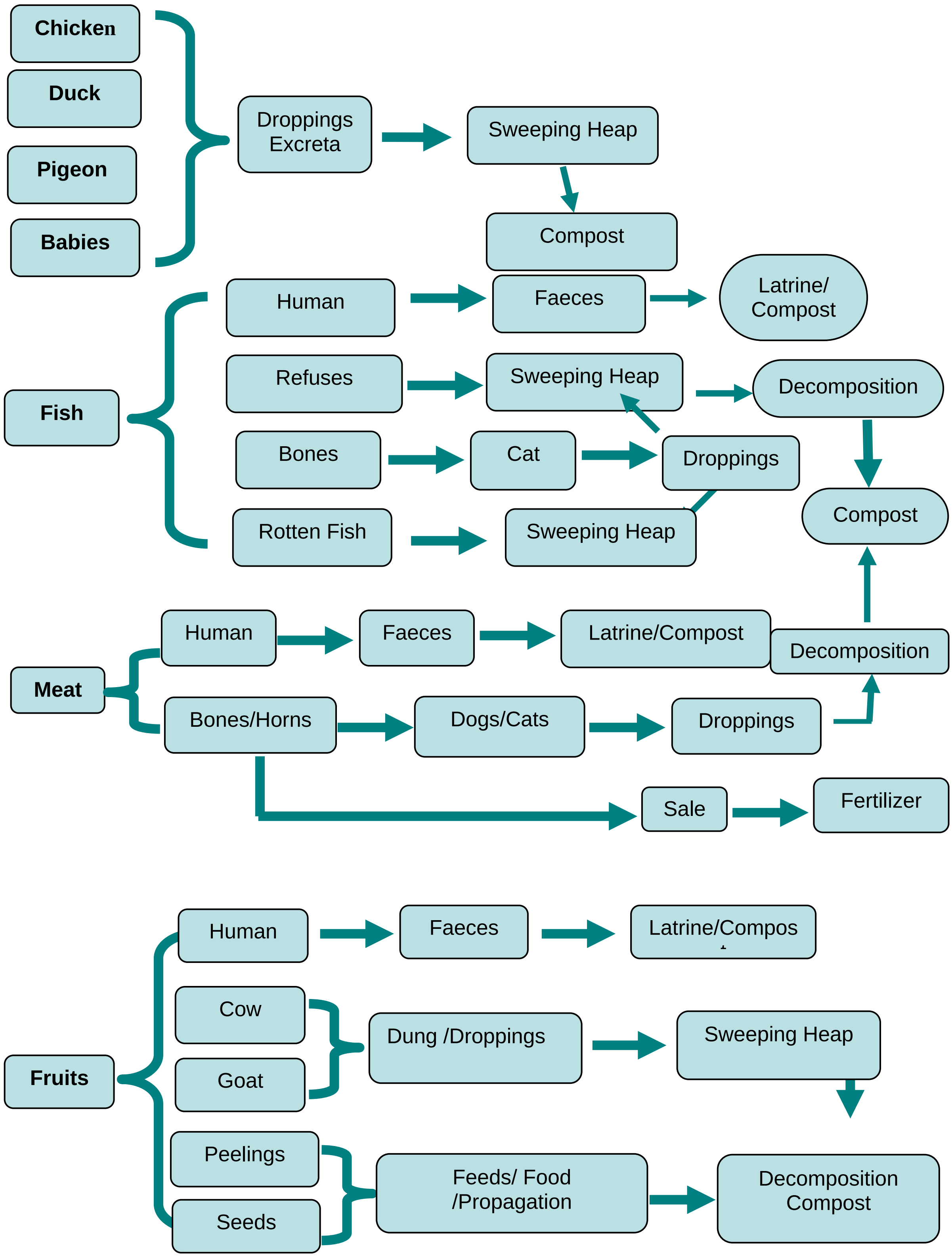
Figure 27 Bamboo beams & thatched roof

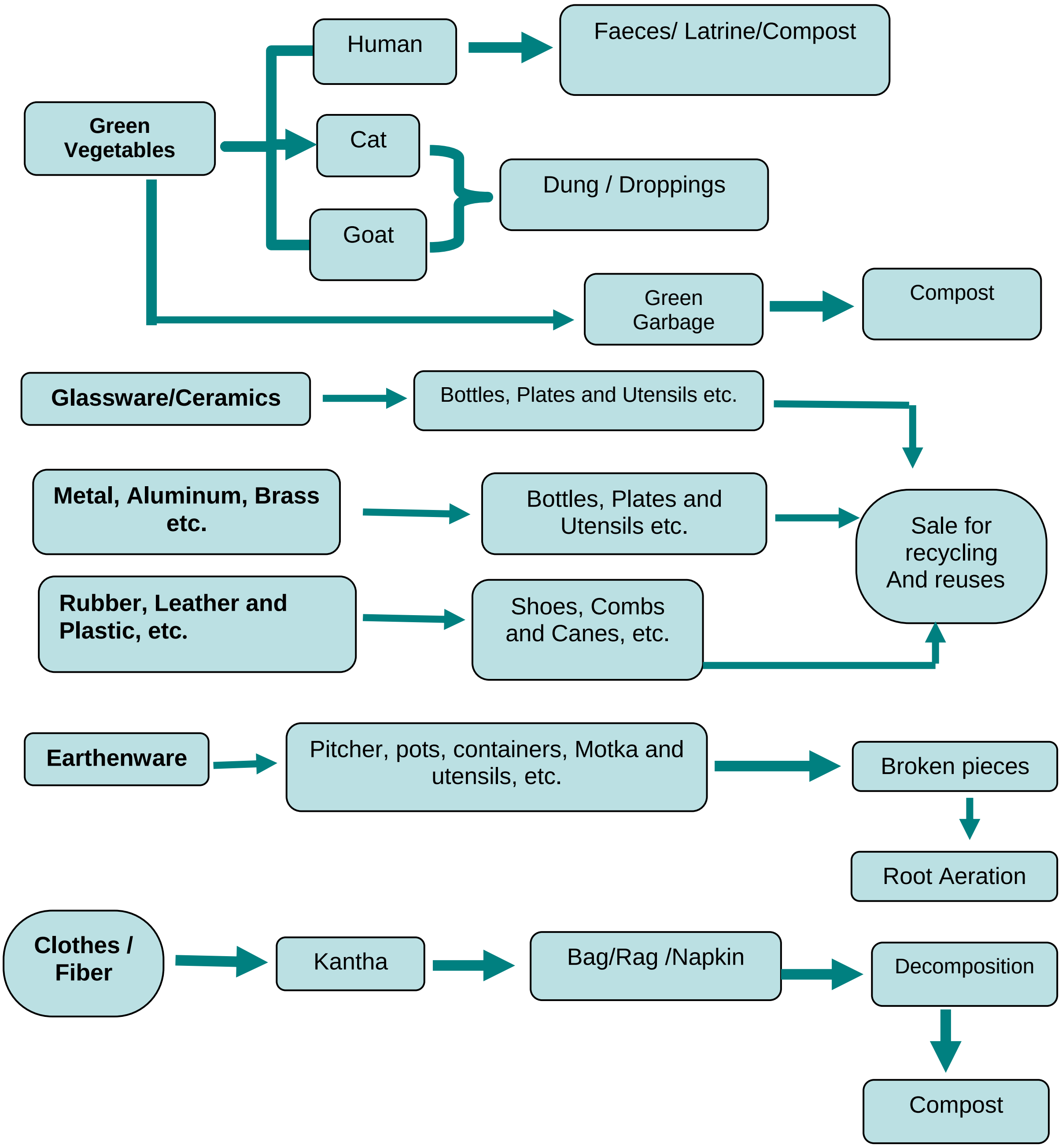
Figure 28 Betel nut leaf fence

Figure 29 Luxariant growth of homestead plants

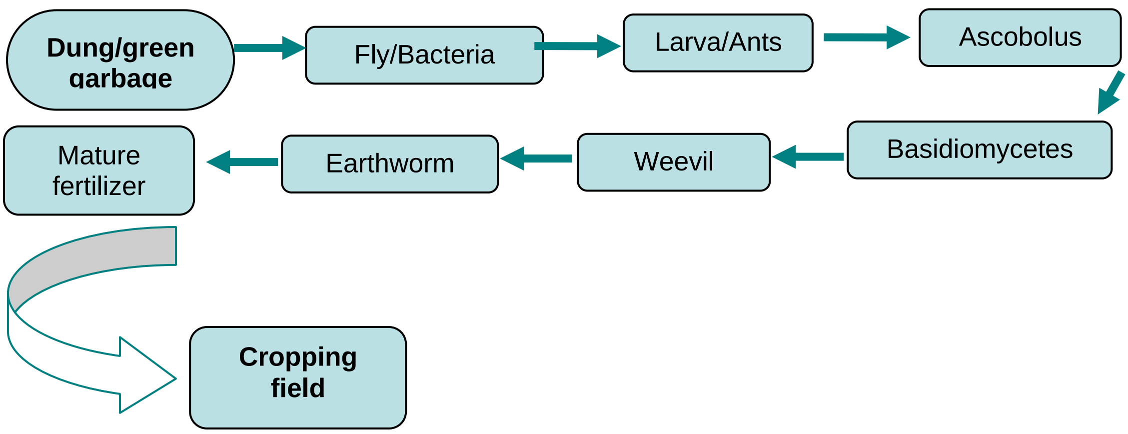
Utilization and Decomposition Chart of Household Refuses




Chicken
Duck
Pigeon
Babies
Droppings Excreta
Sweeping Heap
Compost
Fish
Human
Faeces
Latrine/ Compost
Refuses
Sweeping Heap
Decomposition
Bones
Cat
Droppings
Compost
Rotten Fish
Sweeping Heap
Meat
Human
Faeces
Latrine/Compost
Decomposition
Bones/Horns
Dogs/Cats
Droppings
Sale
Fertilizer
Fruits
Human
Faeces
Latrine/Compos
Cow
Goat
Dung /Droppings
Sweeping Heap
Peelings
Seeds
Feeds/ Food /Propagation
Decomposition Compost



Succession of Decomposition Flora and Fauna during Green Garbage and Cow-Dung Compost



RESULTS AND DISCUSSIONS

Chemical analyses revealed that the total organic matter and the ingredients viz. nitrogen, phosphorus, potassium, sulfur, magnesium, calcium, iron are not depleted after intense cropping. Analysis was done by taking samples from the fields which were not applied with any chemical fertilizers other than compost and mulching and no significant change was observed after intense cropping. The result is shown in the table 5

Table 5 Soil analysis report

Soil ingredients	Ingredient in April 2007 (ppm)	Ingredient in April 2008 (ppm)
Nitrogen	1230	1410
Potassium	85	95
Phosphorus	40	40
Magnesium	55	55
Calcium	100	110
Iron	125	120
Sulfur	45	40
Total Organic Matter (%)	1.57	1.61

Green garbage and cow-dung are decomposed in a 3m X 3m X 1.5m open pit, usually 20-30 meter from the houses. The major wastes are cow-dung, vegetables refuses, wet straws, green grasses, urine-mixed straws and sweepings from the cowshed. It takes about 7 to 8 months to complete decomposition starting from the month of February and March. The villagers do not mix ashes and dry leaves with the green garbage and cow-dung. Since ash does not contain nitrogen and dry leaves contain very low nitrogen, decomposition of green garbage delays significantly.

However, all fallen leaves and sweepings are gathered in a separate place and chicken, pigeon and duck droppings etc. are kept together for quick decomposition. As the dry leaves have very high carbon and low nitrogen (Rahman 2004 and 2005), the villagers are used to add fish remains, chicken droppings and baby stool etc. which contain high nitrogen (Talukder et al. 1993) with sweeping leaves for quick decomposition. However, in the wet season: June to August the sweepings decompose readily but in the dry season especially from October to April they use the sweepings mostly for mulching and some people burn them to make ashes.

The villagers are found to store ashes in a separate place or container. The ashes are mainly from wood, rice husk, jute sticks, rice straws, burnt leaves, dry cow-dung (Ghote) and cow-dung sticks, rejected or withered building materials. Leaves of coconut, betel nut and Palmyra palm etc. are usually used for making brooms, household utensils, handicrafts, fencing and also for mulching of coconut, areca nut, bamboos etc. However, after withering they are often used as fuel. These mulches are readily decomposed and the ashes are used as fertilizer and also to control insects.

After decomposition of the refuse, the villagers obtain manure and use this according to the needs of the crops. They use ashes for enrichment of soil fertility and to control pests and diseases. Thus, they ensure recycling of biomass to the cropping land which keeps the soil at zero depletion of nutrients through their traditional practices.

However, with the advancement of modern technology, mechanization and urbanization have been hampering rural home-based short-cycled biomass recycling and the countryside is suffering a great nutrient depletion. Therefore, we need in-depth study to incorporate traditional knowledge for improving the fertility of the soil of Bangladesh.

ACKNOWLEDGEMENTS

I gratefully acknowledge Professor M Alimullah Miyan, Vice Chancellor and Founder of IUBAT—International University of Business Agriculture and Technology for sponsoring the project. I would also like to acknowledge Professor Eric Frank, a pioneer in the fields of Education for Sustainability and a naturalist, and Former Professor of University of Bath, United Kingdom for financial support, as well as, his encouragement and cooperation. I am grateful to all of the villagers of Ishwarganj and Nandail Upazilas of Mymensingh, Bangladesh, who helped me to provide valuable information.

Special thanks are extended gratefully to my colleague Dr. A.C. Basak, my friend Dr. Robin Upton and my students of College of Agricultural Sciences, who scrutinized the manuscripts with great patience and helped me in many ways.

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ISBN: 978-984-33-0761-3, Vol. 2, pp.717-726

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Public and Private Sector Participation for Solid Waste Management in Dhaka City

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ABSTRACT

At present daily solid waste generation in Dhaka City Corporation (DCC) area is around 3,200 ton which is expected to be around 4,624 ton by the year 2015. DCC, different CBOs or NGOs and individual groups are involved in solid waste management in Dhaka City. Based on secondary information, household questionnaire survey, and focus group discussion, the paper tries to investigate the deficiencies in existing solid waste management system and the major problems faced by households and CBOs during waste collection and disposal. Despite having shortage of resources DCC even can not use its existing resources appropriately to manage solid waste in Dhaka City. Even, they do not have enough funds for solid waste management. The majority of households are not satisfied about the secondary waste collection system, which is mostly done by the DCC. However, despite some limitations around 85% of the households are pleased with the service level of primary collection system, which is usually done by different CBOs or NGOs or different unauthorized groups. CBOs/NGOs are doing huge profit from primary waste collection and this is the reason why besides primary waste collection now they want to be engaged in secondary waste collection and street/drain cleaning also. Based on the information some recommendations have been made in order to evolve an efficient solid waste management system for the city.

INTRODUCTION

Dhaka, the capital city of Bangladesh, is one of the fastest growing cities of the world. The growing number of population is generating large amount of solid waste every day. Dhaka City Corporation (DCC) is the legitimate authority to collect and dispose the solid waste generated within its jurisdiction. The waste generation rate in DCC is 0.558 kg/c/day whilst the rate of domestic waste generation is calculated 0.340 kg/c/day (BCAS, 1998). According to the national census in 2001 the population of DCC area was about 5.3 million; and considering the previous population growth rate it is predicted to be 6.74 million and 7.73 million by the year 2010 and 2015 respectively (BBS, 2001; Ahmed, 2006). At present the total solid waste generation of the city is around 3,200 ton/day, which is predicted to be 3,909 ton/day and 4,624 ton/day by year 2010 and 2015 respectively. However, only 37% of the total waste is collected by DCC and the rest remains uncollected or thrown illegally by the residents into the vacant land, low land, on street, and along the drain (JICA, 2004). Moreover, due to lack of the financial and legal framework, DCC is struggling to provide services with its limited resources.
Households are expected to store or collect waste in bins and dispose them in containers located on the main streets provided by DCC. However, DCC does not make house-to- house collection of waste. Most of the local streets are too narrow for DCC trucks to enter and collect waste. On the other hand, residents are reluctant to carry the solid waste up to the DCC collection points. Usually residents of Dhaka City are used to dispose waste on streets near to their doors. Consequently, community based organizations (CBOs) have come forward for door-to-door collection to keep the communities or neighborhoods cleaner. The first CBO to collect waste in Dhaka City has been developed in 1987 in the Kalabagan area and over the last years CBOs approach have been extended almost in all parts of the city (Banu, 2000). Currently a lot of NGOs/CBOs are operating in primary waste collection (house-to-house) with DCC’s approval. However, the main streets of the city still remains unclean as the daily collected waste by the CBOs/NGOs can not be disposed off to the

landfill site by DCC. One possibility may be to strengthen the capacity of the CBOs so that they can help the DCC to keep the city clean and healthy. This study is an effort towards this direction and aims to evolve an efficient solid waste management system for Dhaka, and thus made a relation among the stakeholders/participants to develop a well-organized waste management system.

The major objectives of the study are to investigate the deficiencies in solid waste management system of DCC, the problems faced by households and CBOs, and provide guidelines to evolve an efficient management system. To represent the scenario of whole city the study area has been selected from different parts having different characteristics: one planned neighborhood (Gulshan) and another unplanned neighborhood (Magh Bazar). Having the resource constraints only about 43 households from Gulshan and 77 households from Magh Bazar area have been selected (about 0.5% of the total households of the study area) through the systematic cluster sampling method and surveyed through a pre-determined structured questionnaire. Beside this, one CBO and one unauthorized individual person have been explored and about 15 officials working in the Conservancy Department of DCC have been interviewed. Other secondary sources such as reports, books, journals, government documents, etc. also have been reviewed and studied.

SOLID WASTE MANAGEMENT IN DHAKA CITY

Solid waste management system is a process to supervise the handling of waste material from source through recovery method to disposal, by any person engaged in such process as a business, or by any state agency, city authority, country or any combination thereof. Storage, collection, transportation and disposal of waste are the major elements of the system. The procedure of resources extraction or value from waste is referred to as secondary resource recovery or recycling; which is very significant of reducing waste volume and gaining economic benefit. Solid waste can be recycled as reuse or recovery or conversion (Cointreau, 1985); whilst disposal methods could be open dumping, sanitary landfill, incineration, composting and digestion.

In many cities of Asia, deficiencies in the provision of waste management services are the result of inadequate financial resources, lack of management and technical skills of the municipalities (Enayetullah and Sinha, 2000). For these reasons municipalities have encouraged the private sectors, for example, CBO or NGO to provide services. CBOs collect waste from door to door (in lieu of a charge paid by the households) and store at community bins from where waste is removed to the disposal site. Recently CBO has taken initiatives to motivate people in segregating waste at source and composting of organic waste.

Low-income countries generate lowest rate of waste, ranging between 0.4 to 0.9 kg per capita per day whilst particularly the countries having GNP less than US$ 400 produce less than 0.7 kg per capita per day (Furedy, 1992). Table 1 presents urban waste composition of low-income countries in Asia. Generally low-income countries have highest amount of compostable organic matter (40 to 80% of the total) in urban waste. High use of plastic and paper material will eventually increase the waste volume. Thus, the low and middle-income countries may experience nearly a 3-fold increase in their total waste quantities and volume while the developed countries will stay relatively constant by the year 2025.

Table 1 Composition or types of solid waste generated in low income countries

Components	Nepal	Bangladesh	Myanmar	Lao PDR	India	Sri Lanka	China	Est. 1999	Est. 2025
Urban Pop. 1995(million)	2.9	21.9	12.2	1.1	249.1	4.1	363.7	655	1526
Year	1994	1992	1993	1998	1995	1993-94	1991-95		2025
Waste Type	MSW %	Dom. %	Dom. Com. %	Dom, IC%	MSW %	Dom., Com. %	Dom, Com, MSW %	%	MSW %
Compostable	80	84.37	80	54.3	41.8	76.4	35.8	41.0	60
Paper	7	5.68	4	3.3	5.7	10.6	3.7	4.6	15
Plastic	2.5	1.74	2	7.8	3.9	5.7	3.8	3.8	6
Glass	3	3.19	0	8.5	2.1	1.3	2	2.1	3
Metal	0.5	3.19	0	3.8	1.9	1.3	0.3	1.0	4
Others	7	1.83	14	22.5	44.6	4.7	54.3	47.5	12

(Source: World Bank, 1999.)

The major portion (more than 80%) of domestic waste in Dhaka City is organic material (i.e. food, paper, wood, grass), including food waste (JICA, 2004). According to the BCSIR in 1998, moisture contents in domestic waste are high and its contribution is around 50%. Depending on income range, the domestic waste generation rate in Dhaka City varies between 0.21 kg/c/day to 0.59 kg/c/day and the estimated average rate is 0.34 kg/c/day. In accordance with the estimation of 2004, total solid waste from domestic source of 5.728 million people is around 1,945 t/d whilst from business is about 1,035 t/d (JICA, 2004). JICA estimated one sweeper can sweep about 110 m of road length and average volume of street waste is 365 kg/km of road length. Standard of required number of cleaners may be 1 or 2 cleaners per 1,000 populations in a city. As about 5,000 cleaners of DCC are cleaning the streets, 200 t/d (0.365 t/km x 110m x 5000) street waste is generating. Thus, the total amount of solid waste generation of the city is around 3,200 t/d.

At present, involvement of private sector or CBOs or NGOs is very common in primary waste collection (door-to-container) services where Conservancy Department of DCC is engaged in secondary waste collection (container to disposal sites) system in Dhaka City (Mohit, 1995). DCC has divided the city in 10 operational zones (1 to 10) for collection and disposal of waste; where only Zone 9 and 10 is managed by private sector. DCC has 1,289 units of storage facilities and 385 units of collection and transportation vehicles that can store and transport respectively 2,451 ton and 2,766 ton waste per day. Everyday DCC can collect only 1,193 ton waste (37%) and then the collected wastes are disposed in landfill sites of Matuail, Gabtoli and Uttara. This reveals that storage and transport capability of DCC are under-utilized and the same time the resources (both human and material) are not distributed proportionately in different zones. DCC spends 18% of its total expenditure for solid waste management where only 6% revenue is generated from this sector (Haque, 1993).

Various types of organizations or individuals (i.e. NGOs, CBOs or local organizations, organized communities or associations, clubs) are engaged to provide door-to-door waste collection services in Dhaka City. It is assumed that more than 130 organizations were involved in door-to-door waste collection services in 1999 (JICA, 2004). With the aim of organizing the primary waste collection activities, DCC has initiated an approval system in 2002 for the NGOs or CBOs or private organizations to provide door-to-door waste collection services at ward level. Generally rickshaw vans are used for door-to-door collection, where waste picker collects waste from each house and keep the waste into the rickshaw van. Sometimes residents bring their waste to rickshaw vans using buckets or bags. Then the van carry the waste to the dustbins or containers from which transported at land fills for disposal. NGOs or CBOs charge fees of BDT 10 to 50 per month per household in low and middle income areas and BDT 50 to 100 or even more per month in high income residential areas like Gulshan and Banani.

DCC collects the waste from the communal dustbins or containers and later transports to the disposal sites based on conventional model of solid waste management that is ‘collection-transportation-dumping’ of waste. The conservancy department of DCC is the main or core for solid waste management of the city. Operations of solid waste management of DCC are classified into four categories: cleaning of road & drain, collection & transport, dumping & landfill, and repair works. Total expenditure for solid waste management of the city was BDT 476 million, which stands for BDT 930/ton or US$16/ton, in the fiscal year of 20002-03. The major portion (85%) of the total expenditure was spent for cleaning of road & drain and collection & transportation of waste.

According to the estimation, amount of waste generated from Zone-5 is the largest (197 t/d) followed by Zone-6 (175 t/d) and Zone-8 (156 t/d) (JICA, 2004). Around 385 units of vehicles have been allocated for waste collection and transportation services of DCC, of which 65 are now under repair. Assuming two trips for open truck and three trips for container carriers, estimated total capacity of collection and transportation of DCC’s vehicles is approximately 2.76 t/d. Assuming the size of dustbin 2 m^3 and bulk density of waste 500 kg per cubic meter, total storage capacity of all dustbins and containers in 10 zones has been estimated approximately 2,451 tons (DCC, 2004). There are various methods used for solid waste treatment and disposal in developed and developing countries. However, DCC practices open dumping crude method or insanitary landfill. However, the landfill operation is being conducted without having any covering of soil, leachate collection, and gas removal facilities.

The existing bins and containers can store 78% of the daily generated waste volume of 3,200 ton whilst the remaining is disposed or thrown into low land, vacant land, ditch area, drain, water body and road. However, only 48% space or storage capacity of the container or bin is used and the remaining is unused because of inappropriate design and careless dumping into the bins and containers. DCC uses only 43% of the total transport capacity because they make less number of trips. Open truck and container carrier can collect and transport 86% of the waste by making two and three trips respectively per day. Through proper utilization of existing capacity of bins or containers and transport vehicles, DCC could collect and dispose approximately 2,766 tons (86%) of waste per day. It can be concluded that DCC has to use properly its existing resources as well as increase capability in order to improve solid waste management of the city. By increasing 22% of storage and 14% of transport capacity, DCC may able to collect and dispose the whole waste generated in Dhaka.

PRIVATE SECTOR INVOLVEMENT IN SOLD WASTE MANAGEMENT

Local government is responsible to provide solid waste management services in urban areas. This does not mean that local government has to carry out the whole solid waste service with its own resources such as staff, cleaner, vehicle, equipment and money. Private sector can play their role in some parts of entire waste management service. Responsibility of the government could be reduced through the involvement of private sector in service delivery. Some important criteria are efficiency, capability, competition, accountability, and cost recovery etc. to consider whether the private sector will be involved in waste management or not. The most common methods of private sector participation in solid waste management are: contracting, concession, franchise, and open competition (Cointreau, 1995). Among the above methods, DCC follows ‘contracting’ for the privatization of solid waste management in some wards of Dhaka City. Usually in contracting the government makes an agreement with a private firm for the delivery of waste collection service, street sweeping service, transfer station operation, collection of recyclable waste, fleet maintenance and disposal site operation, etc.

Problems of solid waste management are acute in many cities of the developing countries. The shortcomings and solutions of managing solid waste in these countries are more or less similar. Some relevant experiences have been described here. Facing the problems of poor collection and disposal of waste, Exnora (an NGO) was founded in Chennai of India in 1989 with the aims to aware people about environmental problems from solid waste and reduce the problems through community participation. Exnora deploys Street Beautifier to collect waste with a charge of Rs 10 from door to door by tri-cycle cart and transport to the transfer point from where municipal authority remove the waste to the disposal sites. However, as the municipalities are not capable of transporting the collected waste to the disposal sites, Exnora has introduced new methods of waste recovery (i.e. waste segregation at source and composting of organic waste at household). Households were encouraged to segregate waste and the civic Exnora has provided green color basket to the households to keep organic waste; which is composed to produce fertilizer and the remaining non-usable waste is transported to the transfer points for dumping. At present around 3,000 Civic Exnoras are working in India.

A group of housewives of Baloch Colony of south Karachi in Pakistan had formed Karachi Administration Women’s Welfare Society (KAWWS) in 1990 and started to organize people for private waste management in their neighborhood. As secondary collection system by the municipality is not regular, KAWWS manage the refuse vehicle driver with regular payment to ensure waste transportation to the disposal sites. In 1994, KAWWS has got a grant from UNICEF for purchasing waste bins. The efforts of KAWWS have made the area cleaner and improved environment.

Community organization ‘Baromtrilokanat 21 Community’ in Phitsanulok province of Thailand was formed by 289 people from 81 families with the support of Phitsanulok Municipality in 1997. With the aim of people’s participation in community management they prepared a community waste management plan. Under the plan, the measures of composting organic part (kitchen and garden waste collected in brown bin and called as compostrainer), reuse (recyclable wastes are segregated at households and sold to recycler), and dumping of unusable waste (which is not usable kept in green bins and disposed by the municipality) was taken. Assessment of these activities revealed that before introducing waste separation everyday the community produced 306 kg whilst after segregation it becomes only 132 kg. Moreover, income of the households raised by selling recyclable waste, expenditure for waste management of the municipality has reduced, local environment improvement, and the people consider waste as resource.

The project called ‘Public Private Partnerships (PPP) in Community Waste Recycling’ had been initiated in Penang Island of Malaysia in August 2002 to improve the living conditions and waste disposal practices. The project partners comprises the Northeast District Rukun Tetangga (Neighbourhood Association Coordinating Committee) as a representative of community people because of their knowledge about the society problem and capability to support grass-root level, LHT Kitarsemula Sdn. Bhd., a recycling agent, as a private partner, together with other recycling agents and manufacturers, as well as the municipal council of Penang. Discussions are carried out at the community level in local languages to implement PPP in community recycling project because the inputs are needed from the stakeholders. The community recycling committee has launched recycling activities at each pilot community. Community recycling day is observed regularly to increase community's awareness for household waste management and recycling. Innovative approaches (i.e. art competition among the children, cooking classes, street theatre and games) are arranged to attract residents during the awareness campaigning and training sessions.

Private Sector Involvement in Dhaka City, Bangladesh

At present 47 authorized CBOs/NGOs and some unauthorized groups are involved for primary waste collection in Dhaka City (Enayetullah and Sinha, 2000). Among them, a CBO operating in Gulshan and an individual person operating in Magh Bazar have been studied. Gulshan is the planned residential area of about 2.79 sq km area where around 48,876 people (mostly high-income group) are living. On the other hand, approximately 87,406 people (mostly mixed-income group) are living in around 1.28 sq km area of Magh Bazar (Ahmed, 2006). Many commercial activities and tall apartment buildings have been developed in Magh Bazar and a significant number of residential buildings have been transferred in non-residential functions in Gulshan. Most of the household size of the study area ranges from 4 to 6. About 48% of the residents have education of graduate level.
Kitchen and vegetable waste is the largest amount of total domestic waste in Dhaka City while paper (53%) is the second largest and then plastics (35%). Approximately 80% of the households of the city dispose their waste everyday. Around 68% of the residents store waste in plastic basket whilst 17% use metal or *tin balti* (sometimes paper or jute bag) and give the waste to the CBO's cleaner to dispose. About 92% of households dispose waste through the CBOs/NGOs (some cases by unauthorized individuals) and pay a service charge of BDT 5 to 200 (vary in different areas according to income level of the households). However, the service charge of the unauthorized individuals in Magh Bazar are so high that some households are not interested to have the service rather they dispose themselves in community bin. People find it inconvenient if the cleaners of CBO are irregular or collect waste in different times at different days, demand high service charge, scatters waste along the streets from overloaded van, etc. However, 85% of the households are satisfied with the service level of primary collection provided by CBOs/NGOs and 96% think that the situation has improved after CBO's involvement in door to door collection. In contrary, most of the residents are not satisfied with the secondary collection. Table 2 shows the major causes of poor performance of secondary collection are: waste is not removed from the containers for long time which causes environmental problems and spreads bad smell around the container, inappropriate design and placement of the containers, etc.

Table 2 Reasons for poor performance of secondary waste collection of DCC

Reasons	Gulshan (43)		Magh Bazar (77)		Total (120)	
	Frequency	%	Frequency	%	Frequency	%
Waste is not removed for long time from container/community bin/dustbin	37	86	73	95	78	94
Inappropriate design of bin/container	34	79	65	85	60	72
Inappropriate placement of container	21	49	59	77	50	60
Nuisance during waste loading in trucks	15	35	30	39	30	36
Open truck transport to disposal site	13	30	23	30	22	27

Note: Multiple Choice, Source: Field Survey, 2005

A private company is responsible for secondary waste collection in Gulshan and they provide better service compared with DCC serving in other areas. Even though most of the residents do not practice segregation of waste at source, around 72% of them recommended for it. About 88% of them suggested for appropriate designing of community bin and covered rickshaw van, awareness building through television and education at school for proper waste disposal. Campaigning is indispensable for making people aware about the importance of environmental and economic value of waste segregation at source. People highly appreciate the community based waste management but not pleased with the secondary waste collection of DCC. It was found that although households face some problems, they are satisfied with the performance of CBOs/NGOs for waste disposal.

The problems that the residents are facing for waste disposal with the CBOs or NGOs are: high charge (even different rate from different households) and even continuous increasing rate of the charge, and even if the demanded charge is not paid waste is not collected regularly, waste from the households is not collected in time and there is no regular fixed time for that; and sometimes waste is scattered from the overloaded van on the streets while carrying to the dumping station. Few people in Magh Bazar area dump the waste along the road and into the drain which pollutes the surrounding environment. The majority (92%) of the households want waste to be collected from their house everyday (mostly in afternoon 12 pm to 2 pm and evening 4 pm to 6 pm). About 81% express the design of rickshaw van should be covered.

Primary waste collection by NGO or CBO is very profitable. Cost of primary collection by CBO is BDT 304 and by unauthorized individual is BDT 118 for each ton. Secondary collection cost by CBO in Gulshan is BDT 298 per ton, less than that of DCC (BDT 402). CBO/NGO is working in organized manner and besides primary collection could be engaged in secondary collection and street/drain cleaning as they can manage with lesser cost.

At present different groups of city dwellers have come forward to handle the problem of inadequate solid waste management system. Haque Bhai Bhai Cleaning and Service and the individual person initiatives are such, working in Gulshan and Ward 54 of Mag Bazar area respectively, have been surveyed and their activities are presented below.

Haque Bhai Bhai Cleaning and Service in Gulshan

Haque Bhai Bhai Cleaning and Service, a CBO, have been working in Gulshan-1 and some part of Gulshan-2 for the last 12 years to serve approximately 6,000 households. This CBO has 14 rickshaw vans and each van makes three trips per day. There are two persons with each van – one driver and one cleaner. Rickshaw vans, belcha, tukri, kata, are used for waste collection from house and transport it to the community bins or dumping stations. They collect waste from 11 am to 18 pm for one time from households and also clean local streets in the morning from 7 am to 11 am. There is no dustbin in this area. The drivers or cleaners separate paper, plastic bottle from collected waste and sell to the shops (*vhangari dokan*). The drivers or cleaners or waste pickers segregate recyclable waste without wearing gloves or any safety measure to protect health, consequently they are vulnerable to health hazards. Sometimes dog and crow scatter waste from dumping station to the surrounding area that causes probable health risk for inhabitants. Income and expenditure of this CBO for primary waste collection vary in different months of the year. However, annual income has been calculated as BDT 72,00,000 where expenditure is only BDT 14,28,000 and BCR 4.92.

Individual Person in Magh Bazar (Ward 54 of DCC)

There is no NGO or CBO involved in door-to-door waste collection in Magh Bazar area. DCC authorized the responsibility to a CBO to manage domestic waste collection in this area but due to the conflict with Ward Commissioner it can not operate here. However at present, primary waste collection is controlled by some unauthorized individuals with the support of Ward Commissioner. One of these individuals has been interviewed who has been collecting waste for the last 6 years and currently provides services to around 400 households. He makes two trips per day and provides service from 12 pm to 3 pm and 4 pm to 6 pm and takes a fee of BDT 30 per household. After collection, waste is transported to the container in dumping station. Per ton primary waste (domestic waste) collection cost of the unauthorized person is BDT 118 and this person collects only 3.05% of total generated domestic waste in Ward 54 of DCC. Yearly income of this individual operator is BDT 1,44,000 where expenditure is BDT 36,000. BCR of the primary waste collection project is 3.751; which indicates the project is highly profitable for this unauthorized person.

MAJOR DRAWBACKS

Major deficiencies in solid waste management of DCC are: technical limitations, managerial drawbacks, financial limitations, and legal problems. There is lack of responsibility allocation and coordination among the concerned departments and divisions of DCC. Moreover, deployment and allocation of drivers, waste containers and transportation vehicles have not been done properly. The total solid waste generation in Dhaka City is approximately 3,200 ton/day where the estimated capacity of the existing vehicle fleets (385) is 2,766 ton per day, means daily shortage of 434 ton. Additional 29 units of 5 ton container carrier vehicle are needed. Total storage capacity of 1,289 units bins or containers is estimated equivalent to 2451 tons which is not enough to store the daily generated waste. Additional 150 units of containers with 5 ton capacity are required to collect the present amount of solid waste generated. Due to shortage of technical personnel and required tools, only small repairing works for transport vehicles and equipments are done in the DCC workshop. An organized and scientific database is unavoidable for preparing future plan on solid waste management, which is not available in DCC.

The total expenditure of DCC for solid waste management for the past four years has shown the negative balance of financial condition (Table 3). At present, conservancy tax is the sole income of DCC for waste management, which is equivalent to only 6% of annual revenue. The most important reason behind the financial deficiency is low tax rate.

Table 3 Financial Balance of SWM (BDT. in Million)

Items	1990-00	2000-01	2001-02	2002-2003	Ratio in own DCC
Overall SWM Income	126	141	150	176	6%
Overall SWM Expenditure	367	383	402	476	18%
Balance	-241	-242	-252	-300	

(Source: DCC, 2004)

Section 78(1) of the DCC Ordinance mentioned that the occupiers of the buildings and lands other than those of DCC are responsible to remove refuse from their buildings and lands; however, it is not clear when and where to carry the waste. Moreover, there is no provision for approval or authorization to CBOs/NGOs for primary waste collection in the ordinance. According to the Environmental Conservation Act 1995, the validity of the Environment Clearance Certificate (ECC) for Matuail Disposal Site has expired (GoB, 1995).

Problems Faced by NGOs or CBOs

NGOs or CBOs or individual persons involved in primary solid waste collection in Dhaka City are also facing several problems. Problems of Haque Bhai Bhai Cleaning and Service working in Gulshan area are: a few number of households do not receive door-to-door services from CBO and usually *Tokai* throw their waste into the lake or drain along the road; provided open dumping station (made of brick) is not well designed; and a private company called ‘Bangladesh Shomonnito Porishad Unnoyan Forum’ is responsible for cleaning drains and secondary collection whilst the CBOs are responsible only for cleaning the streets and primary waste collection but if the drain is not clean residents blame the CBO (because they do not know actually who is responsible for drain cleaning). On the other hand, the individual person working in Magh Bazar area can not give services to more households as he does not have enough money to hire employees and purchase the required number of rickshaw vans or equipments. DCC trucks do not come in time to carry the waste from container to the disposal site and most of the time the containers are overloaded.

Role of the Related Sectors and their Linkages

The major gaps have been identified by studying the existing waste management system of DCC, waste disposal practices of the household and CBOs are:

- communication gap among few residents (who are not participating in the community based solid waste management and dispose waste inappropriate way), between DCC and small local groups.
- inappropriate design of rickshaw van.
- lack of good relationship between ward commissioner and CBOs or NGOs.
- some unauthorized groups are working and lack of monitoring on CBO’s or NGO’s activities.
- lack of waste segregation at source.
- different rate of service fees collect by DCC and CBOs/NGOs.
- lack of coordination among the relevant departments of DCC.
- lack of accountability.
- timing of waste removal from households and containers (DCC trucks come in late to transport waste from container to final disposal sites, therefore waste remains in the container for long time).
- there is no synchronizing between primary and secondary waste collection.

DCC is not capable to run waste management system without involvement of private sector and active participation of people. JICA study team has proposed a ward based waste management system (WBWMS) for Dhaka City for efficient solid waste management. Figure 1 indicates the linkages among the DCC, NGOs or CBOs and community at Ward level for efficient solid waste management. Communication and cooperation among the DCC’s employees (all staffs have to communicate among themselves), linkage among the various Departments of DCC, linkage between SWM Division and other participants (i.e. NGOs or CBOs) should be ensured.

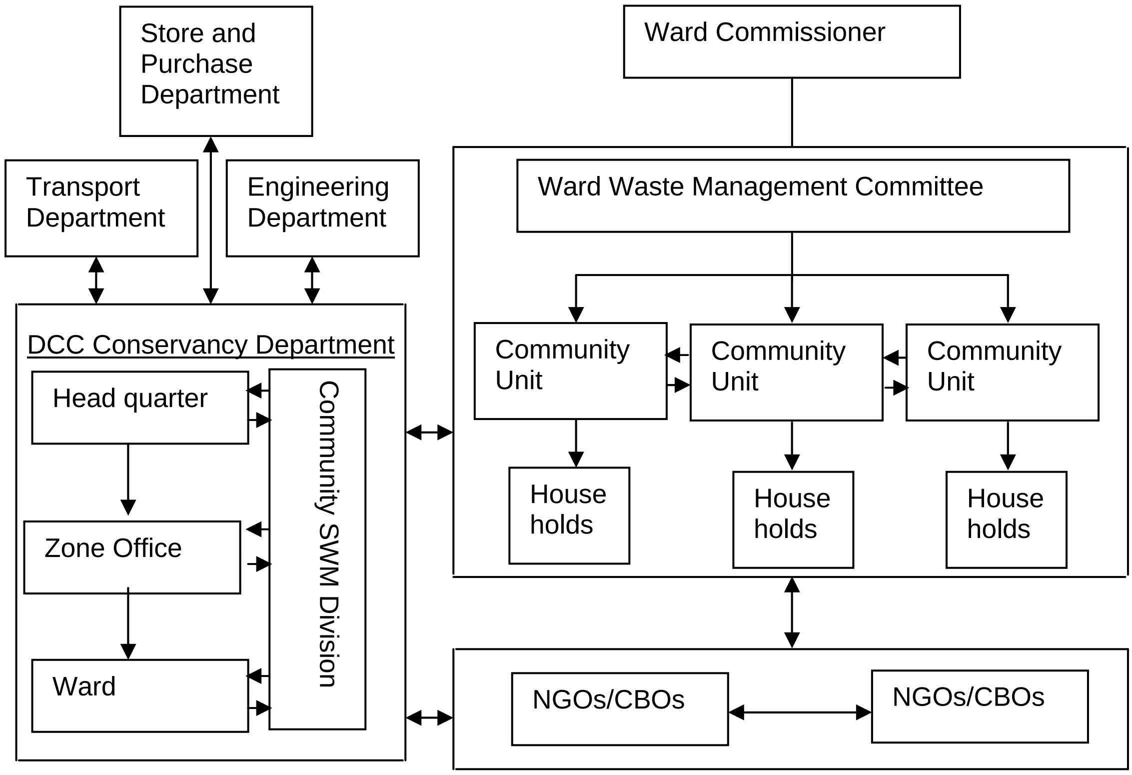

Figure 1 Linkages for solid waste management at ward level (Source: JICA, 2004)

SUGGESTIONS FOR IMPROVED SOLID WASTE MANAGEMENT

The proposed recommendations for effective solid waste management system in Dhaka City are:

- An effective Management Information System (MIS) is needed for DCC. Coordination and cooperation is essential among the related departments and divisions of DCC.
- Increase the number of vehicles and efficient use of vehicles (container carriers) to collect and transport waste. Additional 29 units of 5-ton container carrier vehicle are needed.
- Redesign the container (with cover), increase the number and suitable placement of containers. Additional 150 containers with 5-ton capacity has to be located in suitable places in right way not obliquely (placed at a distance from houses that will not threaten the health of residents).
- Redesign of rickshaw van (covered) and dumping station.
- Cooperation between waste pickers and DCC for the interest of both side (material recovery and waste pickers do not spread waste around the container). Participation of slum dwellers in waste management.
- Proportionately distribute the resources in different zones or areas of DCC.
- Sanitary landfill with required approval and improved operation. The number of landfill sites has to be increased and located planned way in different parts of the city in accordance with waste volume.
- Removal of the illegal (open) small dumping sites.
- Improve efficiency of the staff of DCC and their awareness generation about laws and rules.
- Improve transparency of the ordinance and activities of DCC, avoid political influence for authorization of CBOs or NGOs. DCC may follow ‘franchise’ method for the authorization of primary waste collection. Besides primary waste collection the same NGO/CBO may get the authorization for secondary collection and street/drain cleaning through competitive process under ‘contracting’. Various groups are involved now disorganized way at local level and some of them are more interested of making business rather providing proper service. Monitoring and evaluation of the activities of CBO’s/NGO’s and actions against unauthorized individuals or small groups to prohibit their illegal activities.

- Support from DCC to NGOs/CBOs. Build up relation between ward commissioner and CBO or NGO. DCC may provide land to CBO/NGO for establishing composting plant through 'concession' method of privatization to encourage CBO/NGO/private firm to set up composting plant. It is necessary to give the responsibility only one CBO or NGO in a ward.
- Maintaining the fixed time schedule everyday for waste collection by CBOs/NGOs.
- Proper uniform and use of health protection materials (i.e. gloves, shoes, medicine, etc.) for the workers during waste collection and transportation.
- Increase the rate of SWM tax and fixation of reasonable service fee by NGO/CBO. DCC may fix fees for primary waste collection according to socio-economic condition of the different areas and encourage households to pay service charge to the NGOs or CBOs in time.
- Set up a service centre by CBOs or NGOs (each CBO/NGO should have a service centre where residents can give any complain about the waste management system).
- Discouraging households from illegal (open) dumping, and impose financial penalty if do such. Financial penalty has to be implemented on the households who are not disposing waste properly.
- Encourage the households for waste segregation at source. As CBOs/NGOs are able to make money from solid waste management, they are trying to communicate with the households and raise public awareness for segregate waste at source.
- Accelerate the monitoring of secondary waste collection by DCC.
- Increase awareness among the decision-makers and generate public awareness program through TV and other media to aware households to segregate waste at source. Environmental studies should be included in textbooks of school.
- Establish a new Community SWM Division, a common platform for all actors in waste management at community and ward level, with required employees has to be established under Conservancy Department of DCC to improve the solid waste management. This Division will form Ward Waste Management Committee and will prepare legal framework and guidelines for solid waste management at ward level through community participation. The Ward Committee may consist of 8 to 10 persons (representatives of households and volunteers, including one influential person) to prepare waste management plan and program of the Ward. The committee will form some community units which will implement all waste management programs, motivate the residents to dispose waste environmental friendly way as well as observe waste management of CBOs/NGOs.

It may be concluded that DCC, CBO/NGO, community people and Ward Commissioner have to come in a common platform through linkage in order to make an effective community based solid waste management system. Because, cooperation between all parties involved is a must for improved solid waste management system.

CONCLUSIONS

Since the involvement of CBOs or NGOs in primary waste collection (door to container), neighborhoods of the city become cleaner than previous time and this system is well accepted by the households. However, now the main streets are becoming dirty as the containers become overloaded and waste exists for long time to be transported in the dumping site or land fill. Due to the inefficient use and shortage of resources, DCC is not capable to remove waste effectively from the container to the final disposal sites. Consequently residents are not pleased with secondary waste collection (container to disposal sites) managed by DCC. Some CBOs/NGOs are well organized and making higher profit from primary waste collection. For this reason, besides primary collection they also want to be involved in secondary waste collection and street/drain cleaning. Already they have proposed a cost for secondary waste collection which is less than the cost currently DCC bearing for that purpose. It would be better if the same NGO/CBO gets the responsibility of both the primary collection, secondary collection, and street/drain cleaning, which in turn will bring coordination and integration between the two systems. However, if another firm can manage secondary collection and street/drain cleaning with lesser cost then they should be given the priority for that responsibility. Finally, DCC could encourage privatization of overall solid waste management with proper amendments of their ordinance whilst all the actors involved in waste management have to make a link among them to facilitate the activities at ward level.

ACKNOWLEDGEMENT

The authors would like to thank the Research Assistant of SusTRANS Bangladesh for the assistance while conducting the field investigation of the research.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.727-736

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Biomass Waste Utilization: An Approach for Solid Waste Reduction

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ABSTRACT

Three approaches have been devised by Central Philippine University (CPU) in utilizing the enormous biomass waste generation in Western Visayas region of the Philippines. These approaches are direct combustion, gasification and pelleting/briquetting. Gasification technologies developed by the University include steam-injected stoves and gasifiers which are all fuelled by either rice husks or sawdusts and are good alternatives in reducing the generation of such wastes. To explore options for value adding to Alternative Fuels and Raw materials (AFR), a manually-driven pelleting/briquetting machine was developed and tested at Calajunan waste disposal facility in Iloilo City. This test included recovered light packaging materials, carbonized rice husks, sawdusts and low grade quality paper residuals to produce pellets which may be utilized as AFR by the cement industry. A second test for pelleting/briquetting was also done in order to produce alternative fuels for household consumption as substitute for wood fuel and charcoal. A total potential use of 18 to 139 tons of biomass per year may be utilized from the waste generation of Western Visayas based on the actual number of user of stoves and gasifiers. These approaches developed can help reduce emission of harmful gases to the atmosphere caused by the indiscriminate open burning of biomass wastes. Converting biomass wastes into pellets and briquettes can serve as substitute fuel for household and industrial heat applications.

INTRODUCTION

Annually, the Philippines generate large volumes of agricultural wastes. This can be attributed to the fact that the country utilizes almost one-third of its agricultural lands for rice production (FAO 2000), and is considered as a promising option to enhance resources utilization instead of open burning or uncontrolled waste disposal, which are still the dominating practices for agricultural and municipal waste management in the Philippines. During post-harvest phases large volumes of biomass residues are being generated on many agricultural used areas. One of the ubiquitous generated agricultural waste is rice husk, the outer covering of paddy which is removed after rice milling and accounts for 20-25% of its weight (Jenkins 1989). The total rice husk potential for the country according to the Crops Statistics of the Bureau of Agricultural Statistics was estimated to be 3.14 million metric tons in 2005. Western Visayas (Figure 1), one of the rice producing regions of the Philippines generates approximately 313,400 metric tons of rice husks and among the 6 provinces composing the

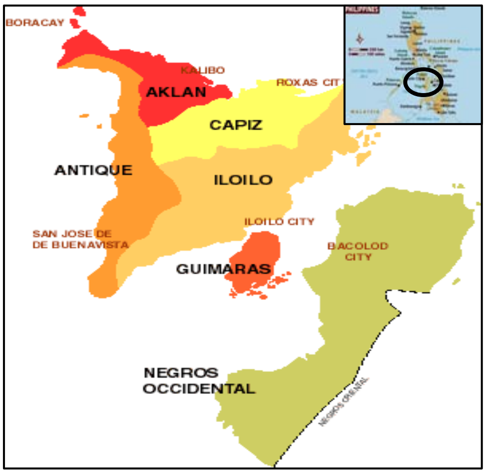

Figure 1 Location of Iloilo City, Western Visayas, Philippines

region, the Province of Iloilo generates the highest volume at 165,000 metric tons annually (compare http://www.aseanenergy.org/download/eaef/105-2004%20Project%20Summary%20for %20web.pdf). These voluminous wastes are often dumped at the back of rice mills, simply left along the roads during travelling or at the backyards of rice mills to decompose, or thrown into natural depressions or near creeks, rivers and streams. In worst cases, these wastes are openly burned on rice fields, an activity specifically banned by Republic Act 9003, also called the Ecological Solid Waste Management Act of 2000 (Oposa 2002), since this practise generates and emits harmful gases into the atmosphere.

Failure to utilize rice husk is tantamount to wasting a high calorific resource since this waste contains a heating value of 3000 kcal/kg (Beagle 1978) and with its widespread availability, it could clearly be a practical source of energy (Borman & Ragland 1998) if properly utilized. The use of rice husks as fuel for cooking using appropriate technologies like cookstoves and gasifiers can minimize dependency on fuel wood and charcoal reducing the impact of deforestation. In addition, the increasing cost of fossil fuels has also led the consumers to explore other potential sources of energy.

One such potential source of energy is the recovery of other useful wastes in a disposal facility. In Iloilo City, a 100-day material recovery test was done at the Calahunan disposal facility to recover organic waste and Alternative Fuels and Raw materials (AFR) that can still be processed into useful source of energy such as fuel for industrial and household use (Paul et al. 2009). These discarded waste materials from the disposal facility may be explored further by converting them into pellets and briquettes using the most viable mixture. The practice of generating fuel energy from solid wastes like biomass and AFR can be an environmentally sound technique for waste reduction, and contributes largely to enhance solid waste management.

OBJECTIVES OF THE STUDY

The following are the objectives of this study

- To develop technologies that utilize biomass wastes as source of energy;
- To document the design specifications and operating performance of the direct combustion technologies developed in terms of boiling time, fuel consumption rate, percent char produced, steam consumption rate, and thermal efficiency;
- To document the design specifications and operating performance of the gasifier technologies developed in terms of fuel consumption rates, percent char produced, and thermal efficiency;
- To document the operating performance of the pelleting and briquetting technologies in terms of finding the most viable mixture in producing pellets as alternative fuels and raw materials for industrial use and briquettes for household application using only biomass wastes; and
- To identify the advantages and limitations of the developed technologies as an approach in reducing solid wastes.

MATERIALS AND METHODS

Technologies Developed for Biomass Waste Utilization

Three major types of technologies have been developed at CPU for the utilization of biomass wastes in an attempt to help reduce the inappropriate disposal of these wastes. The direct combustion stoves were developed especially for areas with no access to electricity. These technologies, as shown in Figure 2, are easy to operate. These started with simple designs of step-grate and conical stoves in which the rice husk fuel is directly loaded into the hopper. For the step-grate, the fuel is burned on top of a slatted metal grate built in an inclined manner to allow combustion of the fuel to continue. Unlike the conical stoves in which the fuel is burned inside an inverted cone grate where burning takes place with the supply of both primary and secondary air. These stoves consist of major parts like the pot holder, fuel hopper, ignition port, discharge lever, char pan, and support stand. In an aim to continually improve the design of cooking stoves, CPU developed stoves that integrate the use of steam. These new technologies, namely, the side-in and super turbo stoves inject steam into the combustion chamber of the stove providing substantial heat to satisfy the highly endothermic chemical reactions during combustion. The mixture of air and steam during operation serves as the gasifying agent, thus producing a turbulent pinkish-luminous flame that is different from the previously developed biomass cooking stoves. These steam-injected stoves have an additional part of steam tank, steam burner, and steam injector.

Figure 2 Direct combustion stoves developed for biomass waste utilization, namely from left to right: step-grate stove, conical stove, side-in, and the super turbo

The biomass gasification technologies developed (Figure 3) for thermal application, in turn, ranged from single to multi-burner gasifier stoves for household and industrial use, to dual-reactor and continuous-flow type gasifiers for industrial applications. These technologies basically consist of similar parts, namely: air moving device (fan/blower), burner, char chamber, char grate, discharge lever, chimney, gas pipe, gas regulator, pot holder, and reactor. During the operation of these gasifiers, the burning layer of biomass fuel in the reactor moves downward until all the fuel is used up. The more air is introduced by the fan/blower in the fuel bed, the faster is the downward movement of the fire. It is during this early stage of gasification that the heat generated vaporizes the volatile components present in the biomass fuel in the presence of limited air. As the combustion zone moves downward, the fuel is left inside the reactor in the form of char. The unburned carbon present in char then reacts with the air that is supplied by the fan/blower thus producing combustible gas.

A manually-driven pelleting machine and briquette molder were developed to explore options of value adding to materials that have been recovered as Alternative Fuels and Raw materials (AFR) during a 100-day recovery test at the Calajunan disposal facility of Iloilo City, Philippines. AFR materials included mostly light packaging materials, biomass wastes like carbonized rice husks (CRH) and sawdusts, and low quality waste paper which were converted into pellets and briquettes. Pellets mixed with plastic materials were produced for industrial utilization while briquettes, without the mixture of light packaging materials, could be used as substitute fuel for cooking (Figure 4).

Figure 3 Gasifier technologies designed for biomass waste utilization, namely from left to right: single-burner, multi-burner, dual-reactor, and continuous-flow type gasifiers

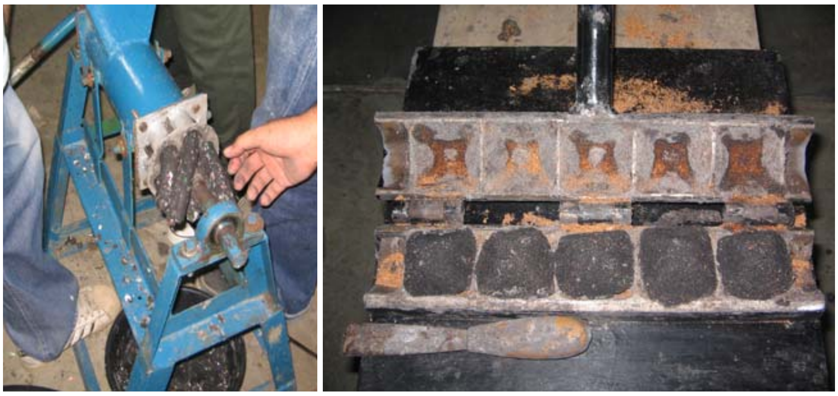

Figure 4 Pelleting machine and briquette molder used for converting wastes into pellets as AFR for industrial use and briquettes for household use

Performance Evaluation

Evaluation of the technologies developed was done at the Appropriate Technology Center of Central Philippine University, Iloilo City, Philippines. These technologies were tested on their capacity to utilize biomass wastes. Biomass waste like rice husks were obtained from near-by rice mills. The sawdusts and CRH used for briquetting and pelleting were mostly obtained from Guimaras Island with some CRH from stoves and gasifiers developed, while the AFR materials used, mostly made of light packaging materials, were recovered during a 100-day recovery test at the Calajunan waste disposal facility of Iloilo City.

Basically, the procedure in evaluating the direct combustion stoves and gasifiers were very similar. For direct combustion stoves, the biomass fuel was loaded into the hopper to determine initially the fuel capacity of the stove. After ignition of fuel the cooking pot with certain volume of water was placed on the pot holder for the thermal efficiency of the stove using the water boiling test. Operation continued and biomass fuel was loaded to the hopper until the water boiled while burnt fuel or char was discharged at the bottom of the grate by slightly manipulating the lever. After the operation, data on: weight of fuel consumed, weight of char produced, weight of water evaporated, initial and final temperature of water, total operating time, and steam evaporated from steam-injected stoves were collected. After which, parameters like fuel consumption rate, steam consumption rate, percent char produced, and thermal efficiency were analyzed.

For gasifiers, biomass was loaded until it filled entirely the reactor of the gasifier. The fuel was then ignited while its air moving device (fan/blower) was switched on. This device was responsible in delivering the needed amount of primary air for rice husk gasification to produce combustible gas for cooking. A cooking pot with water was also used for the boiling test and the operation was timed until all the fuel in the reactor was converted into char. Similar data with that of the direct combustion stoves were gathered and parameters analyzed except for the exclusion of steam consumption rates.

The pelleting machine and briquette molder were simple devices developed to provide low cost solutions in utilizing AFR from a disposal facility and biomass wastes like CRH and sawdusts. The pelleting machine used contained a feeder at the top, a rotating screw for compaction at the center, and a final outlet with changeable die plates. Two workers were needed to operate this machine. One person is responsible in feeding the prepared mixture while the other person manipulates the screw by gradually rotating it until pellets come out of the die plate. The briquette molder, on the other hand, is a smaller unit that can be operated by one person only. The machine consists of two symmetric half forms with five molders each. These were connected on one side with a hinge and on the opposite side with a handle, thus creating a movable top that could be opened after the prepared mixture has been compacted. Compaction of the briquettes was done after the prepared mixture was placed at the bottom half of the molder by closing and pressing down the movable top against it. After manual pressure has been exerted, the movable top was opened and the briquettes were removed for sun-drying.

Preparing the Mixture for Pelleting/Briquetting Evaluation

The needed materials for this specific test were made available in sacks with shredded AFR coming from the Calajunan disposal facility. The particle size of the shredded AFR was approximately 4 to 10 millimeters (mm). The CRH and sawdust were smaller in a range of 0.1-0.6 mm. Corn starch used as binding material was obtained from a local supermarket. These materials were then mixed by hand until a homogeneous mixture was created. The corn starch was weighed and then carefully suspended in water for boiling until a jelly-like appearance was produced. The binding material was then mixed with the dry mixture until again a homogeneous state was reached. The particle size distribution and properties of the different ingredients are essential for the stability and density of the produced pellets, because potential airspace volumes in-between the bigger particles can be filled with smaller ones. Bigger and smaller particles together create a more stable compound.

RESULTS AND DISCUSSIONS

Design Specifications and Operating Results of Stoves and Gasifiers

Table 1 presents the design specifications of the four different types of direct combustion stoves developed that utilize biomass waste as fuel, a common type of solid waste generated in most parts of the country. Among the four stoves, the step-grate and the conical-type are not steam-injected since they were the pioneering stoves developed unlike the side-in and the super turbo which operate with steam as an enhancing factor in their performance. As further shown, the four stoves have similar dimensions, with the step-grate having the widest diameter at 22 cm while the three others have a diameter of 17 cm. In terms of width and height, step-grate is wider at 50 cm but a bit lower at 45 cm compared to those of the other stoves at 47 cm and 51 cm, respectively.

As to the stove operating performance (Table 2), all the stoves were designed to be operated continuously as long as burned fuel is replaced in the hopper. A 1000 ml water was used for the boiling test in which the non-steam-injected stoves registered a boiling time of between 9 to 10 min, whereas, the steam-injected stoves registered a faster boiling time of between 6 to 7 min. The data obtained further indicate that as the fuel consumption rate of the stove increases, the boiling time decreases. This can be attributed to the increase in the heat energy given off by the biomass fuel. In terms of percentage char produced, the four stoves converted the biomass wastes into char by a range of 25 to 28% by weight of rice husk. This shows that the discharge from these stoves were mostly char and not ash which is 15 to 22% by weight of rice husk (Kaupp, 1984). The significance of this char is that it can still be processed into another useful form of fuel which is briquette. Water boiling test was used in computing for the thermal efficiency of the stoves. This parameter measures the percentage of heat energy produced by the fuel reaching the water in the pot. As presented in the table, the data obtained for the stoves were almost similar at 9.87 to 10.64%. This shows that steam is not a factor in the production of heat by the biomass fuel.

Table 1 Design specifications of the direct combustion stoves

Type of Stove	Steam-Injected	Hopper Type	Diameter of Combustion Chamber (cm)	Max. Width of Stove (cm)	Max. Height of Stove (cm)
Step-Grate	no	step grate @ 5 hor. slots	22	50	45
Conic	no	conical	17	47	51
Side-In	yes	conical	17	47	51
Super Turbo	yes	conical	17	47	51

Table 2 Results of the operating performance of the direct combustion stoves

Type of Stove	Vol. of Water (ml)	Boiling Time (min)	FCR (g/min)	Char Produced (%)	Steam Con. Rate (ml/min)	Thermal Eff. (%)
Step-Grate	1000	10.00	28.82	28.34	-	10.11
Conic	1000	9.22	26.00	24.58	-	9.87
Side-In	1000	7.18	29.00	26.67	3.93	10.64
Super Turbo	1000	6.00	30.00	25.00	6.67	10.49

Five different types of gasifiers were developed for biomass waste utilization. Unlike the direct combustion stoves that can be operated without the aid of an air-moving device, gasifiers are dependent on this device as a source of limited air during the combustion of biomass in the reactor. As shown in Table 3, the single and double-burners for household use (H/U) and industrial use (I/U) were batch-type in terms of mode of feeding. The single-burner which is driven by a 16-watt static fan has a single reactor and the smallest among the five gasifiers in terms of size. The double-burner gasifier for household use is the smallest compared to the other double-burner designed for industrial use. The former has an inner reactor diameter and height of 20 cm and 95 cm, respectively, while that of the latter is 95 cm and 124 cm, respectively. There are two gasifiers designed for continuous feeding, one is a dual-reactor in which two reactors are operated alternately making the operation non-stop. The other gasifier has only one reactor but it was designed that burned fuel can be discharged at the bottom without interrupting the gasification process, unlike the rest of the four gasifiers that unloading can only be done once all the fuel inside the reactor has been used up. The two continuous-type gasifiers have the same inner reactor diameter of 25 cm and height of 100 cm.

Table 3 Design specifications of the gasifiers

Type of Gasifier	Mode of Feeding	Air Moving Device	No. of Reactor	Diameter of Inner Reactor (cm)	Ht. of the Reactor (cm)
Single-Burner	Batch-type	Fan	1	15	60
2-Burner (H/U)	Batch-type	Blower	1	20	95
2-Burner (I/U)	Batch-type	Blower	1	40	124
Dual-Reactor	Continuous-type	Blower	2	25	100
Continuous-Flow	Continuous-type	Blower	1	25	100

The operating performance of the gasifiers shows that each has a different fuel capacity that ranges from 1,200 g for the single-burner to 20,000 g for the initial filling up of the continuous-flow. The batch-type gasifiers can be operated in 30 to 50 min on the average. Each of the reactor of the dual design can be operated for 30.48 min, a data that is similar to that of the double-burner for household use since the two gasifiers have also similar specifications. The continuous-flow with its initial loaded capacity was operated for 145.80 min or nearly 2-1/2 hours. Among the five gasifiers, the double-burner for industrial use had the highest fuel consumption rate (FCR), however, the general data revealed that as the length of operating time increases, the fuel consumed per unit tends to increase also. This parameter indicates that the last three types of gasifiers are the most ideal in utilizing biomass wastes since they require more wastes per operation. The continuous-flow gave the highest conversion of biomass fuel into char by almost 50%. This is due to its mode of feeding in which the fuel is continually loaded while also manipulating the discharge lever without unloading the entire burned fuel. The four other gasifiers including the dual-reactor have nearly similar percent char produced that ranged from 21 to 28% due to their batch-type mode of feeding in which the entire burned fuel has to be unloaded first before a new a batch of fuel is to be loaded. This is the same principle for the dual-reactor except that it has two reactors that work alternatively making its operation continuous. Using again the water boiling test for thermal efficiency computation, the continuous-flow registered the highest efficiency at 63.49% followed by the dual-reactor at 39%, whereas, the batch-type gasifiers have a thermal efficiency of less than 11%. The two continuous-type of gasifiers have the highest value due to their longer operating ability making them consume more fuel and utilize more heat (Table 4).

Table 4 Results of the operating performance of the gasifiers

Type of Gasifier	Wt. of Fuel used (g)	Op. Time (min)	FCR (g/min)	Char Produced (%)	Thermal Eff. (%)
Single-Burner	1,200	45.00	26.67	28.05	11.42
2-Burner (H/U)	2,120	30.60	69.28	24.68	4.74
2-Burner (I/U)	14,700	52.20	281.61	21.91	2.86
Dual-Reactor	5,000	30.48	164.04	25.00	39.00
Continuous-Flow	20,000	145.80	137.17	48.90	63.49

Results of Pelleting and Briquetting Tests

Fifteen different tests, as presented in Table 5, were conducted using different mixing ratios of plastic wastes and paper from the disposal facility, and biomass wastes like carbonized rice husks (CRH) and pure sawdust. The materials were mixed with corn starch as binding material, although waste paper was also tried as alternative binding material for household fuel production in some of the test runs. Paper was not used in the industrial fuel mixtures, because it was assumed that the quantitative demand on paper required for the pellet mixture would not be available within the local municipal solid waste (MSW) stream.

Table 5 Summary of composition and mixing ratio used for the pelleting and briquetting tests

Test No.	Plastic		CRH		Sawdust		Paper		Corn Starch		Water	
	(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)
1	500	10	2000	40	1000	20			1500	30	3000	38
2	1000	18	2000	36	1000	18			1500	27	3000	35
3	1500	25	2000	33	1000	17			1500	25	3000	33
4	2500	39	500	8	500	8			3000	46	2000	24
5	2500	42	500	8	500	8			2500	42	2000	25
6			3000	55	1000	18			1500	27	2000	27
7			2000	53	500	13			1250	33	2000	34
8			2000	47	1000	24			1250	30	2000	32
9			2000	50	1000	25			1000	25	2000	33
10			2500	50	1000	20	1000	20	500	10	2000	29
11			2500	50	1000	20	1500	30			2000	29
12			2000	40	1000	20	2000	40			2000	29
13			1000	20	1000	20	2500	50	500	10	2000	29
14			1000	20	1000	20	3000	60			2000	29
15							5000	100			2000	29

As shown in Table 5, the first 5 tests were done to analyze the maximum percentage of plastic wastes that could be added to biomass wastes like CRH and sawdust with corn starch as binding material for the pelleting test. This test aimed to determine the feasibility of producing pellets as an AFR for industrial applications. Based on the results, the plastics used started out with the least percentage as component material, while CRH and sawdust have higher percentage and hence were gradually decreased as plastics were increased. The amount of binding material was also increased with the amount of plastics. Among the five tests for AFR pellet production, Test 4 with components of 39% plastic, 8% CRH, 8% sawdust, 46% corn starch, and 24% water gave the most suitable mixture for the manual production of pellets containing plastics. The mixture of 8.5 kg was processed with the pelleting machine in less than half an hour corresponding to an output of approximately 15 kg per hour of dry pellets. The other tests also produced pellets but these were not as compact as those of Test 4. Furthermore, it is difficult to manually produce pellets with mixtures of more than 40% plastic using the machine developed because the materials can not anymore be screwed out of the die plate. However, if the design would be improved, a possibility of utilizing more plastic wastes may be achieved.

Tests 6 to 15 were done to determine the best mixture for household fuel production using only biomass wastes. Tests 6 to 9 were done with corn starch used as the binding material. Results revealed that a mixing ratio of 47% CRH, 24% sawdust, 30% corn starch, and 32% water appeared to be the most suitable mixture for the manual production of household fuel. The worker using this mixture was able to produce 5 kg of briquettes per hour with 20 min spent in preparing the dry mixture of 4,250 g. Tests 10 to 15 were done with paper, pre-treated using a pulping machine, as the main binding material except for Tests 10 and 13 which made use of additional 10% corn starch. Based on the results, briquettes produced with a little amount of corn starch are the most suitable (20% CRH, 20% sawdust, 50% paper, 10% corn starch, and 29% water). The test further revealed that paper alone can not replace starch as binder. In Test 15, which used only paper and water, the machine was able to produce very compact briquettes with 21 briquettes produced in 5 min.

Impacts of the Biomass Technologies on Solid Waste Reduction

Table 6 presents the summary of biomass technologies developed and their impact in terms of amount of biomass wastes, specifically rice husks,that may be reduced from the estimated yearly generation in the Western Visayas Region of the Philippines. The rice husk generation was based on the actual rice production of the region with 20% of its weight allotted for rice husks (Jenkins 1989). As shown, based on the actual number of units sold in the region, the total utilization of biomass wastes when used for an estimated 6 hours daily for 8 months operation range from 18 tons/yr to as high as 139 tons/yr. When computed further, approximately 0.17% of these rice husks maybe reduced from the actual generation of such waste. This value maybe insignificant, however, if every household with open access to biomass wastes would be encouraged or provided with such technology, this value is foreseen to increase. Presently, biomass wastes are mostly dumped at the back of rice mills, usually causing problems on its disposal. Others are burned openly or under uncontrolled conditions affecting the air environment. The use of these stoves and gasifiers would help prevent the practice of open burning indiscriminately biomass wastes because they could be utilized as fuel for heat applications.

Table 6 Impact of the technologies developed as an approached in reducing the generation of biomass wastes

Technology Developed	No. of Units Sold	FCR (tons/yr)	Ave. RH Generation of Iloilo (tons/yr)	RH Reduced (%)
A. Direct Combustion Stoves				
1. Conic	12	27	313,400	0.01
2. Side-In	38	95		0.03
3. Super Turbo	29	75		0.02
B. Gasifier				
1. Single-Burner	60	139		0.04
2. 2-Burner (H/U)	3	18		0.01
3. 2-Burner (I/U)	5	122		0.04
4. Dual-Reactor	3	42		0.01
5. Continuous-Flow	4	47		0.01
Total	154	565	313,400	0.17

The method of converting other types of solid wastes is also feasible by converting them into pellets and briquettes. Plastic wastes from the disposal facility can also be utilized as AFR for industrial applications provided that they can be sieved into smaller particles (less than 0.25 in.) in order for these materials to be converted easily into pellets using the manually-driven pelleting machine. The use of this machine could produce an output per hour of 15 kg. However, this rate of production is way too low if used at the Calajunan disposal facility. Earlier studies at Calajunan had revealed that up to 20% of AFR could be recovered, which translates to > 30 tons/day (Paul et al. 2007 & 2009). To achieve more production of pellets in order to cope with the generation of wastes at the disposal facility, a much larger and mechanized pelleting machine would be needed to provide a higher output.

The production of briquettes for household purposes using the necessary materials like CRH, sawdust, corn starch and water is possible. Using a hand-driven briquette molder, a person could achieve an output of approximately 5 kg/hr. Further, it is revealed that paper alone can not replace starch as a binder.

CONCLUSIONS

As an agricultural country, great potentials on the utilization of biomass wastes can be achieved in the Philippines using the technologies developed at CPU. The utilization of these wastes as fuels in stoves and gasifiers could help reduce problems on its disposal especially on rice milling areas with limited space. Another approach, which is the conversion of biomass wastes like rice husks and sawdusts into briquettes, is also a feasible option for waste reduction. Briquettes produced can be a used as alternative fuels for household consumption to substitute charcoal, a still widely used household fuel in the Philippines.

The method of recovering useful wastes from the disposal facility of Iloilo City and converting them into pelletized Alternative Fuels and Raw materials (AFR) is also a feasible option for waste reduction. These AFR pellets are foreseen to be an ideal substitute fuel for industrial applications.

The following are the benefits derived and limitations from the use of the biomass utilization technologies:

- The stoves and gasifiers are ideal technologies in solving problems on the disposal of biomass wastes since these wastes can be used directly as fuel for heat applications.
- By using biomass wastes the cost of cooking in a household as well as in small–scale industries spending on conventional fuel sources such as electricity and wood can be significantly reduced.
- Carbon dioxide emissions released by the indiscriminate open burning of biomass wastes which
- also contributes to the ozone layer depletion leading to problems of more environmental concerns like
- climate changes can be reduced with the proposed alternative technologies.

- The utilization of biomass for alternative fuels can assist to preserve the forest by reducing the cutting of trees for the production of wood fuel thus, minimizing problems concerning drought during summer, flood and erosion during the rainy season.
- The by-product of rice husks after using them as fuel is char, which is another viable byproduct which can be converted into briquettes and pellets using the briquette molder and pelleting machine developed. These briquettes and pellets can be used as an alternative fuel for household and industrial use.
- The technologies developed are best applied in areas with abundant supply of biomass wastes.
- In conclusion, the approach of generating fuel energy from solid wastes like biomass and AFR is considered as a promising option to enhance resources utilization instead of open burning or uncontrolled waste disposal. This can be an environmentally sound technique for waste reduction, and contribute largely to enhance the solid waste management especially on the Western Visayas part of the Philippines.

PROPOSED NEXT STEPS

Commercialization and intensive promotion of the specifically developed stoves and gasifiers are already underway to fully increase public awareness that these technologies can already be utilized and are available as a low- cost source of fuel like rice husks and sawdusts.

The mixtures that were identified are suitable for pelleting as well as briquetting and could be tested on a larger scale using industrial equipment, whereas, corn starch as a binder should be replaced by cheaper binders. In terms of producing briquettes for household use, it is reasonable to continue product development towards a toolkit for this purpose, which includes the briquette molder, instructions on the production procedure and mixing ratio to be used. The product could then be distributed to be tested at the household level in Calahunan. Tests will be done on the quality of briquettes produced particularly to determine general physical and chemical properties such as water content, ash content, volatile compounds, fixed carbon content, and heating value. Further analyses should clarify the elementary composition including carbon, hydrogen, oxygen, nitrogen, and sulfur; and oxidation analysis and determination of properties of the ashes especially the melting point.

ACKNOWLEDGMENT

The Authors wish to express their sincerest thanks to Central Philippine University for providing research funds which led to the development of biomass technologies; the Environmental Management Bureau and the German Technical Cooperation for providing the technical and financial support to venture into pelleting/briquetting study; the College of Agriculture and the Appropriate Technology Center for providing the equipment/instruments. Heartfelt thanks are extended to all the Student Research Assistants for their invaluable help during the conduct of the study, and also the Faculty of the College for the assistance extended in editing the paper.

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ISBN: 978-984-33-0761-3, Vol. 2, pp.737-742

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Problems of Handling Mining and Power Plant Solid Waste with its Solution in India

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ABSTRACT

India ranks third in world coal scenario mainly due to 89% contribution from opencast mining or surface mining technology. The coal produced by opencast mining technology is one of the major inputs to the thermal power plants which cater to the 80% of energy demand of India. Both the above processes generate two kinds of solid waste i.e. Waste rock/soil and coal ash respectively. Disposal of these two wastes in a safe, economic and eco-friendly way are the biggest challenges to the both coal mining industry and power plant industry of India.

For solving the above problems related to opencast coal mining and coal based power plants, an experimental and research work is carried out by mixing fly ash with waste soil/rock of Sonepur- Bazari opencast mine , located in eastern part of India.

The findings on research work carried out by mixing coal ash and waste soil/rock of the external dump (i.e. waste dump outside the opencast mine) of Sonepur-Bazari opencast mine are discussed in this paper.

SOLID WASTE DISPOSAL IN OPENCAST MINING

Coal India (a major coal producing organisation of India) which has a share of 79% of national coal production produced 379.49 million ton of coal in 2007-08 out of which 335.95 million ton has been produced by opencast mining or Surface mining technology. It is pertinent here to mention that to mine out 335.95 million ton of coal from opencast mining, 610.34 million cubic metre of waste rock and soil was excavated in the year 2007-08. But a major hindrance in sustaining such huge coal production from open cast mining is the requirement of vast amount of land for the disposal of waste rock/soil. Land requirement due to opencast coal mining in India has been estimated to reach 2925 square km including 730 square km of forest cover as against the present requirement of total land of 1470 square km for opencast mining. It is also estimated that 0.85 million people will be displaced by the opencast coal mining projects by the year 2025 and would require to be suitably rehabilitated (Choudhury 2008 and Debnath et al. 2008).

This socio-environmental predicament requires a solution and the only possible way is to increase the slope angle of the waste dump embankment by reducing the land requirement for its placement. But this solution creates another problem in itself i.e. the stability of the waste dump which is one of the major problems faced in the open cast coal mining operation in view of several fatal accidents due to slope failures in some of the large opencast mines of India.

SOLID WASTE DISPOSAL IN COAL BASED POWER PLANT

Coal ash is the finely divided mineral residue resulting from the combustion of coal in power plants and in present scenario; it occupies about 80,000 acres of precious land for disposal of coal ash in ash disposal pond (Paul 2005).

This generation of huge quantity of coal ash poses a multiple environmental and other serious problems besides occupying large areas of land for its storage and disposal. Some of the environmental hazards associated with this type of coal ash disposal are as follows:

- After getting dry, it gets airborne in the nearby areas and cause ailments like allergic bronchitis, asthma etc.
- It contaminates surface water and have adverse leaching effect on the ground water.
- Aquatic life gets seriously affected if it gets into the nearby pond/river/sea or any other public utility water body.
- Use of water from coal ash ponds in agricultural purpose have also adverse effect on plant life.
- In this backdrop, a research work is carried out on external dump of Sonepur Bazari Opencast mine considering the following three problems simultaneously :

    - ❖Land area requirement for both waste dump and coal-ash disposal pond.
    - ❖Stability of waste Dump in view of number of incidences of fatal accidents in recent years.
    - ❖Environmental friendly method of fly-ash and waste dump disposal to prevent contamination of land and water body.

PROBLEMS OF SLOPE FAILURE

The Sonepur-Bazari opencast mine (Figure 1) is producing 3.0 million ton of very high quality coal with stripping ratio of 4.72 cu.m/tonne and is being operated by both dragline and Shovel-truck combination (CMPDI 2005). The mine is capped with 15m thick clay strata, which is almost fully saturated with ground water table. Due to enormous production of overburden dump comprising of both waste rock and clay soil, the mine operator is left with no alternative other than putting a portion of excavated waste rock/soil outside the quarry to a height of 75m above the clay strata (Figure 2) which is termed here as external dump (Figure 3).

Figure 1 Pictorial view of Sonepur-Bazari Opencast mine

This external dump experienced a slope failure concurrent with floor heaving near toe of the dump in April 2005 (Rohella et al. 2008).
Failure occurred in two stages:

1st stage - Circular failure in the upper layer and consequent toppling of dumper. The debris of failed dump mass fell and came to rest on the berm width exerting surcharge load on the lower layer. It is envisaged that the presence of clayey soil in the upper layer is one of the major causes of failure.

2nd stage - The lower layer also failed subsequently leading to heaving of floor of dump i.e. ground surface level near toe of dump. Base failure is observed here. Surcharge load of debris from upper layer coupled with weak base of dump fully saturated with ground water table is one of the major causes of the base failure.

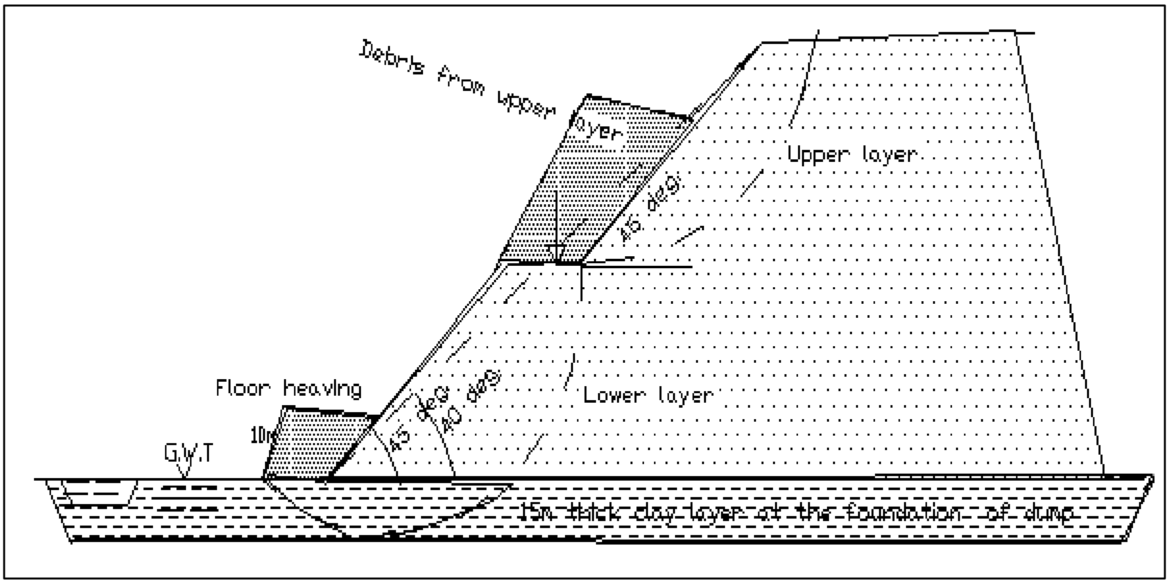

Figure 2 Failure process in an external dump

Figure 3 External Dump of Sonepur-Bazari opencast mine

The project officials tried to solve this problem by separating clay dump from the rock dump, which requires extra space for making a clay dump of around 30m high.

Due to above, a research study was conducted at the Geo-technical laboratory of Birla Institute of Technology, Mesra in collaboration with Sonepur-Bazari opencast project, for improving the stability of clay dump by mixing it with coal ash rejects from power plant as it will not only help in stabilizing the dump but also help in fly-ash disposal.

MODALITIES OF FLY ASH DUMPING

The major factor involved in the stability of a clay dump is the shear strength parameter of the clayey soil. As per research in the field of foundation engineering, mixing of flyash to the clayey soil in some definite proportion increases its shear strength (Khan et al.2004 and Mir et al.2003). Till date, most of the research has been in using the flyash to enhance the shear parameters for solving the problems in foundation engineering (Pandian 2003), but limited study has been carried out on its use in stabilizing slopes. In all the studies, the flyash is thoroughly mixed with soil with respect to weight/volume and then the shear strength parameters are found by various methods. The case dealt here eliminates the practicability of thorough mixing of flyash with the soil because of the huge volume of the excavated soil to be dumped and the unavailability of machinery to carry out the mixing operations.

Instead, this research work proposes to mix fly ash with respect to height of clay dump, which can be implemented in the project site i.e. by dumping a fly ash layer in between layers of clay dump.

LABORATORY INVESTIGATION

The geo-technical parameters such as (1) Field dry density, (2) Atterberg limits, (3) Shear strength parameters of the soil samples from the dump under saturated conditions, (4) Grain size distribution and (5) moisture contents pertaining to field density were determined in the Geo-technical laboratory of Birla Institute of Technology, Mesra . To simulate the field conditions, Standard Procter Test was done to determine the moisture content at which the field density would be attained by giving 25 blows thus compacting the sample in the Procter Mould. Keeping in mind the feasible method to dump fly-ash, the fly-ash was put in layers during compacting e.g. in a 3.6cm high clay sample a layer of fly ash to height of 0.36cm was mixed in case of 10% fly-ash.

Similarly, laboratory investigation was carried out for 0% fly ash to 25% fly ash by height.

Unconsolidated Unconfined Tri-axial Test was carried out in the laboratory to determine the shear strength parameters on clay samples prepared in simulation to field condition for different variation of percentages of fly-ash.

STABILITY ANALYSIS

A computer programme has been developed for this site specific study of detailed stability analysis of clayey soil dump with or without embedded fly ash.The Computer programme involves application of both Fellinius and Bishop's Simplified method by considering following geo-engineering parameters (Roy 1998).

The geo-engineering parameters considered are as follows:

- Geo-technical parameters of clayey dump with or without fly ash and that of foundation material.
- Buoyancy force of water on the foundation of the dump.
- Depth of clay strata below external dump.
- Surface drainage due to rainwater through water flowing channel on the surface of the dump.
- Seismic force on the external dump.

Table 1 Results of stability analysis

COMPOSITION	'c' kg/sq cm	'Φ' degree	MAX. PERMISSIBLE SLOPE for DUMP HEIGHT OF 30 m. (degrees)
0% fly-ash (100% soil)	0.56	09.0	36
10% fly-ash + 90% soil	0.74	21.0	47
15% fly-ash + 85% soil	0.77	23.0	50
20% fly-ash + 80% soil	0.75	23.5	50
25% fly-ash + 75% soil	0.68	22.0	47

The maximum permissible slope angles for different percentage of fly ash and Factor of Safety of 1.2 were determined and documented in Table 1 and Figure 4.

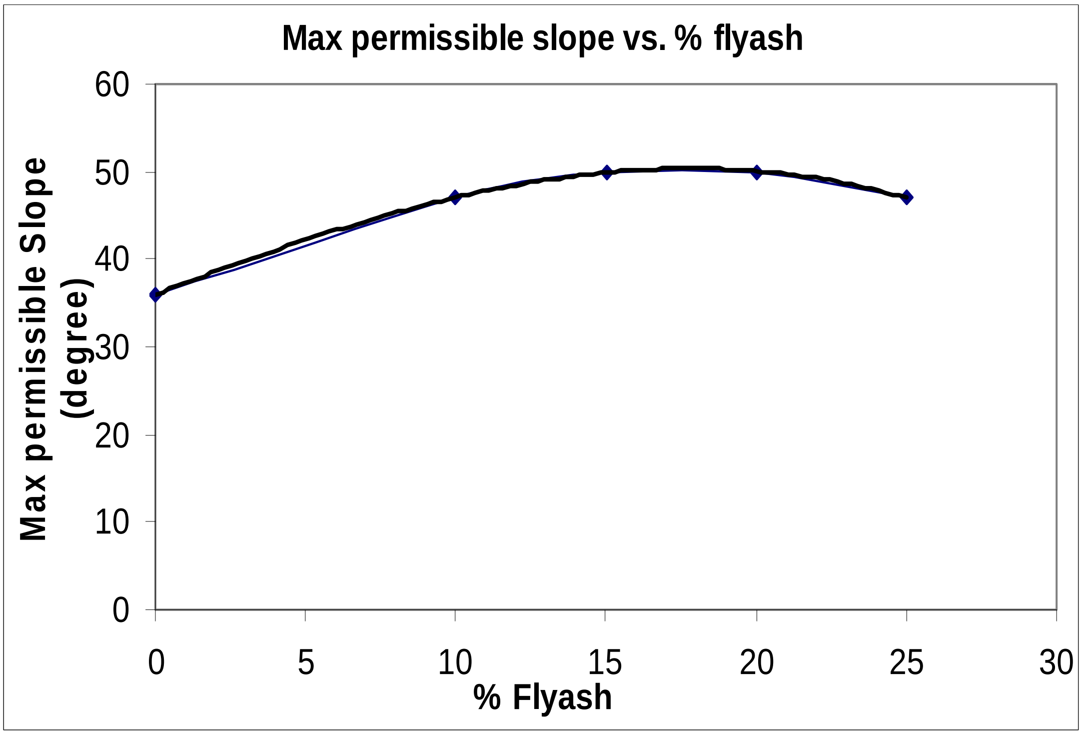

Figure 4 Maximum permissible slope angle of soil dump vs. % fly-ash.

CONCLUSIONS

Addition of 15% to 20% fly-ash to the clayey soil increases the permissible value of dump slope by 14 degrees thereby the same volume of soil can be dumped with lesser base area. The fly ash was added to the clay samples with respect to height i.e. in a 3.6cm height of clay sample, 0.36 cm height of fly ash(in case of 10% fly ash) was added during laboratory investigation.
The illustrative calculation is documented (Fig 2).

Dump Height = 30 meter, Base Diameter = 150 meter
Dump Volume with 0% Fly-ash = 262896 m^3
Net Soil Volume with 15% Fly-ash for Diameter of 70 m = 275414 m^3
Area of Land saved for Dumping the same amount of Soil = 2278 m^2

Hence it can be concluded that in a 30m high external clay dump, by adding a layer of fly-ash to a height of 4.5m(15%) to 6m(20%) embedded within clay dump will help in increasing the stability of external dump i.e. there is an increase in safe slope from 36 degree without fly ash to 50 degree with 15-20% fly ash.

ACKNOWLEDGEMENT

The views expressed in this paper exclusively are of the author and not necessarily of the organization which he belongs. I also express my sincerest gratitude to the management of Birla Institute of Technology, Mesra, Ranchi, India for giving permission to publish and present this paper at this conference.

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M Alamgir, QS Hossain, QH Bari, IM Rafizul, KMM Hasan, G Sarkar & MK Howlader (Eds.)
ISBN: 978-984-33-0761-3, Vol. 2, pp.743-748

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Practice of Demolition Waste Management

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ABSTRACT

Demolition is an engineering process by which a structure is destroyed for beneficial purposes. A questionnaire survey was carried out in Khulna city area. Data about the causes of demolition, its process and waste managing procedure were collected from Khulna. It is found that demolition of an existing building or part of it, for further development or renovation is very common in Khulna city. Demolition process usually creates wastes of engineering materials like floor finish and plaster dust (rubbish), pieces of concrete, bricks in regular or irregular shape etc. These are generally used for filling of low land, height raising the paving area etc. Regular maintenance and renovation of structures in KUET also produces huge amount of rubbish and its authority have been using these wastes for filling of low lying area. The paper focused mainly about the renovation and demolition waste generation and its utilization in Khulna city.

INTRODUCTION

Demolition is the opposite of construction, the tearing-down of buildings and other component of structures (Allen 1993). In Bangladesh demolition of full building or structure is not very common. Hence the technology involved in the demolition of structure is not properly developed here. Recently, few works have been done in major cities and towns such as in Dhaka, Chittagong, and Khulna. Demolition is done for various reasons like old age of buildings, renovation, maintenance and repair, illegal construction etc. In Dhaka Rangs Bhaban (22 storied) is demolished for illegal construction by using manual and mechanical method. The company assigned in demolishing work did not have past experience of breaking such types of massive structure. Eventually accident was commenced there causing death of labors. Its clearly explains the lack of technology & expertise in this area in the country.

In Khulna most of the building was demolished for several reasons: (i) exceeded design life; (ii) to construct new multi storey buildings; and (iii) to clear abandoned structure etc. For example Hotel Deluxe, Ajmal Plaza, G.M. Bakash Tower etc are demolished mainly for above causes. Table 1 shows the survey information of various demolished building site in Khulna, cause of demolition and techniques applied. In KUET, infrastructure development works continues for a long time which includes vertical extension of existing academic building, teacher's quarters, student hall of residence etc. Vertical extension of building requires replacement of older roof slab by new one. Again regular maintenance of existing building is very common here as it is situated in the saline zone. All these works produces huge amount of construction & demolition wastes (CDW) and becomes a headache for disposing these in a safe way. There is enough low lying area in the campus which gives KUET authority to handle nicely to solve this problem. In addition KUET authority uses these wastes to prepare sub base of new roads.

METHODOLOGY AND TECHNIQUES

A questionnaire survey was carried out and data from different building sites in the city area were collected. Annual repairing data were also collected from the KUET engineering office. Again land fill sites were visited by the authors and area was measured.

There are various methods for demolition of structures; namely (i) Manual demolition; (ii) Engineered demolition; (iii) Demolition ball technique; (iv) Pusher arm technique; (v) Pressure jetting for concrete repairs; (vi) Thermic lance technique; (vii) Microwaves technique; (viii) Concrete sawing. Suitable method is chosen from these depending upon the size, location, available space etc.

Larger buildings may require the use of a wrecking ball, a heavy weight on a cable that is swung by a crane into the side of the buildings. Wrecking balls are especially effective against masonry, but are less easily controlled and often less efficient than other methods. Newer methods may use rotational hydraulic shears and silenced rock-breakers attached to excavators to cut or break through wood, steel and concrete (Liu 2003).

Table 1 List of demolished buildings in Khulna

Buildings of	Location Near	Reasons	No. of storey before demolition	Proposed storey	Date of Starting of demolition	Procedure applied	Equipments	Date of Starting of new construction
Hotel Deluxe	Picture palace	Design life exceeded	03	08	Jan-07	Manually	Hammer, Sani	–
Ajmal plaza	Picture palace	Design life exceeded	04	06	Jul-05	Manually	Hammer, sani	Jan-06
G.M. Bakash Tower	Basic Bank limited.	Multistory purposes	01	10	Apr-07	Manually	Hammer, Sani	Feb-07
A. Hossain Plaza	City Bank Limited (sir Iqbal road)	Design life exceeded	02	06	Apr-05	Manually	Hammer, Sani	–
Residential Building	Commerce college	Design life exceeded	01	07	Feb-07	Manually	Hammer, Sani	-
National Tower	City Law college	Design life exceeded	02	09	-	Manually	Hammer, Sani	Mar-07
Commercial Building	Hotel Royal	Design life exceeded	01	04	Jan-06	Manually	Hammer, Sani	Aug-06
Residential Building	50, Cemetry road	abandoned	01	O5	–	Manually	Hammer, Sani	–
Slab of Central old library	In KUET	Damage of roof slab	02	02	April 07	Manually	Hammer, Sani	June 07

CURRENT MANAGEMENT PRACTICE

Before taking decision for demolishing of a structure, an assessment is carried out by a group of expert for institutional structure like structure in KUET campus, Cable factory etc. Institution or company usually involves engineers for making decision about renovation or demolition of their infrastructure. In case of public building, they decide their own on the basis of visual inspection and self judgment. For example, the decision for demolition of Hotel Deluxe is taken by the owners them selves. The institutional body invites contractor by open tender for maintenance and demolition works. While general people directly assign labors on daily basis for the same work.

Demolition is not an easy task. In Bangladesh manual method is mostly used and mechanical method is hardly used. Traditional tools and equipments are used in manual method for chipping old plasters and breaking of parts of concrete. Tools like hammer, sani etc are frequently used for this purpose. A sequence of works is observed while demolitions proceed in a site. Its initially start by removing window and door panel. Next electric wiring and plumbing pipe is removed sequentially. Then breaking of the roof concrete and cutting of reinforcing bars is performed from one side of the slab as shown in Figures 1 and 2. Removal of plaster and masonry works is handled as sincerely as possible to separate each piece of brick in its original shape as shown in Figure 3. It can be used for other construction as a cheap recycle material. Finally beams and columns are demolished from the top floor of the building as shown in Figure 3 and 4. Initial storage of recovered reinforcing bars are shown in Figure 5 and storage of concrete & brick wastes are shown are shown in Figure 6. A list of construction wastes and its source of generation with further use is shown in Table 2.

Figure 1 Demolition of Slab in progress

Figure 2 Mechanical cutting of slab

Figure 3 Demolition of brick works

Figure 4 Rubbish & concrete pieces

Figure 5 MS bars from demolished slab

Figure 6 Storage of C&D wastes

A group of labors break together the structure and other group carries the materials outside of the building and dumps it in a predefined location. It is then carried to the site where it can be used by using men driven two wheeler curt (locally called thela gari), men driven tricycle carriage (called van gari), trucks etc.

Table 2 Types and the probable uses of building renovation and demolition waste

Sl. no.	Waste types	Sources	Further uses
1.	Woods	Door, window of buildings	Repair & Reuse
2.	Electric wire	Electric wiring	To reclying process
3.	Plumbing pipe, fittings	Water supply & drainage system, toilet, kitchen	To reclying process
4.	Plaster & Floor finish (rubbish)	Building surface	Land filling
5.	Concrete piece	Slabs, beams, Columns etc	Land filling
6.	MS rods	Slabs, beams, Columns etc	To reclying process as scrap, used for making nut ,bolt etc
7.	Full size Brick	Masonry works, Partition wall	To use in masonry works, making khoa etc.
8.	Half brick	Masonry works, Partition wall	Making khoa, Land filling,

MANAGEMENT PRACTICE IN KUET

Huge low lying area gives an option to KUET authority to dispose and manage construction wastes easily. Before starting demolition and maintenance works the engineering office of KUET decides the locations for reclamation of low land by construction wastes. The area of the central play ground has been extended by dumping 12”-18” wastes as first layer and laying 12” soil as top layer is provided to have a smooth surface and to avoid any hazard caused by the sharp edge of the waste. In case of pond filling, the bottom 1m layer was filled by construction waste and then top 2-2.5m layer was covered with normal soil. They also use the waste for raising the height of land for connecting roads. They have done all these filling works successfully and not facing problems with those sites. Table 3 shows the different location and total volume of waste used in that site. All of this waste generated from either renovation, maintenance or demolition works inside the campus. Some times it becomes difficult to resolve the problem. For example, after disposing of a huge amount of waste it is hard to find new location this year to dump. Sometimes demolition and repairing contractor manage and find out a customer or they buy it directly. Situation can be worst and much critical when the demand for wastes to a customer less than the generated waste. In that case they offer the waste to someone for free of cost so as to clear the site.

Table 3 Details of land filling sites in KUET campus

Sl. No.	Location	Area in m^2	Volume of waste in m^3	Type of waste
1.	Play ground East	3146	1133	Rubbish
2.	Civil Eng. Bldg. north	137	21	Rubbish, brick & concrete pieces
3.	Two ponds, Front of Canteen	850	1000	Rubbish, & concrete pieces
4.	Street near School, south	106	38	Rubbish, brick & concrete pieces
5.	Street near Mosque. south	67	24	Rubbish, brick & concrete pieces
6.	Street near MAR hall, east	133	48	Rubbish, brick & concrete pieces

ADVANTAGE & DISADVANTAGE OF LAND FILLING

Though land filling by construction waste is an option to manage these types of waste, it also has disadvantageous too. For instance it is greatly harmful if these are dump into the cultivable land (Weber and Jang 2000). Again it is mentioned by the people in the interview that they face problems for foundation construction of new building in the site previously filled by construction wastes. Because in that case it essential to clear the waste again from there. If these are used for filling area like new roads and for paving area systematically then it is more advantageous and do not affect soil environment.

FINANCIAL INVOLVEMENT IN DEMOLITION WORKS

Resale value of an old building depends on some parameter such as age, size, material, & location of building. Cost of per square feet of floor is 30-35 tk. Demolition cost of per square feet is 35 percent of building cost. The expenditure of demolition depends upon the location & size of the structure, material of construction, skillness of workers and methods to be followed for demolition. As in Khulna city manual method is applied for most of the cases, the maximum cost goes for labor payment. Generally labors are paid on daily basis at the rate of 150-190 BDT /day. In some cases works are done by selecting on unit rate basis. The working efficiency and unit rate for demolished works of different items are shown in Table 4.

Table 4: Demolition rate and working efficiency considered to evaluate demolition time

Item	Material	Volume of work (cft / 2person day)	Rate of work BDT / cft
Grade beam	Stone	4-5	100-110
	Brick	8-9	65- 70
Wall	Brick	80-100	10-12
Beams & Columns	Stone	10-12	80-90
	Brick	15-18	55-60
Slab	Stone	10-13	20-25
	Brick	12-16	18-22
CC works	Brick	15-20	20-25

Demolition wastes have salvage value as mentioned above. There are many vangary shops at sheik para area in Khulna city, which buy old reinforcing bars, sanitary pipes and fittings etc. Many people buy rubbish for land filling purposes. Cost of Rubbish depends upon the size of carriage.

Selling price of demolition waste:

Full Brick = 60% of new bricks
Half brick (local name - adla) =20-25% of new brick.
Rubbish=200~500 BDT per truck.
Reinforcement =60-65%of original cost
Ties and stirrup=500 BDT for 100 numbers.

RECOMMENDATION ON DEMOLITION PRACTICE

The manual method is found to be more economic and creates less environmental problems as the noise generation is comparatively less. But it requires more time. On the other hand mechanical method is more costly and requires less time. However from close observation, it has been seen that the safety issues are ignored while demolishing a structure. Proper safety should be used in every demolition works for our own safety. In Dhaka, during the demolition of Rangs Bhaban proper safety has not taken. Twelve workers have lost their life due to poor safety measures during the works.

More analysis on the suitable method for demolition of structure in Bangladesh is required. Further study could be carried out to develop models on efficient sequential demolition process and on waste generation.

CONCLUSION

- The overall practice of demolition and renovation waste management in Bangladesh, especially in Khulna is satisfactory as most of the waste is reused by the different end users for different purposes. Nine buildings were safely demolished in Dakbangla area of Khulna since 2005 and the new buildings already have been constructed.
- Demolition rate varies from tk.10 to 110 per cubic feet depending on the type of structure component. A person can demolition concrete works 2 to 6 cft for stone aggregate and 4 to 8 cft for brick aggregate.
- The demolition practice in KUET campus is well managed. The renovation and demolition waste is disposed properly considering good safety measures.

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ISBN: 978-984-33-0761-3, Vol. 2, pp.749-756

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Solid Waste Based Stakeholders and Their Livelihood Patterns in the Marketing Channels at Khulna City of Bangladesh

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ABSTRACT

Municipal Solid Waste (MSW) in Khulna City area of Bangladesh is partially managed by Khulna City Corporation (KCC) itself and different stakeholders of the concerned community, for example Non-government Organizations (NGOs), Community-based Organizations (CBOs) and interested individuals especially the peoples from slum areas, locally known as 'Tokai'. The research find out the management of this MSW includes recycling, reuse, resource recovery, treatment and corresponding resource recovery and other such processes. In all cases, the research observed that an informal marketing channel has been established in KCC area - alike other cities of Bangladesh. A variety of stakeholder groups such as Tokai, Vangari Shop Owner and others are involved in the mentioned management system. Still no scientific study has been conducted yet to find out their involvement, marketing system and other such kind of activities. Thus the study tries to find out how much waste material were recycled for marketing, assessing their market value, marketing channel quantities and types, and number of people involved in this business. The research also included - how they expend their livelihood patterns on these activities, what's their socioeconomic and hygienic situation during the businesses. The research revealed that more than 40 tons of solid wastes are recycling and recovered by the primary level of stakeholders in solid waste marketing channel and this group includes Tokais, Feriwallas and Waste puller of KCC. This amount of these recycled and recovered wastes finally goes to the large industries by a chain of buyers. In this way, a total amount of business transaction is more than 5 million Taka / day that equivalent to 17,520,000 Taka / year. This amount is indirect cost for KCC solid waste management system. The research calculated that 10,000-15,000 number of peoples' livelihood depend on this marketing channel. During survey, the research also find out that lower level employee faces different social discrimination such as social dignity, security and other relevant discomfort situations, but they are preventing the KCC dwellers from relevant pollution problems like air pollution, bad odors, nuisance and other relevant situations, and earning a significant foreign currency because the recycled final products are mostly exported to the foreign countries and also utilize as precursors of many products that made in Bangladesh.

INTRODUCTION

The genesis of waste is as old as human inhabitation on earth; therefore, they go hand in hand. As to the sources of waste generation and associated management problems, the environmental historian Martin Melosi (1981) succinctly points out that: "Since human beings have inhabited the earth, they have generated, produced, manufactured, excreted, secreted, discarded, and otherwise disposed of all manner of waste. Among the myriad kinds of rejectamenta, refuse-solid waste-has been one of the most abundant, most cumbersome, and potentially most harmful to society. Beginning with ancient civilization, there has always been a refuse problem." Solid waste management is a major challenge in urban areas throughout the world (Hwa 2007). Many of the cities in the developing world rank solid waste management as one of their major concerns. It is easy to understand why. As urban populations grow, waste collection services seem to fall further and further behind, and piles of waste grow relentlessly, blocking drains and even roads. The smells of rotting garbage and of the smoke from burning waste are well known in many cities (Coad 2003).

Dumping of waste on the roadside or in public places is a common practice in Asian developing countries. These are concerned with ever increasing amount of solid waste in their municipalities. The increase of solid waste in every Asian city is mainly attributed to population increase, industrialization, and the improvement of living standards (Hwa, 2007). The growing volume of waste spawned by changes in consumption patterns is presenting a formidable challenge to all. The problem is how to deal with a large increase in waste without changing the lifestyles of the people. The current practice in most municipalities is to dispose of their waste into open garbage dumps. Pressure to protect the environment is now coming from the public through media reports and Non-Governmental Organizations (NGOs). The waste that is currently disposed of in dumps, landfills, or incinerators presents the greatest potential for recycling, processing, or reuse. In many countries, inorganic waste such as paper, metals, and plastics are readily recycled, as the world demand for this waste is growing. What is needed is the creation of a proper marketing system for recycling so that this waste can be sold based on world prices. More and more countries are using the materials recovery facility option to gather these valuable items (Koh 2007).

Khulna City Corporation (KCC) generates around 455 tons municipal solid waste per day, of which, managed waste is 26.5 tons, KCC collects 240-260 tons and unmanaged waste (mainly organic) is 191.3 tons of total waste (WasteSafe 2005). The 40% – 50% unmanaged waste and its uncontrolled disposal degrade the quality of urban living environment in the KCC area (Salequzzaman et al. 2006). A significant inorganic portion of the solid waste is being collected by the solid waste collectors of different level of existing solid waste marketing channel in the KCC area. It helps to reduce the quantity of inorganic waste of the city.

OBJECTIVES OF THE STUDY

The overall objective of the study is to discover the solid waste marketing channels that are contributing the Bangladesh economy significantly. The specific objectives of the study are:

a) To explore all possible actors involved in the solid waste marketing channels and to classify them according;
b) To quantify the amount of solid waste and their corresponding monetary values in the marketing channels; and
c) To identify and compare the livelihood patterns of the solid waste based stakeholders.

METHODOLOGY

Methodology can be defined at least two ways. In one form, methodology is identical to a research model employed by a researcher in a particular project, including basic knowledge related to the subject and research methods in question and the framework employed in a particular context. For good accomplishment of the research work a well arranged methodology is extremely needed. For this research work, as such a well-arranged methodology followed sequentially to satisfy all the objectives of this study.

Conceptual Framework

Several things, which are relevant to the present study, have played an incremental role for developing the concept about the study. It was necessary to grow up a wide concept of the different issues of the thesis was achieved by:

- Communication with resource person
- Literature Survey
- Guidance for Questionnaire preparation and Data analysis from expert person

By communicating with the resource persons and studying different books, journals, seminar papers, report and publications, which focus on the issue related to the topic; finally, the existing solid waste marketing situation of the study area influenced to conceptualize the present work.

Selection of Study Area

Discrete selection of the study area is very much significant for any study. It is remarkable that the ultimately success of any research work fully depends on the selection of the study area. Since Khulna city is the third largest city of Bangladesh and it is rapidly urbanizing. Management of solid waste in the municipal area is the responsibility of K.C.C. Present area under its jurisdiction is 44.78 square kilometer divided into 31 wards with population 1227239.

Location and Layout

Khulna is situated below the tropic of cancer, around intersection of latitude 22.49^0 North and longitude 89.34^0 Eeast. Surrounding districts are Satkhira at west, Bagerhat at east, Norail at north, and Jessore at northwest, and the Sundarbans, then the Bay of Bengal at its south. It lies along the Bhairab River. The city stands on the bank of Rupsha and has an important river port. It is connected by river, road and rail to the major cities of the southern Gangetic delta. Minimum journey time is 6 hours from Khulna to Dhaka by bus and now direct train service is also available. The physical shape of Khulna city is controlled by its geo-physical conditions. It is long-shaped a city extending from southeast to northeast along Bhairab-Rupsha River. The spontaneous nature of city growth and its shape are greatly influenced by the river Bhairab-Rupsha and Khulna-Dhaka road (WasteSafe 2005).

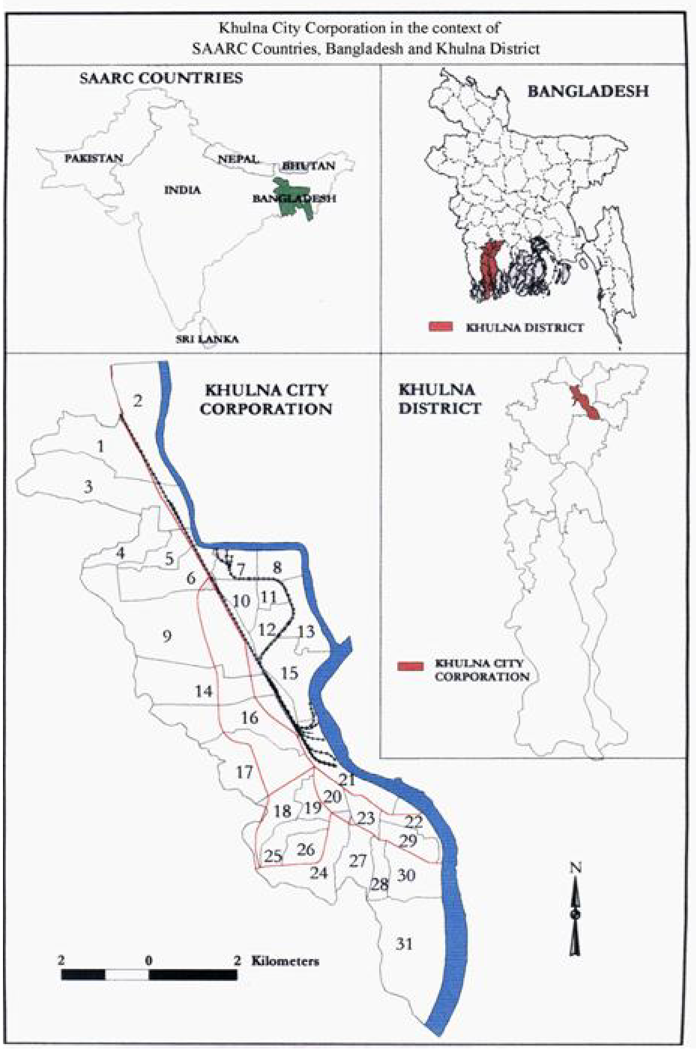

Figure 1 Location of Khulna City Corporation

Identification and Estimation of Actors and Amount of Waste Involved In Solid Waste Marketing

Sinah and Enayetullah (2000) give the method to identify and number of actors, total waste collected by actors at the respective level for a city. To identify and estimate the actors and total solid waste collected of the study area the follow steps are followed.

Step-1

A reconnaissance survey in the study area was conducted. The objective of this survey to identify the actors involved in waste marketing. Generally, several actors are involved in waste recycling trade/ marketing of cities of least developed countries, which are:

- Waste pickers
- Hawkers
- Small shops dealing with Recyclables
- Wholesale shops
- Industries (Large and small)

As shops dealing with recyclable materials are clustered in certain areas of the study area, information about the location of this shops and numbers, and industries from hawkers, waste pickers, municipal officials and NGO's were collected.

Step-2

Then the number of actors involved in each group was estimated. To estimate the number of actors, to whom they sell their retrieved / collected materials and how many are there who collect the same and sell was asked to each actor. For instance, hawkers sell their collected materials to small shop owners, so small shop owners were asked how many hawkers sell their collected materials to their shop. Each shop, has usually fixed number hawkers who provide them materials daily. For example, if there is 50 small shop which buy recyclables and each shop has in average 3-4 hawkers who provide them with recyclables, the total number of hawkers can be roughly estimated as 50 shops × 3 hawkers = 150. Similarly, the number of actors involved in each group was calculated.

Step-3

A questionnaire survey amongst all actors to collect data about the items collected as well as their quantity and value was conducted. Then the total quantity of recyclable collected in the study area by each actor was estimated. For instance, if there is 100 hawkers in a area and each collects on an average 5 kg paper daily, then total paper collected by the hawkers in the particular area is 100 hawkers × 5 kg = 500 kg.

RESULTS AND DISCUSSIONS

In Bangladesh, socially disadvantaged poor people of the informal sector are mainly engaged in Waste Recovery and Recycling practices. A significant amount of waste is reduced because of their recycling activities. These waste collector groups from private sector are playing a prominent role in the collection of recyclable materials as a main source of income. All of the buyers of waste material are from private sector and only a few formal manufacturers are involved in using this material as raw material. There are several stages of solid waste marketing in Khulna city.

Solid Waste Marketing Channel of KCC

Informal sector in Khulna is playing an important role in marketing of solid waste. 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 substance as raw material. Although recycling of solid

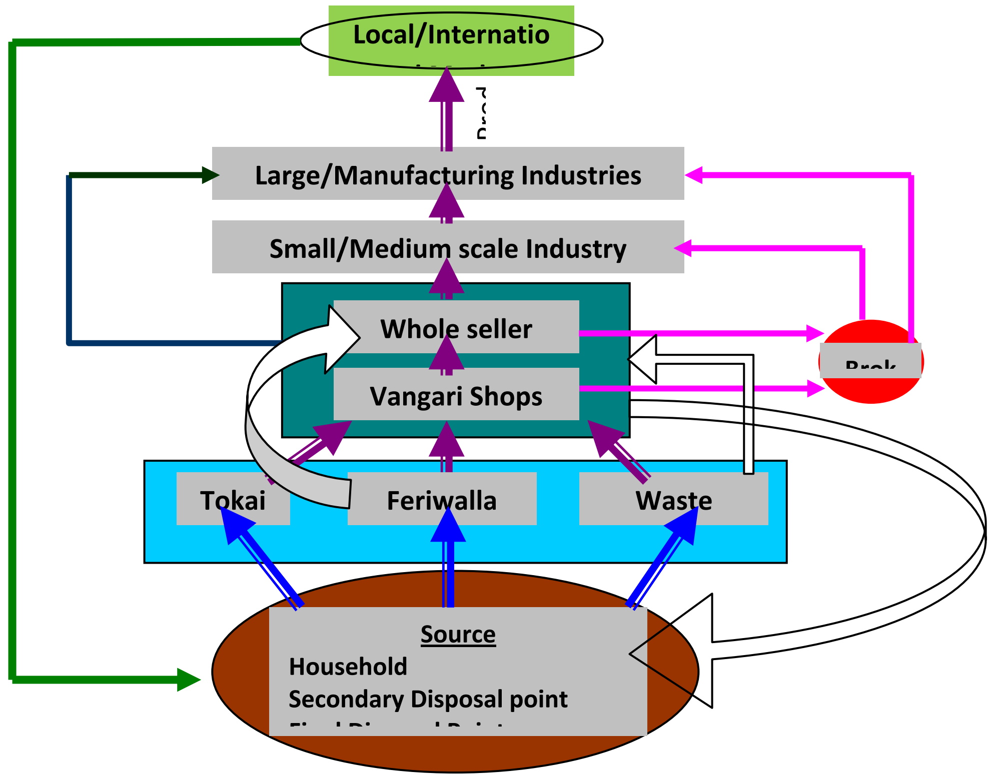

Figure 2 Solid Waste Marketing Channel in KCC

Waste is not included in the national environmental policy, yet it has become a main source of income for several groups of the informal sector. Organic waste which forms almost 78% of the total waste has no significant selling value to the actors involved in recycling trade. Inorganic waste is their main source of income for livelihood, and this has created a complex system, with every actor having a self-functioning network.

According to the extensive field visit and questionnaire survey three levels of marketing channel was found after the source in Khulna area. Several actors are involved in these three levels of solid waste marketing channel. These are:

Primary Level: Tokais, Feriwallas, and Waste puller
Secondary Level: Vangari Shops, Wholesaler Shops
Tertiary Level: Small Scale Industries, Large/Manufacturing Industries

Tokai

At the lowest stratum of the marketing channel is the wastebin tokais. They are visible in every community of the city and come from nearby slums and squatter settlements. It is estimated that at present more than 1,500 tokais are working in KCC area. This figure has been based on the data provided by the tokais, feriwallas, vangari shops and wholesalers operating in KCC area. They scavenge any thing that has value in the waste market. For recovering, they use either bare hand or bent rod or a wooden stick. They sell their recoverable material to feriwallas or vangari dokanandar usually in small volume. Following Table 1 shows the daily quantity of recyclables collected by the tokais.

Table 1 Types, daily quantity, total quantity of waste material collected by Tokai's in KCC

Type of Waste	Average collection/ Tokai/day (Kg)	Total Collection/ day (Kg) in KCC	Percentage	Selling Price (Tk/Kg)	Total selling Amount in KCC
Plastic	0.5	750	11.62 %	25	18,750
Paper	1.0	1,500	23.26 %	8	12,000
Metal	1.3	1,950	30.23 %	30	58,500
Glass	0.5	750	11.63 %	1	750
Others	1.0	1,500	23.26 %	3	4,500
Total	4.3	6,450	100		94,500

Source: Field Survey, 2008.

The ratio of collected material is shown in the Table 1 and Figure 3. Both shows that among the collected items by wastebin tokais percentage of metal is highest followed by paper and plastic. Aluminium and hard plastic is the most profitable item for the waste bin tokais.

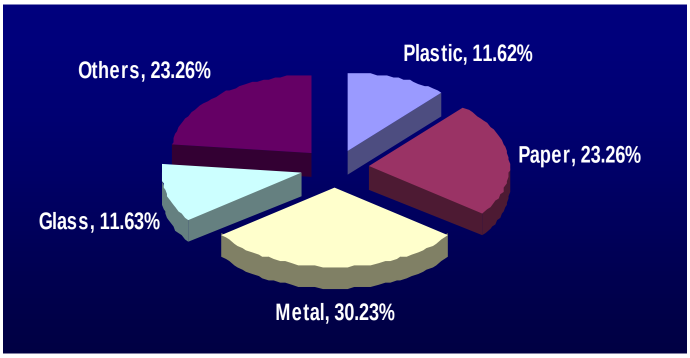

Figure 3 Percentage of collected materials by Toaki's

Table 1 show that each tokai collected about 4.3 kg of waste per day. It has been estimate that the total amount of waste collected by toaki's is about 6,450 Kg/day and their approximate value is 94,500 Tk. One important thing is that the selling price of the product collected by the tokais is the lowest among the entire collector. This is probably due to the low quality of the collected waste materials. Because most of the tokai's collected waster materials either from roadsides, or secondary disposal points or final disposal points. Figure 4 shows the ratio of different sources from where tokai's collected marketable materials.

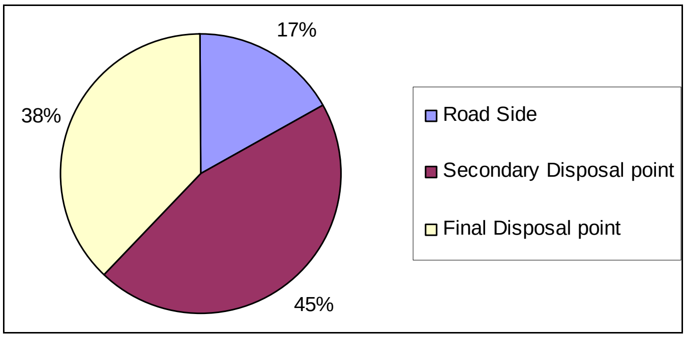

Figure 4 Ratio of collection point for Tokai.

Livelihood of Tokai's

The livelihood situation of tokai's found in the study is described below:


Picture- Children Tokai


Photo- Women and Male Tokai

Types of Tokai and Their Involvement

Figure 4 shows the types and ratio of tokai's in KCC area. From field data it was found that most of the tokai's are children whose age is under 13 years followed by female and male. Most of the female tokai's are either widowed or their husband left them and male tokai's are old people who are unable to do hard work.

The highest duration of involvement in this profession is between 1 to 3 years. This is representing about 48.67 % among the respondent. This is probably due to the worse economic condition for the last few years. They generally come to this profession by seeing the neighbors or family members. Tokai's are on an average 6.5 hours spent for collection of waste materials every day.

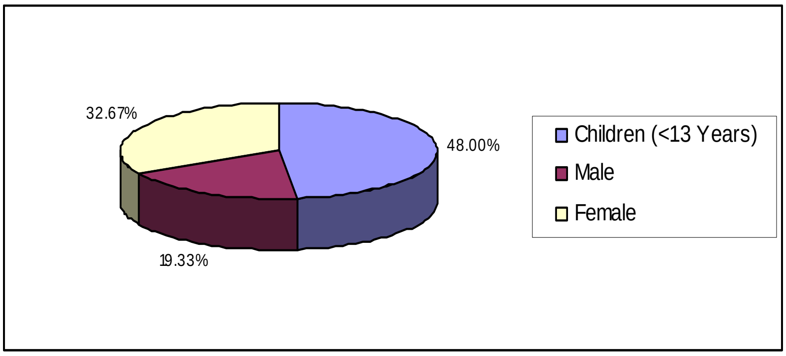

Figure 5 Types and ratio of Tokai's in Khulna Area.

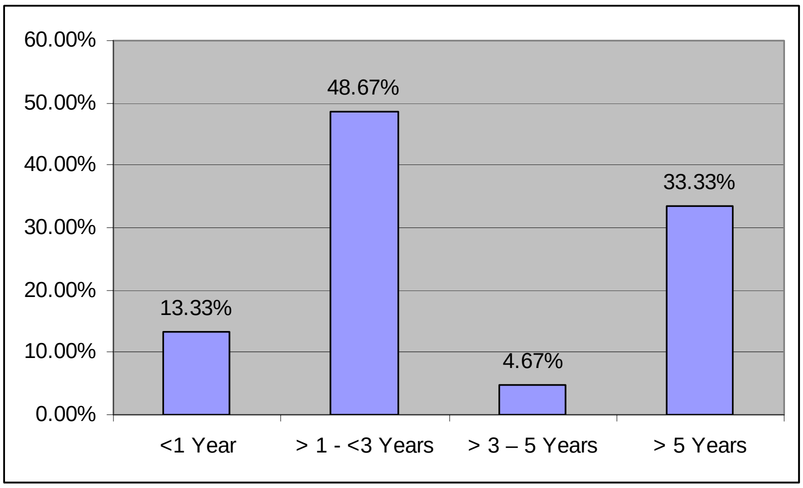

Figure 6 Involvements in Waste Picking

Socio-Economic Condition

The family size of toaki's on an average is big, about 5 members. Their average income is 55.50 Tk./day, which is very small amount for their livelihood. For this reason other member of the family involved in the same profession among the maximum respondent. About 76% of the tokai's are dissatisfied in their income. Some of the tokai's save some money for their family members and mostly in the NGOs. They generally face social discrimination, especially social dignity and some face security generally young women for this profession.

CONCLUSIONS

The present practices of solid waste management in KCC are not environmentally friendly. The stakeholders involved in this practice are not awarded well and trained. However the practice brings a profitable business in KCC like other cities of the country, Bangladesh. The stakeholders classified as primary, secondary and tertiary level. The ratio of income in these three levels in an average is 1:3:30. It means that the main stakeholder of this practice is loosing significantly in the monetary matter. In addition the financial transaction reveals that a good amount of money is hiddenly used for foreign currency income generations.

In Khulna City Corporation area, 8.0 percent of the total generated waste is retrieved by informal sector. This informal sectors deal with only inorganic wastes. From the study it is estimated that the informal sector is removing more than 40 tons of solid waste per day in Khulna. Thus, this informal sector is savings Khulna City Corporation Tk. 17,520,000 annually by removing 40 tons of solid waste. Moreover at present it is estimated that between 10,000 to 15,000 people are working in the informal sector activity relating waste recycling and marketing. Therefore, the recycling and marketing of solid was playing two important roles for the Khulan city as well as for the country and the earth. Firstly, it is providing livelihood for a significant portion of people of Khulna city as well as playing a role in the National Gross Domestic Product (GDP) by saving money from dumping and recycling. Secondly, it is saving our environment from deteriorating further and recovering the resources for using productive purpose. Most of these wastes are non-biodegradable and if goes to the environment they do not degrade for decades. But in the study it is found that the key role players who are responsible for the primary level of the waste marketing channel that is Tokais, Feriwallas and Waste puller face social discrimination for this job. A significant percentage of primary level stakeholders also suffering from different health problems for not use proper safety materials and lack of knowledge about the risk of the waste material handling.

RECOMMENDATIONS

Fore effective solid waste marketing and to improve the marketing channel following things can be done:

- Government policy for solid waste management by recycling, resource recovery and their proper marketing should be established.
- The households should be motivated for the on-site waste sorting and keeping them on different bins.
- A list of recyclable materials and their present market value can be disseminated among the public by paper, postering, add, billboard and media.
- The importance of recyclable materials for the protection of environment and national economy can be incorporated in the primary and secondary education curricula to aware from the very early stage of life.
- A recycling platform should be established by the local authority.
- The marketing of recyclable materials should be ensured.
- The Tokais should be rehabilated by providing vocational training and education.
- A health program should be started for the collectors to reduce the degree of infection by applying protective measures and cleanliness.
- The social status of Tokais, feriwallas, waste pullers and vangari shop owners should be improved by informing the society about their role in the protection of environment and economy.
- The Tokais, feriwallas, vangari shop owners, workers of processing and remolding factories should be provided training to increase the productivity and environmental awareness.
- The informal recycling sectors should be provided loans and incentives to enlarge their recycling activities.
- Public should be motivated to use recycled products.

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ISBN: 978-984-33-0761-3, Vol. 2, pp.757-762

Proceedings of the International Conference on Solid Waste Management
Technical, Environmental and Socio-economical Contexts - WasteSafe 2009
9 to 10 November 2009, Khulna, Bangladesh

Availability of Reuse and Recycle of Wasted Roof Tile as Water Environment Restoration Material

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INTRODUCTION

Human beings have been established the abundant material civilization based on the development of sciences and technologies. The results pursuit of the development weighted to the convenience of life, however, our human life faced to serious problems such as nature destruction, depletion of natural resources, discharge of vast amount of waste, and so on. It is an urgent question how to construct the cyclic society system of resources for gaining the sustainability of human life by means of optimized production and consumption. As well, the minimized amount of wastes treating them as the resource, and develop the effective reuse and recycle method will be also important in the future. Following to the activation of such human life, deterioration of water environment have been actualized gradually in all over the world. Especially the increment of domestic and industrial waste water supplies excessive pollutants such as nutrients and organic matter, lead the water quality of rivers and lakes into terrible condition. Stagnant water area, such as ponds and semi-enclosed bay where the self purification ability is low, easily accumulate these pollutants and make the water quality become worse. Eutrophication, abnormal growth of phytoplankton, and anoxic water occur in these water areas and generate some serious problems; damage of aquatic ecosystem and difficulty of water use for human beings.

Based on these backgrounds above, authors have been suggested the cyclic utilization of water purification material based on the demolished concrete. After supplying the concrete structures, they are used to be demolished, crashed into small particles, utilized for base course material of road construction and reused again for concrete; called as “recycled aggregate”. However, Sato et al. (2004, 2005) have clarified that calcium and alkalis included in concrete can remove the phosphate ion in environmental water (Arita 1998). It suggests us that demolished concrete can be reused mentioning not only its physical properties but also chemical properties, and can expand the effective way for the utilization.

Disposed industrial waste without reusing up to now is focused in this study. The objective material is Japanese roof tile, called Kawara generally in Japan. In the experiments, fundamental ability of Kawara for the water purification material is investigated, adsorption capacity of phosphate ion and availability for functional overlying sand.

Outline of Material and Experiments

Kawara, the Japanese traditional roof tile, are made of clay materials, and firing with high temperature (higher than 1,200). Shimane Prefecture, Chugoku region in Japan, has been known as one of the most famous productive area of Kawara, 600,000 tons per a year of the roof tile is produced at Chugoku region. Up to now, both its production process and after its utilization, vast amount of the wasted roof tile are treated as the industrial waste and reclaimed at the landfill site without reusing. However, recent legal improvements in Japan don’t permit such situations and require to reuse or to recycle from the viewpoint of effective use of resources. The picture of the wasted roof tile is shown in Figure 1. In the experiment, firstly, adsorption ability of phosphate ion in water is examined. Secondly, safety of this material is investigated because roof tile usually use the glaze when they are produced for changing into the popular color. Furthermore, recycling style of wasted roof tile for the optimized utilization as the restoring material for the water environment is evaluated.

Figure 1 Picture of wasted roof tile

Evaluation of Phosphorous Removal Ability

Firstly, basic removal ability against phosphate ion of wasted roof tile is examined. Secondly, for reusing and recycling the wasted roof tile effectively, we add the firing process after crashing into small particles in order to generate the micro cracks on the surface of roof tile particles. This process may expand the contact area between the materials and environmental water. Wasted roof tile is firing for two hours using electric furnace with different firing temperature; 100, 300, 500 and 1000℃, respectively. Removal ability of phosphate ion is examined with using each material.

Experimental procedures are described as follows; 50 g of wasted roof tile was put into 2 liters of aqueous solution which concentrations of phosphate ion was adjusted to 1mg/L, stirred until 168 hours.

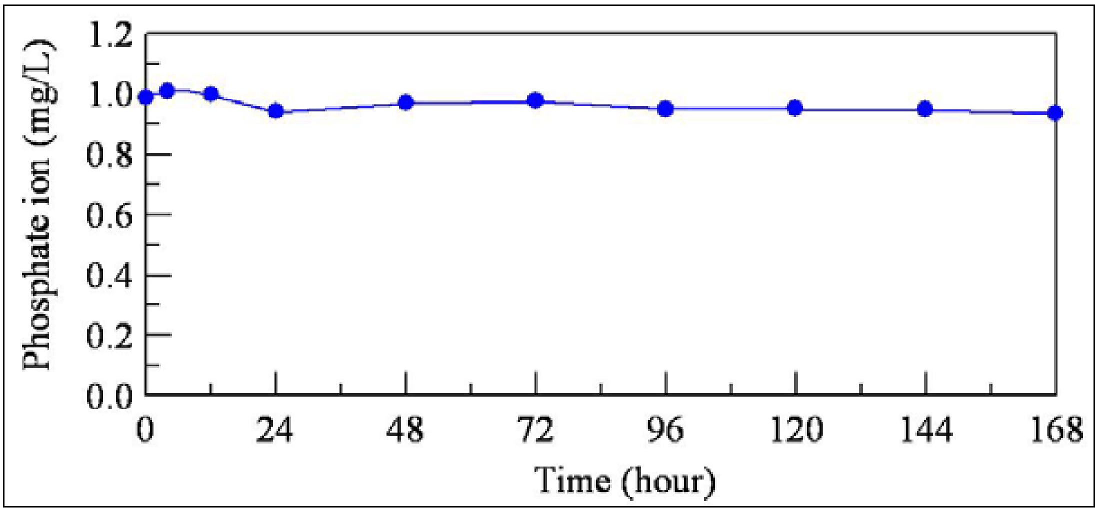

Figure 2 Removal ability of phosphate ion without firing process

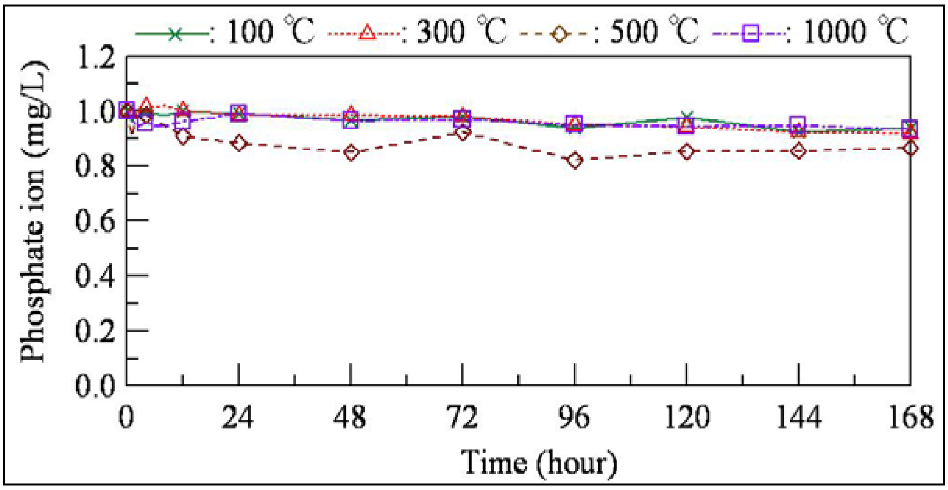

Figure 3 Removal ability of phosphate ion firing different temperature

Experiment was started at the moment when the waste roof tile was soaked into the solution. 25mL of solution was sampled at 0, 1, 2, 4, 8, 12, 24, 48, 72, 96, 120, 144, 168 hours. Concentrations of phosphate ion were measured by molybdenum blue method.

The result on change with time of phosphate ion soaked in wasted roof tile is shown in Figure 2. It is confirmed that this material, without the firing process, doesn't have huge removal ability against phosphate ion, however, slight performance is appeared. From this result, 0.07 mg of phosphate ion is removed at 168 hours after starting the experiment.

The results on removal abilities of phosphate ion of wasted roof tile introduced the firing process are shown in Figure 3. There are no significant concentration differences from the beginning and ending of the experiment in 100, 300, and 1000℃ firing temperature. Slight difference is confirmed with the 500℃ firing temperature, but it seems not so much effective on the removal ability of phosphate ion. It is considered that this type of material doesn't have huge chemical adsorption ability because clay soil, main component of roof tile, is electrified with negative, same charge with phosphate ion, and it is impossible to couple electrically between the wasted roof tile and phosphate ion. Therefore, it is not expectable enough to utilize the roof tile for the direct removal material of phosphate ion. On the other hand, this result means this type of material has possibility to show high performance on removal of cation such as Ammonium ion dissolved in water, further experiment will be done in the future.

Table 1 Concentrations of pollutants dissolved from wasted roof tile

(Unit mg/L)

Element	As	Cd	Cr	Se	Mn
Waste roof tile	0.0058	--	.0045	0.007	0.2354
E.Q.S*[1]	0.01	0.01	0.05	0.01	10

*[1]*Environmental quality standard in Japan*

Evaluation of Safety of Wasted Roof Tile

In general, sufficient evaluation on safety, impact to the environment and influence to human health, is necessary when we want to reuse the waste in nature or close to human life (Hyodo et al. 2007, 2008a). Roof tile is usually using glaze for two purposes; waterproofing and coloration. The latter reason, the coloration, it is necessary to use some metals such as copper, cobalt, nickel, chromium, and so on. Therefore, it is necessary to confirm the dissolution characteristic of these metals because some of them could be harmful for creatures, especially when reuse it in environmental water for water purification material. Dissolution amount of As, Cd, Cr, Mn, and Se were measured for the confirmation of safety in this experiment. 50 g of waste tile, before the firing treatment, was soaked into 2 litter of ultra pure water, the sampling time step was same with the last chapter. ICP-Atomic Emission Spectrometry was used for measuring the concentration of dissolutions.

The result of this experiment is shown in Table 1. It is confirmed that dissolved amount of As, Cd, Cr and Se are not so high concentration comparing with Environmental quality standard values in

Japan (Arita et al. 1998). On the other hand, dissolved amount of manganese is larger than other elements comparatively. Manganese is considered to be dissolved from the graze of roof tile. However, manganese is not designed to harmful matter in Japan, furthermore, smaller than Environmental quality standard value. From the results above, it is considered that wasted roof tile will not affect to human body and the environment when use it in environmental water.

Reuse for Functional Over Lying Sand

Sand capping is adopted as a countermeasure for the suppression of the internal load in stagnated water area (Hyodo et al. 2008b). However, it is difficult to practice the sand capping in the future because natural sand is also depleted in Japan. Also this method, sand capping, is indicated that the suppression effect is not so long term. In this study, functional over lying sand was produced using fine demolished powder of wasted roof tile, and its suppression ability against the increment of internal load was examined.

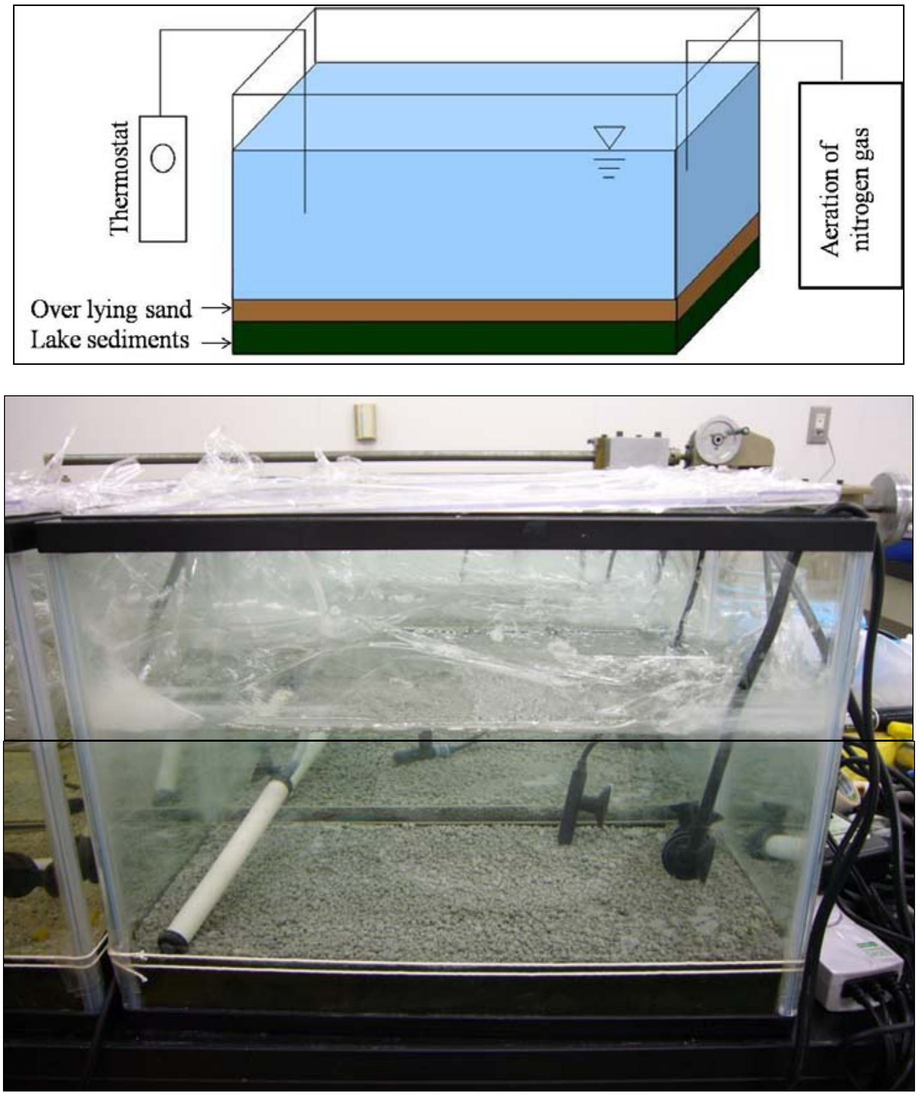

Figure 4 Outline and picture of experimental apparatus

Wasted roof tile was crashed into small particles, and particle size of 2 to 5 mm was selected and used as over lying sand in this experiment. Size of water tank was 0.22 m in length, 0.36 m in width, and 0.26 m in height. Sediments gathered from Nakaumi, one kind of stagnated blackish lake in Japan, and laid into the bottom of water tank with 30 mm thickness. Crashed tile particles were set over this sedimentation with the thickness 10 mm. After that environmental water getting from the same lake was poured statically in the water tank not to mix the conditions. Outline of experimental apparatus and picture are shown in Figure 4.

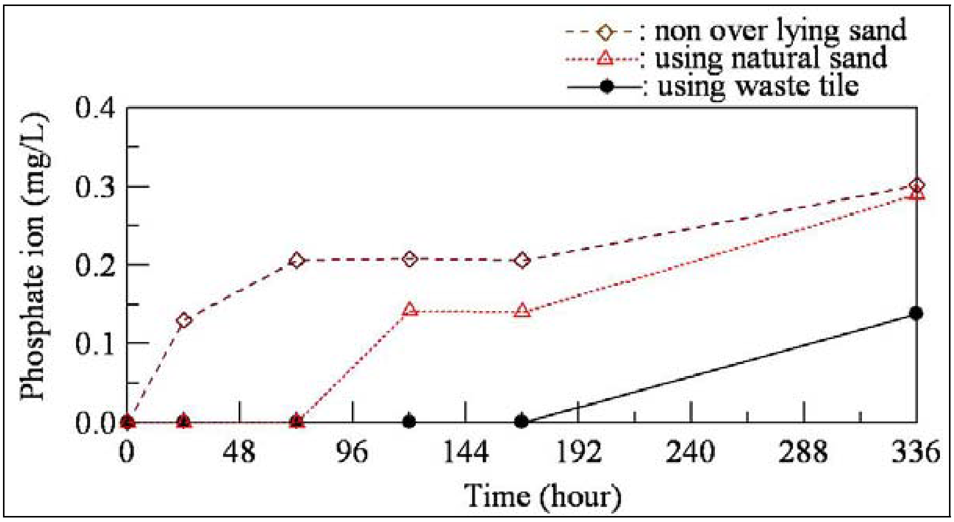

Figure 5 desorption rates of phosphate ion from lake sediments

Suppression effect on nutrient of wasted roof tile as over lying sand was examined under these conditions. Focused kind of nutrient was phosphate ion, water in tank was sampled at 0, 24, 72, 120, 168, 336 hours and measured the concentration of it. In order to clarify the suppression effect of overlying sand in actual environmental water, condition was simulated to summer season when the phosphate ion was released much and actively; water temperature was controlled to 25℃ using thermostat, dissolved oxygen was less than 1 mg/L by injection of nitrogen gas. In addition, other two conditions, one is no overlying sand and other is using natural sand for overlying material, was prepared for the contrastive study at the same time. Change with time of phosphate ion under 3 experimental conditions is shown in Figure 5. No overlying sand condition indicates that phosphate ion increases to 0.12 mg/L until 12 hours from the starting, active dissolution of phosphate ion from the sedimentation is confirmed. Result using natural sand as overlaying sand can suppress the dissolution of phosphate ion for first 72 hours, but the concentration increases gradually, rise to almost same concentration of no overlying sand at the end of the experiment (336 hours later). Oppositely, small rise of phosphate ion concentration is confirmed during this experiment period when used the wasted roof tile as over lying sand, but there are no dissolution until 168 hours from the beginning of this experiment. Thus, wasted roof tile shows higher suppression effect of phosphate ion than natural sand. Even though natural sand doesn't have the adsorption ability of the nutrients itself, but can work for over lying sand. It means the wasted roof tile has higher possibility to utilize for the overlying sand because its adsorption ability of phosphate ion exists, and actually considered to show the suppression effect.

CONCLUSIONS

In this research, reuse method of wasted roof tile was evaluated from the view point of removable ability of phosphate ion, safety, and effectiveness as overlying sand. As a result, it was confirmed that wasted roof tile has small removal ability of phosphate ion. Examined the safety of this material, concentrations of dissolved harmful matters were lower than the environmental quality standard values in Japan, it was considered that wasted roof tile is possible to use in environmental water. Moreover, applicability of wasted roof tile for the substitute of overlying sand was examined, and it was clarified that suppression effect of nutrient is higher than the utilization of natural sand. From these results, reusing of wasted roof tile was effective as the restoration material for water environment.

For the realization of sustainable society, it is one of the ideal theories to establish the "zeroemission system" of all resources, which do not generate any wastes. Also it is very important to treat the various resources produced from human life, not to treat them as "waste" but to consider them as "by-product", and compose the reuse and recycle system based on their own characteristics; not only one step but also multi steps will be optimum for this type of utilization system. In other words, the cascade utilization system of resources is necessary in the future. Moreover, various unused resources do not exist in universe but do localize due to the regional characteristics. It means that if we might develop only the utilization technology of such resources, it will be difficult for the practical use; if we have to gather or move such unused resources to other far place, it will increase not only transport cost but also environmental impact such as exhausting CO2 amount. Therefore, following concept will be necessary and available for developing any materials in the future; By-products generated in region have to be used at the right place and right way.

ACKNOWLEDGEMENT

The authors would like to thank Mr. Tadanobu KIMURA for his assistance with the sampling and analyses for this investigation. We also appreciate to the help of Mr. Yu FUKUYORI for offering his helpful comments and supports.

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ALPHABETIC AUTHORS' INDEX

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International Conference on

Solid Waste Management

Technical, Environmental and Socio-economical Contexts

WasteSafe 2009

Inherent organizational limitations, lack of peoples' awareness, motivation and participation, in absence of appropriate management system, financial and resource constraints and ineffectiveness of legislation and law enforcement, municipal solid waste remains unmanaged and posed threat to human and nature, especially in the Least Developed Asian Countries, like Bangladesh. To address this most striking social and environmental issue in Bangladesh, Khulna as the case study city, in a safe and sustainable way, a three years partnership project entitled as "Safe and Sustainable Management of Municipal Solid Waste in Bangladesh through the Practical Application of WasteSafe Proposal - WasteSafe II" co-financed by EU-Asia Pro Eco II Programme of the European Commission has been conducting since January 01, 2007. This project is coordinated by the Department of Civil Engineering, Khulna University of Engineering & Technology, Bangladesh 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. To exchange the views and experiences at international level and to understand the solid waste management concept and development as a whole, this International Conference for two days is organized at Khulna, Bangladesh as a part of this project activities.

Organized by

Department of Civil Engineering
Khulna University of Engineering & Technology
Khulna, Bangladesh

Co-financed by

EU-Asia Pro Eco II Programme of the European Commission

In Close Cooperation of

Bauhaus University Weimar, Germany

Khulna City Corporation, Bangladesh

Asian Institute of Technology, Thailand

Lublin University of Technology, Poland

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ISBN: 978-984-33-0761-3