An approach towards sustainable city environment: Critical analysis of municipal solid waste management of Pabna municipality of Bangladesh from the perspective of resource recovery and environmental conservation

A H M Monzurul Mamun
Department of Geography, Environment and Urban Planning,
Pabana University of Science and Technology, Pabna 6600, Bangladesh.
hasnat_pust@yahoo.com

***Abstract*- This study explores the municipal solid waste management of an underdeveloped municipality named Pabna of Bangladesh. Waste generation is increasing with its population and the municipal authority is facing enormous challenges in managing the waste on this low lying piece of land highly vulnerable to seasonal flooding. Leachate contamination and greenhouse gas emission are the prominent environmental concerns. The study suggests manual organic composting as a remedy. Reduction potential of methane (CH_4) emission is identified by calculation and evaluation of dumping site CH_4 emission. Possible environmental, social and economic benefits including landfill area requirement reduction are also identified.**

***Index terms*- Municipal Solid Waste (MSW), Waste Management, Greenhouse gas (GHG), Methane (CH_4), Organic Waste, and Composting.**

I. INTRODUCTION

Waste refers to the quantity of materials and products before recycling and land filling and its quantity mainly depends on population and their living standards, income level, economic growth, consumption pattern and institutional framework (Grossman et all, 1974). In developing countries, it has turned into the most vital urban environmental issue and is considered as one of the important contemporary environmental problems. Municipal solid waste (MSW) generation can be identified as an inevitable consequence of production and consumption activities related to level of income and urbanization (Wang and Nie, 2001). Besides several socioeconomic factors like person per dwelling, their cultural patterns, education and attitudes etc are influencing MSW generation. Management of MSW is an important aspect environmental hygiene and includes planning, organization, administration, financial and legal aspects of various activities associated with generation, collection, transportation, storage, processing and disposal and it adopts principles of economy, aesthetics, energy and conservation (Tchobanoglous et all, 1993). Improper and unscientific management results in pollution such as air, water including ground water and soil pollution and forms the breeding ground of different disease carrying vectors such as flies, mosquitoes, rats and others (Kumar et all, 2009). Cities in developing countries hardly spent more than 0.5% of their gross national product (GNP) on urban waste services, which covers only about one third of overall cost (Word bank, 1999).

In developing country like Bangladesh urban local government is facing enormous challenges in managing municipal waste. This is due to huge waste generation closely related to population growth and unplanned rapid urbanization. In the urban areas of Bangladesh tons of waste from various sources (eg. domestic, industrial, commercial, health care facilities etc) is generated every day. A large portion of it is left on the road side or open spaces creating public menace. In context of Bangladesh municipal waste has a high organic content. These organic wastes are normally considered as green waste or biodegradable waste linked to anthropogenic methane (CH_4) emissions unless managed properly (ISWA, 2009).

Pabna is one of the oldest municipalities of this country. Population increase and unplanned urban expansion create enormous pressure on this low lying piece of land which is highly vulnerable to monsoon flood. Waste generation is increasing with its population and poses a threat to human health and municipal environment with improper disposal and seasonal flooding of the dumping sites. It also causes a variety of problems including contamination of water, soil and air, abundance of insets and rodents and flooding due to blocked drains and canals. To overcome this situation there is an urgent need for planning, designing and implementation of a comprehensive work plan for waste collection, transportation and disposal along with activities to reduce or recycle MSW. The study focuses on overall waste management scenario of Pabna municipality. It tries to outline a comprehensive work plan for waste collection, transportation and disposal along with managing options to lower green house gases (GHG)

© 2014, Scientific Research Journal

emissions and to produce organic fertilizers. Availability of resources and manpower are carefully considered in developing the plan.

II. MATERIALS AND METHODS

The methodology used in this research includes both qualitative and quantitative methods. The whole research methodology is divided into three phases. Phase one includes the problem identification which is done through field observations, surveying literatures and consultations with experts and local people. Second phase includes exploring of present waste management scenario of pabna municipality. To do so, direct measurements of waste generation in different community bins and a number of households are done and secondary data are collected from various sources like municipal authority, waste concern, newspapers, journal articles, published and unpublished project reports etc. Preparing an environmentally and economically feasible plan is the third one. This includes necessary analysis based on collected data, estimation of GHG emissions and identification of alternative disposal options against crude dumping. IPCC tier-1 (2006) calculations are used to calculate GHG emissions which provide the guidelines to estimate carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from municipal waste disposal. This study calculates the CH_4 emission because it is the largest portion (55-75%) of landfill gas composition (Reinhart and Amini, 2008). The following equations are used to calculate CH_4 emission,

CH_4 emission =

$$\left[\sum_{x} CH_4 generated_{x,T} - R_T\right] \bullet (1 - OX_T) \qquad \text{Eq.1}$$

Where,
CH_4 emission = CH_4 emitted in the year T (Giga gram)
T= Inventory year
X= Waste category
R_T= Recovered CH_4 in the year T (Giga gram) OX_T= Oxidation factor in year T (fraction)

$$DDOC_m = W \bullet DOC \bullet DOC_f \bullet MCF \qquad \text{Eq.2}$$

Where,
$DDOC_m$= Mass of decomposable DOC deposited (Giga gram)
W= Mass of waste deposited (Giga gram)
DOC= Degradable organic carbon in the year of deposition (fraction)
DOC_f= Fraction of DOC that can decompose
MCF= Methane correction factor (fraction)

$$L_o = DDOC_m \bullet F \bullet \frac{16}{12} \qquad \text{Eq.3}$$

Where,
L_o= CH_4 generation potential (Giga gram CH_4)
F= Fraction of CH_4 in generated land fill gas
$\frac{16}{12}$ = Molecular weight ratio CH_4/C (ratio)

Pabna municipality is selected as the study area as this municipality has been least researched in the field of municipal waste management (MWM). Absolute location of the "zero point" (traffic more) of this municipality is 24° north latitude and 89°15´ east longitude. It is 219 kilometers away from the capital city (Dhaka) and 103 kilometers from Rajshahi. It is one of the oldest municipalities and the municipal authority was formed in 1876. It serves as a home of 181939 people (www.paban.gov.bd) and one of the major economic hubs of the north western part of Bangladesh.

III. RESULTS AND DISCUSSION

A. Present Waste Management Scenario of Pabna Municipality

MWM in Bangladesh has developed not much over the years. Studies claim that about 40-50% of MSW are collected and the remaining are left uncollected (Hai and Ali, 2005, Zahur, 2007). In Pabna the municipal authority is the only responsible formal organization to manage municipal waste. The conservancy department performs the managing options. According to this department the generation of municipal waste varies and it has an average of 0.3 kilograms per capita per day. Pabna municipality generates about 41 tons of wastes per day and only food and vegetable wastes accounts for 70% of the total generated wastes (table 1).

TABLE I. TYPICAL VALUES (%) OF PHYSICAL COMPOSITION OF MUNICIPAL SOLID WASTE OF BANGLADESH

Composition	Typical values for Bangladesh
Food and Vegetable	70.00
Paper and Paper products	4.00
Polythene and Plastic	5.00
Textile and Wood	-
Metal component	0.13
Glass and Ceramics	0.25
Rubber and Leathers	-
Brick, Concrete and Stone	-
Green waste and Straw	11.00
Dust, Ashes	-
Others	9.62

Source: Bari, Hassan and Haque, 2012.

This amount comes from domestic, commercial, health care facilities and other sources. Conservancy department collects only 23 tons approximately (about 55% of total generated waste). A large portion (about 84%) of this municipal waste is biodegradable which is considered as green waste (ANZECC, 1998). Communal collection is being practiced and crude dumping is the only disposal option. The municipality needs 0.27 acres of land per year to dispose the collected waste. The study finds that the rate of waste generation is increasing and the municipal authority is in a deplorable situation with its limited resource and manpower. Community participation is very limited and there is a lack of awareness among citizen. Recycling practices at a very small scale is found but none of them has legal permission. This kind of indigenous practice and mismanagement of MSW result in pollution and green house gas emission. It is stated earlier that Pabna is low lying and flooding is frequent. Seasonal flooding of the dumping sites increases the rate of pollution in various dimensions like soil and water. Besides, in 21st century, when global warming and climate change is an alarming environmental issue, GHG emission is crucial to waste management studies. IPCC tier 1 gives an account of

© 2014, Scientific Research Journal

CH4 emission from the dumping sites of pabna municipality. Here all the collected wastes are dumped in these sites. To use IPCC tier 1 the study considered the Methane Correction Factor (MCF) as 0.4 due to unmanaged dumping sites based on IPCC (2006) guidelines. It is found from Bangladesh Centre for Advanced Studies (BCAS) that DOC in MSW is 15% (.15). The fraction of actual degradable organic carbon (DOC_f) in MSW is 77% (.77) which value is closed to that of other south Asian countries (Rahman et all, 2011). The fraction of CH4 in the generated landfill gas (F) is considered 0.5 (IPCC 2006 guidelines). In pabna recovered methane (R) is 0.00 and oxidation factor (OX) is also 0.00 because there is no burning on dumping sites. Several years data on waste generation and dumping shows an increasing of dumping site emission.

TABLE II. TOTAL AMOUNT OF WASTE GENERATED AND DUMPED IN LAST FIVE YEARS.

Years	Waste generated (tons)	Waste dumped (tons)
2013	15100.05	8303.75
2012	14837.64	8011.74
2011	14647.45	8055.55
2010	14479.55	7818.30
2009	14183.90	7800.05

Source: field survey and conservancy department.

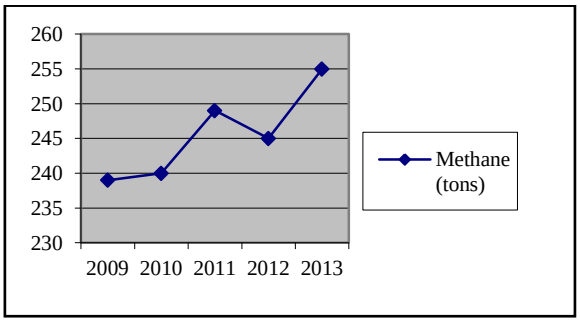

Figure 1: Amount of CH_4 Emission in last five years from the dumping sites of Pabna.

It is a very little amount compared to capital city Dhaka. About 26.89 Giga grams of CH_4 emitted from the municipal solid waste of Dhaka city in 2010 (Rahman et all, 2011). It is not only the CH_4 that emits from the dumping sites, N_2O, CO_2 etc also emit (Reinhart and Amini, 2008). These emissions can contribute to global warming if they are not checked or reduced for a long time period.

TABLE III. WASTE MANAGEMENT SCENARIO OF PABNA MUNICIPALITY.

Waste generation per day, 2013[1]	41.37 tons
Amount of waste generated in the year 2013[1]	15000 tons
Amount of waste collected by pabna municipality in 2013[1]	8300 tons (collection efficiency, 55%)
Biodegradable portion of collected waste[2]	6900 tons
Waste density[3]	272.22 kg/m^3 at collection point
	544.44 kg/m^3 on truck
	1088.87 kg/m^3 at dumping site
Collection vehicle[1]	Truck: 06
	Rickshaw van: 30
Manpower engaged in collection and disposal[1]	221
Community bins[1]	Existing: 80
	Proposed: 40
Collection cost[1]	450 taka/ton (5.78 US$)
Recycling Savings[1]	N/A
Disposal method[1]	Crude dumping
Dumping area requirement[3]	0.27 acres per year

Source: [1]Field survey and conservancy dept of Pabna municipality, [2]after Bari, Hassan and Haque, 2012, [3]Waste Concern, 2005. (1 US$=78 taka).

B. Proposed Municipal Waste Management for Pabna Municipality

The study finds that inadequate collection and unscientific management causes different environmental problems including GHG emission. No utilization of organic waste, lack of awareness among citizens and absence of community participation are also included. The municipality faces problems with its limited number of community bins those are not adequate for a population of 181939. So, open dumping in canals and drains are habitual which results in a breakdown of existing communal collection. In this case block collection in the residential areas like Dhaka and Rajshahi can be introduced to increase collection efficiency. The municipality has a plan to establish 40 more bins in desired locations, this number can be increased easily as block collection is not possible for the whole municipality. Some environmentally sound secondary waste generation points can be established to accumulate collected waste to several locations for a certain period of time. The study finds that 5 to 6 secondary points are adequate to serve this city. These points can be large community bins as established in Rajshahi on a predetermined route of garbage collector trucks. They will collect waste from these secondary points within a short period of time. The following table provides the time frame of this collection procedure,

© 2014, Scientific Research Journal

TABLE IV. TIME FRAME OF PROPOSED WASTE COLLECTION

Collection points	Collection procedure	Collector	Time duration*
House holds	Block	Rickshaw van	Any time of the day
Market places	Sweeping/Gathering	Sweeper and Rickshaw van	9.00 PM to 11.00 PM
Streets	Sweeping/Gathering	Sweeper and Rickshaw van	11.00 PM to 12.00 AM
Bins	-	Rickshaw van	Any time before 12.00 AM
Secondary Points	-	Trucks	12.00 AM to 1.00 AM

Source: Field Survey, 2012-13. (*fixable with changes of seasons and other purposes)

With increased collection efficiency this procedure accumulates waste to secondary generation points. Medical clinics and healthcare facilities are advised to use the incineration facility performed by the government medical hospital. A large number of existed cottage industries of pabna municipality are advised to discharge to predetermined locations and/or secondary points as per order of the municipality.

What to do with this collected waste? Are they going to be dumped? The proposed waste management says no. It indicates sanitary land filling and composting as alternatives of crude dumping. A small scale recycling of plastic and metal can also be done with the concern of the municipal authority to recycle up to 7% of the total generated waste. Recycling of organic waste through composting reduces the disposal costs, landfill area requirement and adverse environmental impacts of landfill sites, as the organics are responsible for leachate contamination and methane problem. It also creates employment, involves the population in waste resource recovery and enhances the sustainability of urban areas (waste concern, 2003). Several studies find the failure of large mechanized composting plants in developing countries which lead this study to propose three ton capacity composting plant introduced by waste concern to produce compost. The following section deals with the feasibility study of this kind of plant.

In this process the collected waste is separated and sorted at the composting plant located in the community and/or at landfill sites and processed into compost by using the aerobic composting of Indonesian windrow technique (waste concern, 2003). The composting method can be regarded as successful because of waste concern's decentralized composting project which is running satisfactory since 1995. Data from this project reveal that from one ton of organic waste 250 kg of compost can be produced and only 15% of rejects are to be transported to landfill sites. The process involves two types of costs, fixed cost for establishing the plant and operational cost to maintain it. The following table provides information about the financial aspects of this kind of plant.

TABLE V. FINANCIAL ASPECTS OF A THREE TON CAPACITY COMPOSTING PLANT

Fixed Cost	
Item	US $
Construction of sorting platform with shed of 360 sq.ft (2.78 $/sq.ft)	1000
Construction of composting shed with drainage facility of 2100 sq.ft (2.78 $/sq.ft)	5838
Construction cost of office, bathroom, toilet and storage for the recovered recyclables	1923.08
Purchase of 5 rickshaw vans	1538.46
Water and electricity connection charge	897.44
Total fixed cost	11196.98
Operational Cost (annual)	
Salary of 11 workers (705.13 $/month)	8461.53
Salary of 6 collectors and 3 van drivers (576.92 $/month)	6923.08
Salary of plant manager (96.15 $/month)	1153.85
Electricity, water bill and maintenance cost (128.21 $/month)	1538.46
Raw materials for compost (153.85 $/month)	1846.15
Total operational cost	19923.07
Earnings (annual)	
Sale of compost of 600 kg/day (61.54 $/day)	22461.54
Charges for block collection service from 1000 households (0.38 $/month/household)	4615.38
Total Earnings	27076.92

Source: After waste concern, 2003 and field survey, 2013. (1.00 US $=78 Taka)

Estimated net earning per year from this process is 7153.85 US $ and it has a payback period of 19 months approximately, which indicates that the waste management cost can be reduced. It has also a significant effect on landfill area requirement and it increases the life of landfill site. The study finds that this process can significantly reduce the landfill area requirement from 0.27 acres to 0.14 acres per year. From the environmental, economic and cultural viewpoint, it suits the local environment, with its easy operation and maintenance it can be easily understood by the people and posses certain flexibility for possible changes. It enhances public health and sanitation awareness, creates employment for the urban poor and saves municipal expenditure on solid waste management up to 85%. Besides, it has a potentiality to reduce CH_4 emission from the dumping site which is up to 400 kg/ton of organic waste (Mamun & Hossain, 2012).

Recycling of organic waste by composting is an environmentally sound waste treating option applicable for all

© 2014, Scientific Research Journal

the municipal areas of Bangladesh. It is beneficial in three ways- it reduces the volume of waste, produces compost (bio fertilizer of good quality) and reduces GHG emission from dumping site. Biogas is also a potential product of composting and can be used as fuel and electricity production. But its extraction requires advanced technology which is not currently available in Bangladesh.

IV. CONCLUSION

Like other municipalities of this country an unhygienic MSW management is practiced in Paban where crude dumping is the only disposal option. Waste related environmental problems including GHG emission are at hand. In addition, no utilization of organic waste, limited or no inorganic recycling, lack of awareness among citizen and absence of community participation are some of the problems of MSW management. Organic recycling is suggested to produce compost and to reduce GHG emission. Feasibility study indicates that manually operated small composting plant (3 ton capacity) is more effective than the larger and advanced mechanized ones. By adopting the procedure GHG emission will reduce in two ways- by avoiding the crude dumping of organic waste and by minimizing the manufacture and use of chemical fertilizer. Leachate contamination and hazardous soil and water pollution can also be minimized. Furthermore launching of public education campaign, provision of adequate training and facilities to the conservancy workers, proper land fill site selection and involvement of Community Based Organizations in MSW management should be ensured to achieve an improved MSW management system and a sustainable city environment.

REFERENCES

[1] Australia and New Zealand Environment Conservation Council, “Green and Organic Waste Management Strategy for Australia”, an ANZECC document, Australia, 1998.
[2] Bari, Q H, Hasan, K M and Haque, M E, “Solid waste recycling in Rajsahi city of Bangladesh”, Waste Management, Article in press, Online publication, 2012.
[3] Grossmann D, Hudson JF, Marks DH. Waste generation models for solid waste collection. Journal of the Environmental Engineering Division 1974; 100:1219– 30.
[4] Hai, F I, and Hai, M A, “A study on solid waste management of Dhaka city corporation: Effect of composting and landfill location”, UAP journal civil and Environmental engineering, vol 1, no 1, 2005.
[5] International Solid Waste Association, “Waste and Climate Change”, published as a white paper, 2009.
[6] IPCC-Intergovernmental Panel on Climate Change 2006. IPCC Guidelines for National Greenhouse Gas Inventories. IPCC/IGES, Hayama, Japan, Retrieved May, 11, 2009.
[7] Kumar S, Bhattacharyya JK, Vaidya AN, Chakrabarti T, Devotta S, Akolkar AB. Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India: an insight. Waste Management 2009; 29:883–95.
[8] Mamun, A H M Monzurul and Hossain, Mallik Akram, “Green waste management and climate change: case of Rajshahi city corporation”, Oriental Geographer, vol 53, no 1&2, 2012, 55-72.
[9] Rahman S, Shams S and Mahmood K, “Study of Solid Waste Management and its Impact on Climate Change: A Case Study of Dhaka City in Bangladesh” Gazipur, Dhaka, 2010.
[10] Reinhart, R. Debra and Amini, Hamid, “Landfill Gas to Energy Opportunities” Orlando, Florida, USA, 2008.
[11] Tchobanoglous G, Theisen H, Samuel AV. Integrated solid waste management—engineering principles and management issues, McGraw Hill International Edition; 1993.
[12] Wang H, Nie Y. Municipal solid waste characteristics and management in China. Airand Waste Management Association 2001; 51:250–63.
[13] Waste Concern, “Decentralized Composting: Through Public-Private Community Partnerships” Waste Concern, Dhaka, 2003.
[14] Waste Concern, “Urban Solid Waste Scenario of Bangladesh: Problems and Prospects”, Waste Concern, Dhaka, June 6, 2005.
[15] World Bank, Initiating and sustaining water sector reforms: a synthesis; 1999, Washington, DC, p. 38.
[16] Zahur M, “Solid waste management of Dhaka city: Public, private community partnership”, BRAC university journal, vol 4 no 2, 2007.
[17] www.paban.gov.bd

© 2014, Scientific Research Journal