Energy Recovery Potential from Municipal Solid Waste in Rajshahi City by Landfill Technique

Barun Kumar Das*‡, Md. Abdul Kader*, S.M.Najmul Hoque*

* Department of Mechanical Engineering, Rajshahi University of Engineering and Technology, Bangladesh

(barun_ruet@yahoo.com, kader_042017@yahoo.com, shumon99234@gmail.com)

‡ Corresponding Author: Barun Kumar Das, Rajshshi-6204, Bangladesh, Tel: +880721-750319, barun_ruet@yahoo.com

Received: 15.03.2014 Accepted: 11.05.2014

Abstract- The underprivileged management of MSW is a growing problem in most cities and small urban communities in Bangladesh. Wsate collection effeciency of Rajshahi city of Bangladesh is not so significant and majority of waste is dumped in the open space. Landfill gas is generated naturally due to the bacterial effect of organic material contained in MSW landfills. Uncontrolled MSW landfills emit methane gas which 21 times potential than the CO_2 gas which is one of the major contributors to the green house gas (GHG) and ozone layer depletion. In contrast of, if the MSW can mange in the systematic way that could be a potential source of electricity generation in our country. This study investigates the generation, characteristics, management of municipal solid waste in Rajshahi City and energy generation by landfill technique. The study suggests that total 7549 ton of CH_4 per year generated from landfill. The energy potential from the landfill gas estimated around 5.3MWe.

Keywords- Landfill gas, waste-to-energy, CH_4 emission, GHG, electricity generation.

1. Introduction

Rajshahi is one of the major divisional cities and well known for its educational intuitions in Bangladesh having population of 0.9 million in 2011 with density of population is about 8700 per km^2. The growth rate of urban population is 3% whereas the rural population is about 0.5% [1-2]. Rapid urbanization brings a huge number of rural people to urban areas each year [3-4].This causes unplanned urbanization and slum development which is responsible for producing a lot of unmanageable quantities of solid waste in all major cities of Bangladesh [5]. Many cities of developed and underdeveloped world faces severe waste management problem due to rapid unplanned urbanization, industrialization and population growth [6]. M. Suzauddin et al. [7] investigate that solid waste management (SWM) is a multidimensional challenge faced by urban authorities, especially in developing countries like Bangladesh.

In Bangladesh, the standard dumping methods of generated wastes have not been practiced till now. Here, land filling is the main existing municipal solid waste (MSW) disposal method. About 50–60% of the MSW is land-filled and mostly open dumping and rest of the wastes are recycled by informal sectors, self disposal around the residential areas ,on the roads, low lying areas and in drains [4]. In all cases solid wastes are dumped in open air where GHG emissions occur along with odors, public health and environmental degradation. E. Friedrich et al. [8], predicts that the GHG emissions from waste management in developing countries increase exponentially. Khajuria et al.[9] reported that the sanitary landfill has proved to be the most cost-effective and satisfactory means for solid waste disposal. By converting the open dumpsites in the urban areas of Bangladesh into the sanitary one and capturing methane, a significant amount of electricity could be produced.In this way, the garbage become gold and revenue is generated as well as significantly reduce the environmental emission.

In this study attempts has been made to estimate the methane emission and potential of electricity generation from disposed MSW in landfills of Rajshahi city. In addition, reviews on the generation, characterization of MSW and landfill management and processes is also discussed.

2. Materials and Methods

Rajshahi is the fourth biggest city of Bangladesh which is situated in the western part of the country. The geographical location of this city is 24º22´N latitude and 88º36´E longitude. Its total area is 96.69 km^2 and is situated on the northern banks of the river Padma. In this study, a field investigation was carried out in different areas of Rajshahi city to determine physical composition of solid waste generated in different areas. The quantity of the constituents was determined by weight in the taken sample. Sampling is done for 2 months from August , 2013 to October 2013 at various locations in RCC area such as Talaimari, Kazla, Kadirgonj, Railway station, Lt. Selim Hall (RUET), Vodra and Shaheb Bazaar. Moreover, density of waste at the collection point was also determined. The calorific value of solid waste is determined by using a bomb calorimeter. Chemical compositions of the solid wastes are identified by the determination of elemental contents in the sample such as Carbon, Nitrogen, Sulfur and Hydrogen. Dried sample of waste stream was taken to Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka for the purpose.

Along with the primary data, secondary data were aslo collected from the Rajshahi City Corporation (RCC), reports and studies by Wastesafe, JICA, Waste concern and World Bank as well as reviewed the reputed journal to achieve the goal of this study. Population data have been collected from population census by BBS (2011) and UN (2011) data for projection in the year for 2015 and 2020. A simple and clear-cut method called the Intergovernmental Panel on Climate Change (IPCC, 1997) methodology has been used to estimate the methane emission from the MSW.

3. MSW Generation in Rajshahi City

In general the amount of waste generation in the developing countries is determined on the basis of per capita waste generation factors and supported with some basic studies. Waste generation rates are also related to economic status of the country as well as population. In general, economic developed and higher the proportion of urban population, produces maximum amount of solid waste [10]. Developed nations are characterized by higher rates of waste generation per capita; while developing nations generate less waste and practice informal recycling that reduce the waste per capita to be collected at the municipal level. Richards,[11] and Mertins et al., [12] reported that the population and wealth , icluding GDP per capita and energy consumption [13] are largely responsible for waste generation.The urban population has been increasing at a very sharp rate and the growing population causes involvement of a lot of human activities, which in turn leads to enhance the waste generation [14].

According to BBS 2011 [1], the total population of Bangladesh is around 152 million. Of them urban population is 28.4% of the total population. This large urban population produces hundreds of tons of waste that lies uncollected on the streets every day and in absence of proper waste management program exposes the city dwellers to greater health risks and environmental hazards. There is a very few reliable information available related to the quantity of wastes generation in the urban areas of Bangladesh. Due to lack of information, an estimation has been made to determine the amount of waste generation. The urban area of Bangladesh generates approximately 16,015 tons of waste per day and 5.84 million tons annually [15]. Bangladesh Department of Environment [16] reported 38 million urban population generate 16384 tones per at the rate of 0.43 kg/capita/day. As per Waste concern [15] and JICA 2005, [17] study reported that the per capita waste generation in urban areas was 0.41 kg/day. Alamgir et al., [18] reported that Rajshahi city corporation (RCC) generates 170 tons day/ MSW at the rate of 0.378 kg/capita/day whereas Waste concern, [15] reported 172 tons/day waste generation at 0.30 kg/capita/day in 2005. The total waste generation in Rajshahi City according to per capita waste generation is presented in Table 1. According to UN 2011 data, total population of Rajshahi city in 2005 was around 0.769 million [2] and taking into account per capita waste generation 0. 378 kg/day [18], total MSW generation was 290 tons/day. While in 2010, total waste generation was around 450 tons/day at the rate of 0.5 kg/capita/day [19]. Bernache-Perez et al. [20], reported that solid waste generation rates range from 0.1 to 0.6 ton /capita/yr in low income countries whereas 0.3 to >0.8 ton/capita/yr in the developed countries. The projection of solid waste generation has been made taking into account per capita solid waste of 0.6 kg/day and estimated MSW generation in 2015 and 2020 are 560 tons/day and 644 tons/day respectively.

Table 1. Waste generation of Rajshahi City in Bangladesh

Year	Population, million	MSW Generation Rate kg/capita/day	Total MSW, tons/day
2005	0.769	0.378	290
2010	0.900	0.50	450
2015	0.932	0.60	560
2020	1.073	0.60	644

4. Characterization of MSW

The characterization of MSW is essential for choosing the management option of waste and energy recovery technique as well as the possible environmental effects of MSW on the earth and its inhabitatnts [21-22]. Physical characterization of solid wastes and their proximate analysis and chemical characterization are done in this study. These analyses indicate the compositional suitability of MSW for energy extraction. The characteristics of MSW are directly influenced by the socio-economic conditions, cultural activities, seasonal and geographical conditions as well.The physical composition of MSW of Rajshahi city is presented in Figure 1. It is observed that the organic matter or biodegradable fraction is usually the major component in the waste stream due to the type and habit of fresh food consumption. Its' socio-economic condition is also very much responsible for the very high percentage of organic component. The rapidly biodegradable portion is normally very high compared to other portions, essentially due to the use of fresh vegetables and fruits. In order to estimate the moisture content, 5 kg of sample was taken and weighted before and after drying for seven days. The percentage of moisture content of solid waste samples taken at different point around the city. The moisture content varied from 50 to 75% in this study. High moisture content causes biodegradable waste fractions to decompose more rapidly than in dry conditions.

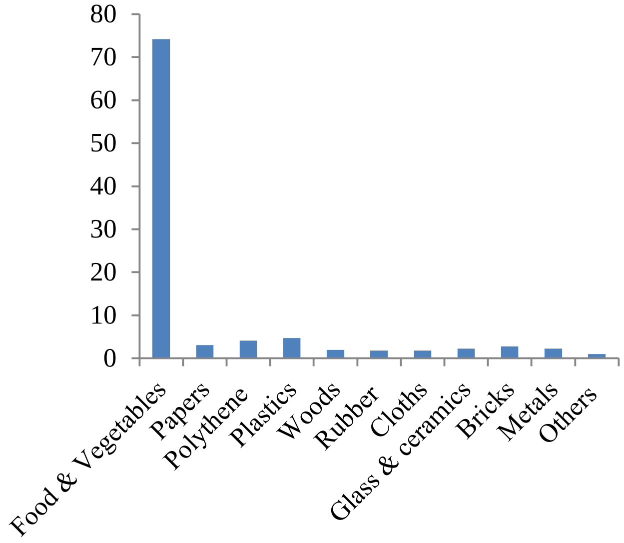

Fig 1. Physical composition of MSW in Rajshahi city (% weight)

A dried combustible sample was taken into the bomb to determine the calorific value and the calorific value was found 21MJ/kg. Chemical compositions of the solid wastes are identified by the determination of elemental contents in the sample such as Carbon, Nitrogen, Sulfur and Hydrogen. Dried waste steam sample was taken to Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka for the purpose. The result showed that Carbon 26.34%, Hydrogen 3.01%, Nitrogen 1.90%, Sulfur 0.03%, Oxygen, ash and others 68.72%. Proximate analysis of solid wastes composition is presented in Table 2 which gives the information about the moisture, volatile matter, ash and fixed carbon. The wastes contain high portions of volatile solids as 62 to around 90%, ash residue maximum around 23%. Ultimate analysis is the percent of carbon, hydrogen, oxygen, nitrogen, sulphur and ash. The detail elemental analysis of waste components is shown in Table 3.

Table 2. Proximate analysis of solid waste components [23]

MSW Components	Volatile Matter, % dry basis	Fixed Carbon, % dry basis	Moisture, % dry basis	Ash, % dry basis
Food waste	72.52	14.49	8.48	4.51
Paper products	75.13	6.68	6.42	5.4
Wood	66.64	17.39	8.8.2	7.15
Plastic	89.32	9.43	0.63	0.62
Rubber	74.84	2.23	0.01	22.91
Textile	89.07	9.28	1.23	0.42
Leaf	62.27	19.67	10.78	7.28

Table 3. Ultimate analysis of solid waste components [23]

MSW Components	HHV, kj/kg, % dry basis	C, % dry basis	H, % dry basis	O, % dry basis	N, % dry basis	S, % dry basis
Food waste	20009	45.06	6.98	40.28	2.90	0.27
Paper products	12548	34.96	4.60	48.51	0.08	0.08
Wood	15684	41.93	5.72	44.40	0.70	0.10
Plastic	21876	62.50	4.76	32.00	0.03	0.09
Rubber	28948	45.72	6.67	30.80	1.45	0.39
Textile	18774	52.54	5.69	40.71	0.44	0.21
Leaf	17258	42.50	5.86	42.99	0.98	0.39

5. Solid Waste Management Practice of Rajshahi City

In Bangladesh, the city authorities generally manage MSW though its solid waste management system is not so up-to-date and well organized. In Rajshahi city, there is no separate department responsible for managing the municipal solid waste. This condition is same as the other city corporations and municipalities in Bangladesh. Conservancy section of city corporation is responsible for maintanace and manage the sanitary system. The chief conservancy officer or the conservancy officer has to comunicate with the transport department to collect the waste from the collection point and bring them to the final disposal site. Some NGOs and private organizations also work along with municipality authorities. Source storage and separation are done in an informal and uncontrolled means; hardly 30-40% of city dwellers practiced it [18]. Recently, in some areas NGOs have taken initiative to collect soild waste from door-to-door. NGOs and city authorities collect wastes from generation sources by door-to-door collection systems. Residents as well as NGOs, city authorities are responsible for bringing their waste to cities waste collection points where dustbins/containers are located. Wastes, which are, dropped into the primary disposal points, are carried to the secondary collection points by vans. Wastes are finally transported from secondary point to the final waste disposal point by trucks and tractors. As there is no special department to handle the situation MSW and conservancy section, in general is conducting this job along with its other responsibilities such as street sweeping, drain cleaning, street lighting etc. As a result, required attention and efficient management could not be obtained from the responsible department of city authority as required.

Around 0.9 million people live in Rajshahi metropolitan area (92.93 km^2). They produce about 450 metric ton wastes/day. Conservancy Division of RCC is set to dispose off and manage these wastes including the medical wastes. Among the 30 wards under RCC, half of the wards are covered by ‘door to door waste collection’ facilities. There are 22 secondary collection points and one dumping site at Terokhadia. Among the different collection points, hospitals, railway station, and Shaheb Bazaar are covered by RCC collection system [24]. Residents of Rajshahi city are responsible for bringing their waste to the collection points where dustbins/containers are located. Some portions of waste however, recycled by the informal sectors or waste pickers and rest of waste disposed onto the low lying areas from the primary disposal points. Wastes, which are, dropped into the primary disposal points, are carried to the secondary collection points by vans. For the secondary collection system, about 213 vans are employed to carry these wastes to 22 secondary waste disposal points in the RCC area. Wastes are finally transported from secondary point to the final waste disposal point by trucks and tractors. About 12 tractors or trucks are employed in order to transport these wastes, to the final disposal point. Final disposal point is located in Terokhadia, Rajshahi. Wastes are also recycled from the secondary disposal points as well as the final disposal points by the waste pickers. Bari et. al. [25] reported that around 8.25% of the daily waste are recyled in this cities. About 310 metric ton/day wastes are collected and disposed off in the waste disposal area rest of wastes are recycled by waste pickers , illegal dumping and are collected by the farmers for making of compost for agricultural lands.

6. Solid Waste Disposal Site or Landfilling

Landfilling is one of the most common and comparable environmentally friendly methods of municipal solid waste (MSW) disposal. In cities waste is collected by respective municipality's authorities and transported to designated disposal sites. The insanitary methods that adopted for disposal of waste which causes serious health and other associated environmental problems. There is no controlled or sanitary landfill in Bangladesh. The unsanitary landfill sites produce leachate which is responsible for the pollution of ground water [26]. Further this also responsible for bad odors and risks of fire of methane gas that can amass at the landfill site [27]. Rouf et al.[28] shows that the huge amount of solid generation by the human activities and its diversification and the detrimental effects on the environment and the human beings, have led to an growing awareness to promote scientific methods for safe disposal of wastes. Batool et al. [29] shows that the landfilling is the major contributor of greenhouse gas emission to environment.

Waste collection rate in different urban areas in Bangladesh in not up to mark and varies from 37% to 77% with an average of 55% with the existing solid waste management structure. The collection of rate of MSW in Rajshahi city was around 56.67 % [4]. Uncollected waste, high proportion of which is organic, deposited in open spaces, where its accumulation contributes to foul odors, rodents, and clogged storm water and sewer drains

6.1. Land Requirements of Solid Waste Disposal

The total land area requirements for dumping the solid waste can be calculated by considering the depth of land filling as 4m and with or without composting. Solid waste density without compaction in the indian sub-continent has been found as 1.1 ton/m^3 [30]. Land requirements for landfilling without composting are calculated as follows:

$$\text{Landfilled area} = \frac{\text{Wsate generationx Collection efficiency}}{\text{Waste density xdepth of landfil area}}$$

Then the total landfill area could be calculated by multiplying a factor of increase in additional area of roads, border setback areas, control building and sanitary facilities, maneuvering yard, etc. This is between 20 and 40% of the area to be filled. Based on the waste collection rate as 80% and a factor of 30%, the projected land requirement for a year is presented in Fig. 2. It is observed that the landfill land increased with the MSW generation in a step rate. In 2005, total land required for land filling the waste was just over 6 acres; it is projected almost double in the year of 2015. This estimates that with further generation of MSW in the growing city, it would be necessary will lead to use much large area for waste disposal. The additional land requirement for waste disposal will lead to reduce the land for crop production as well as the residential area. In this way, in future it create crisis, due to scarcity of land space.

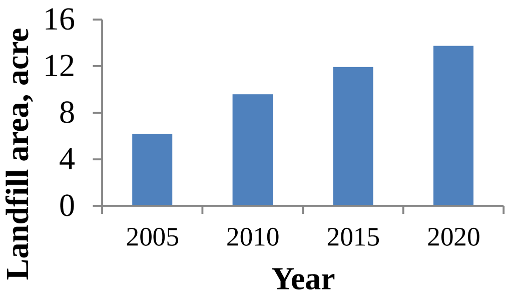

Fig. 2. Estimation of projected landfill land requirements

7. Estimation of Landfill Gas and Energy Potential from MSW in Rajshahi City

Landfill gas from MSW depends on the number of factors. These factors include the composition of waste, moisture content and temperature of the waste as well as the age of the waste. Landfill gas which is CH_4 (50–55%) and CO_2 (40–45%) by volume is produced from waste by bacterial effect. On the other hand, landfills also emit other compounds like nonmethane organic compounds and volatile organic compounds which have the detrimental effects on environments and living beings around the landfill site.

The CH_4 emission from the various organic compounds of waste has been estimated by the method proposed by Intergovernmental Panel on Climate Change (IPCC, 1997) [31].The following equation used to estimate the CH4 emission from landfill:

CH_4 emissions, tones = $MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times 16/12$--------------(1)

Where, MSW_T= Total MSW generation (tones)
MSW_F=Fractions of MSW disposed of to landfills
MCF= Methane correction factor
DOC= Fraction of degradable organic carbon
DOC_F=fraction of total DOC that actually degrades,
F=Fraction of methane in LFG.

Under unmanaged conditions of the landfills, MCF value could be taken as 0.6 [32]. According to IPCC, DOC ranges from 0.08 to 0.21, considering the characteristics of waste DOC value is taken as 0.17. Again, a default value of 0.77 of DOC_F should be considered because the degradation of organic carbon is not tottaly occure over the period of time. On the hand, the vaue of F was taken as 0.55 based on solid waste charatistics [33]. Using equation 1 total methane generation of Rajshahi city from MSW is listed in table 4.

Table 4. Energy and environmental benefits from MSW in Rajshahi City

Parameter	2005	2010	2015	2020
Estimated CH_4 emission, tons /yr	4865	7549	9394	10803
Equivalent CO_2 emission, tons/ yr	102166	158528	197279	226871
Electricity potential, MWe	3.43	5.30	6.61	7.6

It is a great challenge for developing world to develope the innovative, low-cost but effective and sustainable measures to reach a basic level of improved sanitation [34]. However, landfill CH_4 emissions is decreasing in the developing countries as more sanitary landfilling practices are implemented. Capturing the CH_4 gas to generate electricity or other thermal application could be a potential soure of power in addition to sustanable ways to manage the waste.

Total 6.61MWe electricity generation is achievable in 2015, taking calorific value of CH_4 as 55,530 kJ/ kg and efficiency of the gas engine as 40% [35]. CH_4 emission is considered as 21 times more global warming potential than the CO_2 [35] and estimated around 7549 tons/yr. In this way 60-90% waste reduction is acheivable which is one of the major advantages of recovery of energy from solid waste. This will reduce the damand of land as well as the cost of transportation and net reduction in environmental pollution. Such types of project would be viable if environmental management concern along with the energy (heat or electricity) is seen as a bonus [36-37].

8. Conclusion

In 2015 and 2020, the MSW generation in Rajshahi City was projected as 540, and 644 tons respectively. This resulted in CH_4 emission 9394 tons in 2015 and 10803 tons in 2020. Equivalent CO_2 emissions are 197279 tons in 2015 and 226878 tons in 2020. Landfill gas recovery projects provide a highly effective means of reducing overall greenhouse gas emissions from landfills and consequently electricity generation from landfill gas. The electricity generation potential from the landfill gas 6.61MWe in 2015, projected estimation 7.6MWe in 2020. Sanitary Landfilling, which is the controlled disposal of waste on the land, is well suited to developing countries like Bangladesh as a means of managing the disposal of wastes because of the flexibility and relative simplicity of the technology. Government should take initiative along with the NGOs and private body to develop the existing landfill site to capture LFG to generate electricity. This will help to reduce dependency of fossil fuel based power plant to mitigate the current energy crisis as well.

References

[1] BBS, Bangladesh Bureau of Statistics, Bangladesh population and housing census, 2011, http://bbs.gov.bd/Home.aspx,(September 18, 2013)

[2] UN, United Nations, (2011)Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2010 Revision and World Urbanization Prospects: The 2011 Revision.

[3] Salequzzaman, M., “Perceptions of vehicle air pollution in Khulna, Bangladesh”, In: Proceedings of the Habitus 2000, Conference in Perth, Western Australia, September 05–09, 2000.

[4] Enayetullah, I., Sinha, A.H.M.M., Khan, S.S.A., “Urban Solid Waste Management Scenario of Bangladesh: Problems and Prospects”, Waste Concern Technical Documentation, Dhaka, Bangladesh, 2005, 18p.

[5] Salequzzaman, M., Awal, M., Alam, M., “Willingness to pay: community based solid waste management and its sustainability in Bangladesh”, In: Proceedings of the International Conference ‘The Future is Here’, RMIT, Melbourne, Victoria, January 15–19, 2001.

[6] R.P. Singh, V.V. Tyagi, Tanu Allen, M. Hakimi Ibrahim, Richa Kothari., “An overview for exploring the possibilities of energy generation from municipal solid waste (MSW) in Indian scenario”, Renewable and Sustainable Energy Reviews, 2011, 15; 4797– 4808.

[7] M. Sujauddin, S.M.S. Huda, A.T.M. Rafiqul Hoque, “Household Solid Waste Characteristics and Management in Chittagong, Bangladesh”, Waste Management, 2008, 28, Issue 9, pp. 1688-1695.

[8] E. Friedrich, C. Trois, “Quantification of Greenhouse Gas Emissions from Waste Management Processes for Municipalities - A Comparative Review Focusing on Africa” Waste Management, 2011, 31, pp. 1585-1596.

[9] Khajuria, A., Y. Yamamoto and T. Morioka. “Solid waste management in Asian countries: problems and issues,” Proc. of 4th International Conference on Waste management and environment, June, 2-4, 2008, 109, 643-653.

[10] Hoornweg D, Laura T., “What a waste: solid waste management in Asia. Working Paper Series No. 1.Washington, DC: Urban Development Sector Unit, East Asia and Pacific Region,” The World Bank. 1999.

[11] Richards, K., “Landfill gas: working with Gaia,” Biodeterioration Abstracts, 1989, 3(4), pp. 317-331.

[12] Mertins, L., C. Vinolas, A. Bargallo, G. Sommer, and J. Renau, “Development and application of waste factors - An overview,” Technical Report No. 37, European Environment Agency, Copenhagen. 1999.

[13] Bogner, J. and E. Matthews. “Global methane emissions from landfills: New methodology and annual estimates 1980-1996”. Global Biogeochemical Cycles, 2003, 17, pp. 34-1 to 34-18.

[14] Agamuthu P, Khidzhir KM and Hamid FS, “Drivers of sustainable waste management in Asia”. Waste Management & Research, 2009, 27: 625–633.

[15] http://www.wasteconcern.org/database.html, accessed on 12/12/13

[16] Bangladesh Department of Environment. SAARC Workshop on Solid Waste Management, Dhaka, Bangladesh, Prepared by Bangladesh DoE, Waste Concern, and ITN-BUET. October 10 - 12, 2004.

[17] JICA, “Supporting Capacity Development in Solid Waste Management in Developing Countries – Towards Improving Solid Waste Management Capacity of Entire Societies,” Japan International Cooperation Agency. 2005.

[18] M. Alamgir, A. Ahsan, “Municipal Solid Waste and Recovery Potential: Bangladesh Perspective,” Iran. J. Environ. Health. Sci. Eng.,2007, 4, No. 2, pp. 67-76.

[19] Mondal M.A.H. and Denich M., “Assessment of renewable energy resources potential for electricity generation in Bangladesh”, Renewable and Sustainable Energy Reviews, 2010, 14, 2401–2413.

[20] Bernache-Perez, G., S. Sánchez-Colón, A.M. Garmendia, A. Dávila-Villarreal, and M.E. Sánchez-Salazar. “Solid waste characterization study in Guadalajara Metropolitan Zone, Mexico”. Waste Management & Research, 2001, 19, pp. 413-424.

[21] G. Tchobanoglous, F. Kreith. Handbook of Solid Waste Management, 2nd edn. McGraw-Hill, New York, USA.2002.

[22] M. A. Ali. Unmanageable Solid Waste, People’s Report on Bangladesh Environment 2001: Main Report, Unnayan Shamannay, UPL, Bangladesh. 2001. pp. 209-215.

[23] Ari Darmawan Pasek, Kilbergen W. Gultom & Aryadi Suwono. “Feasibility of Recovering Energy from Municipal Solid Waste to Generate Electricity,” J. Eng. Technol. Sci., 2013, Vol. 45, No. 3, 241-256.

[24] Conservancy Division in Rajshahi City Corporation,(2010) Report collected from RCC.

[25] Q. Hamidul Bari, K. Mahbub Hassan, M. Ehsanul Haque, “Solid waste recycling in Rajshahi city of Bangladesh,” Waste Management, 2012, 32; 2029–2036.

[26] Mor, S., Ravindra, K., Dahiya, R.P., Chandra, A.”Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site,” Environmental Monitoring and Assessment, In Press, PIPS No: DO00021505, 2006a.

[27] G Tchobanoglous, Thiessen, H., Vigil, S. McGraw-Hill Series in Water Resources and Environmental Engineering, Chapters 3 and 11. McGraw-Hill, New York, USA. 1993.

[28] Rouf, Md. Abdur, “Prospect of Electric Energy from Solid Wastes of Rajshahi City Corporation: A Metropolitan City in Bangladesh,” 2nd International Conference on Environmental Engineering and Applications IPCBEE 17, IACSIT Press, Singapore. 2011.

[29] S. A. Batool, M. N. Chuadhry, “The Impact of Municipal Solid Waste Treatment Methods on Greenhouse Gas Emissions in Lahore, Pakistan,” Waste Management, 2009, 29**,** pp. 63-69.

[30] Cointreau, S. J. “Environmental Management of Urban Solid Waste in Developing Countries,” A project Guide, The World Bank, Washigton DC, USA. 1986.

[31] IPCC, Intergovernmental Panel on Climate Change; Guidelines for National Greenhouse Gases Inventories. In: Tsai WT, editor. Bio-energy from Land-fill gas (LFG) in Taiwan. Elsevier Renewable and Sustainable Energy Reviews, 1997, 11(13): p. 331–44.

[32] Tsai WT. “Bio-energy from landfill gas (LFG) in Taiwan,” Elsevier Renewable and Sustainable Energy Reviews , 2007, 11(13):331–44.