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LANDFILL GAS-TO-ENERGY PROJECT OPPORTUNITIES FROM THE MUNICIPAL SOLID WASTE OF DHAKA CITY

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ABSTRACT

There is a crucial demand of disposing the waste of densely populated Dhaka City in a systematic manner. On the other hand, there is very high demand of electricity. So it is the time for Dhaka city to come forward in finding the ways and means for harnessing enormous new and renewable source of electric energy along with the sustainable disposing system of municipal solid waste. The waste could provide a means to produce energy particularly the highly desired electricity. The study provides an opportunity to analyze the potentiality of Landfill gas recovery from the waste and introduce a system that will enable to generate energy. Recovering and using the gas from landfill will help to mitigate the methane emission as well as produce energy without the use of coal or oil. As a distributed resources, landfill gas project also lessen the need for building centralized power plants. It also describes the mitigation of environmental hazards those are affiliated with waste and its traditional waste management system.

Keywords: Landfill gas, Energy recovery and Waste management.

1. INTRODUCTION

With a population density of over 950 people per square kilometer, management of waste, especially solid waste is a monumental problem for Bangladesh. About 10 million people live in the Dhaka City, which has an area of 344 square kilometer. Solid waste generated in Dhaka City 4750 tons per day and to dispose this waste is required 110 hectares of land per year. Further population growth will contribute to increase the solid waste proportionately. It is estimated that by the year 2015, the total waste generated in Dhaka city will be about 8000 tons per day and for disposing will require 292 hectares of land per year [5]. Bangladesh, a land scarce country, do not have physical space, however, without introducing alternative options, scarce land will be occupying more. The indiscriminate disposal of solid waste in public places causes serious environmental hazards and health risks. Uncontrolled and open dumping clog the urban drainage system, and cause frequent floods and ultimately contaminate the water supply system. Thus, the growing problem of solid waste in Dhaka City is posing increasing threats to the infrastructure system as well as health of its residents.

As the city is growing, demand on infrastructure and electricity is increasing gradually. Present electricity generating system also cannot provide the demand of electricity and the demand will be increased rapidly in near future. On the other hand, the waste of the city is increasing rapidly. Therefore, proper attention is required in managing the waste of Dhaka City Corporation (DCC).

2. OBJECTIVES OF THE STUDY

- Explore suitable technology of waste disposal for energy recovery from Dhaka City waste
- Assess the amount of energy recovery by introducing sanitary landfill gas project
- To meet the deficit demand from waste to energy project.

3. ENERGY RECOVERY

3.1 Technology Selection

There are various options available to convert municipal solid waste to energy. Mainly, the available technologies are a) Sanitary landfill b) Incineration c) Gasification d) Anaerobic digestion and e) Other types, such as pelletization, plasma arc etc. All these technologies have merits and demerits; the choice of technology has to be made based on the waste quality and local conditions. The best compromise to choose the technology, followings should be considered: the technology i) needs least land area, ii) causes practically no air and land pollution, iii) produces more power with less waste and iv) causes maximum volume reduction. The research is mainly considering waste to energy project due to double benefit of resource generation and pollution abatement through incineration and sanitary landfill.

3.2 Sanitary Landfill

Sanitary landfill is suitable for mixed waste disposal system prior to the availability of suitable lands with close range to the city. It is a reclamation process of disposing of solid waste that fills and contours natural or man-made depression and reclaims low lying or marshlands so that they all can be used productively without creating nuisance or hazard to public health.

With the recent improvement in collection of solid waste, more space would be required for disposal. Moreover land is quite scarce and costly in Dhaka city and it would become very difficult to find suitable disposal site close to the collection areas, resulting high haulage cost. Present dumping at Matuail, situated on southeastern outskirts 3 km outside the corporation area obviously increases in transportation cost if the volume of waste is not reduced. As such, waste reduction methods deserve serious consideration in conjunction with sanitary landfill method, in order to prolong the life of landfill sites and also reduce the solid waste management cost. At the same time significant amount of energy could be harnessed through sanitary landfill method.

3.3 Landfill Gas Generation

The theoretical total quantity of LFG generated from one ton of biodegradable carbon is 1868 Nm^3 (Normal cubic meter). From industrialized countries, the theoretical total quantity of LFG potential to be generated is about 370 Nm^3 /ton of municipal solid waste in place. Because of uneven and incomplete biodegradation, it is generally accepted that a maximum volume of around 200 Nm^3 of LFG can be generated from one ton of land filled MSW.

Several practical factors influence the possibility of capturing volume of LFG generated. The most important are:

- LFG losses to the atmosphere through the surface or through the lateral gas migration.
- Pre-closure loss due to decomposition of organic material under aerobic conditions.
- Boundary effects causing incomplete anaerobic decomposition of the near-surface layer (e.g., air intrusion due to gas extraction).
- Other losses such as washout of organic carbon via leachate.

These losses are significant and real. Even with well-designed covers, few landfills thought to recover more than 60% of available LFG. Normal recovery rates are considered to be in range of 40-50% by volume. The upper yield of LFG generated for practical commercial recovery is about 100 Nm^3 /ton of waste in place, generated over 15-20 years. Methane production has been, analyzed by E-PLUS software, given below for the proposed Dhaka landfill site.

3.4 LFG Composition

LFG consists of a number of components, as illustrated in following table. The most important of LFG are methane and carbon dioxide. As it's peak, the methane to carbon dioxide ratio is 1.2:1. For commercial calculation purposes, however, a ratio of 1:1 is normally assumed.

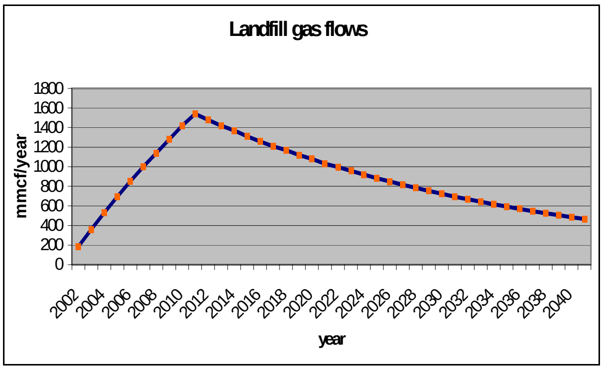

Fig 1. LFG production over time
Source: Analyzing by E-Plus software

3.5 LFG Recovery System

The most common use of landfill gas is for on-site electricity generation. This is the dependable and applicable method for utilization of LFG in lower and middle-income countries. An LFG to electricity system has two basic components: (1) the LFG extraction system consists of the collection system (in the waste) and a suction system (pumps, valves, etc.). The LFG collection system utilizes either vertical wells (placed after infilling of waste) or horizontal drains (placed during infilling of waste). The LFG suction system consists of vacuum pumps, monitoring equipment, and control system. (2) Utilization of LFG, which is commonly achieved through the production of electric power. Gas engine/generator and transmission pipe are needed for that purposes.

3.6 Treatment Cost of Waste by Sanitary Landfill and LFG Recovery

Treatment cost of waste by sanitary landfill is defined as (cost of sanitary land filling cost + cost of gas recovery + cost of electricity generation from gas – energy revenue) and waste management cost is considered here as (collection cost + transportation cost + treatment cost).

Sanitary landfill cost has been taken from the study of consultant Sandra Cointreau who did first phase reconnaissance of selected cities in India and Bangladesh. According to his studies, the sanitary landfill cost varies from 3-10 US$/ton of waste [1]. Here is assumed as 5 US$/ton of waste. Presently DCC is disposing waste to dumping site as 1920 tons/day. Considering 6 working days a week, total waste is 599040 tons /year. Assuming 10 years lifetime of proposed sanitary landfill site, total amount of waste over lifetime is 5990400 tons. After landfill, the density of waste is 1200 kg/cu. m. [2]. Space required for landfill

(5990400 * 1000 kg)/1200 kg/cu. m.
= 818360 cu. m.
= 202 acres.

The financial and environmental aspect of LFG recovery and LFG to energy was analyzed by the E-PLUS version 1.0. Based on the project definition, landfill characteristics, and financial assumptions provided, the following are estimated as per summary results from appendix:

Treatment cost per ton of waste

= (21462240 - 31762740) US$ / 5990400 tons + sanitary landfill cost/ton

= -1.72 US$ /ton + 5 US$/ton = 3.28 US$/ton

Waste management cost per ton= Collection cost + transportation cost + treatment cost

= 7.21 + 4.10 + 6.72 = 14.59 US$/ton

4. ENVIRONMENT

Environment is the sum of substances and forces external to the organism that affects the organism's existence. In relation to man, the environment constitute of air, soil, water, flora and fauna, because these regulate human life. Environment is not only our immediate surrounding but also a variety of issues connected with human activity, productivity, basic living and its impact on natural resources. Land, water, atmosphere, forests, dams, habitat, wild life, energy resources etc. are the natural resources. It is urgent needs to save our environment for the city dwellers as well as global.

4.1 Health Problem Concerning Waste

Good health is a fundamental human right, which is worldwide social goal. Good health is the state of complete physical, mental and social well-being. To achieve it, environmental health should be improved first. It can improve most quickly the condition of the general population. And environmental health is incomplete without considerations of appropriate disposal of solid waste.

Environmental issues exist on three levels. The first one deal with health effects, the second with comfort, convenience, efficiency and aesthetics and the third one is with natural resources and ecosystems [6].

The accumulation of solid wastes in man's environment constitutes a positive health hazards due to following reasons:

- The organic portion of solid wastes ferments and favors fly breeding.
- The waste attracts cats, dogs and birds.
- The pathogens may be conveyed to one through flies and dust.
- There is possibility of water pollution if rainwater passes through deposits of fermenting Wastes.
- Piles of the waste are the nuisances from an aesthetic point of view.

Season also plays an important role on health hazard. One example is a season of the great Muslim festival of Eid-ul-Azha. At that time discarded portions of animal carcasses pose tremendous challenge to waste disposal with attendant threat to health. There are many Tokai (street boys), man and women picking waste from dustbin, container and dumping site without any protective measures. Most often, they are injured and fighting against skin diseases. One report shows that 48.84% were suffering from injury, 20.93% from cold fever, and 19.76% from diarrhea. And more than 22% waste pickers have been suffering due to abdominal pain and worm expulsion [4]. They are always in some physical problem. In fact, this condition is a part of their daily life.

4.2 Environmental Benefit from LFG Recovery and Electricity Generation

From the analysis of proposed Dhaka sanitary landfill site by E-PLUS version 1.0, following environmental benefits can be achieved.

Annual Average Environmental Benefits From Recovering the Landfill Gas:

Methane Emissions: 958.28 thousand tons avoided/year, averaged over the life of the project, 19,165.56 thousand tons avoided total during the project.

CO_2 Equivalent: 20,123.83 thousand tons avoided/year, averaged over the life of the project, 402,476.66 thousand tons avoided total during the project.

Annual Average Environmental Benefits From Generating Electricity from Landfill Gas:

CO_2 Emissions: 9.66 thousand tons avoided/year, averaged over the life of the project, 93.26 thousand tons avoided total during the project.

SO_2 Emissions: 0.28 thousand tons avoided/year, averaged over the life of the project, 5.66 thousand tons avoided total during the project.

Annual Average Environmental Benefits From Using Landfill Gas Directly:

CO_2 Emissions: 31.00 thousand tons avoided/year, averaged over the life of the project, 620.06 thousand tons avoided total during the project.

In Dhaka city, some community based NGO are involved to improve the collection system. Even though the number of involvement is too low, they are coming forward to clean the city as well as improving the environment. The waste can be collected from very first source of waste generation. For doing this, it needs to make arrangements for separate waste boxes for different types of solid waste at every source. It needs to be created public awareness about waste and it's management through mass publication by available media like TV, Radio, Posturing and Leaflet. As the waste is used as raw materials for power generation, waste will be properly utilize and thus disposal problem will be eliminated.

5. CONCLUSIONS

- ❖ Landfill gas project is the possible scientific solution for the disposal of municipal solid waste of Dhaka city. The aim of LFG recovery is to reduce pollution, preserve the fossil fuel, reduce the greenhouse gases and protect the ozone layer.
- ❖ Using landfill gas to generate power utilizes the resource for its economic value and properties and avoids the alternative, leaving the gas unused or flared.
- ❖ Recovering and using the gas from landfills will help to mitigate the methane emission as well as produce energy without the use of coal or oil. As a distributed resources, landfill gas project also lessen the need for building centralized power plants.
- ❖ It is also revealed that through sanitary landfill method about 85-kWh/ton electrical energy generating is possible from the waste of DCC. The waste treatment cost is 3.28 US$/ton. In addition

to generating the electricity, the landfill method has also following positive environmental benefit:

- Generating electricity from landfill gas, 9.66 thousand tons of carbon dioxide and 0.28 thousand tons of sulfur dioxide emissions can be avoided per year in Dhaka city as well as global.
- From recovering the landfill gas, 958.28 thousand tons of Methane and 20123.83 thousand tons of carbon dioxide Equivalent emissions can be avoided per year in Dhaka city as well as global.

6. REFERENCES

1. Cointreau, S., 2001, Solid waste management regional overview: First phase reconnaissance of selected cities of India and Bangladesh. Consultancy for water and sanitation program, south Asia regional office, World Bank, New Delhi, India, 2001.
2. Enayettullah, I., 2001, Public - private community partnership in urban services for the poor, Asian Development Bank, 2001.
3. Johannessen, L. M., 1999, Guidance note on recuperation of landfill gas from municipal solid waste landfills, Urban development Division, the international bank for reconstruction and development/ the World Bank, Washington D.C., U.S.A., 1999.
4. Khanam, K. A., 2000, Thesis paper for Master's of public health, "Socio-Demographic characteristics and morbidity pattern of waste pickers of Dhaka city." National Institute of Preventive and Social Medicine (NIPSOM), Dhaka, 2000.
5. Sinha and Enayetullah, 1997, "Waste as resource." Article in The Bangladesh Observer, Dhaka, November 21, 2001.
6. Tarafdar, M. A. I., Training Manual on solid waste management: "Health and safety", Department of Occupational and Environmental Health, National Institute of Preventive and Social Medicine (NIPSOM), Dhaka.

APPENDICES

Table 1: Methane production over year

Year	**Total Waste**	**Methane**	**Landfill Gas**	**NMOC (Tier I)**
	Tons	mmcf/yr.	mmcf/yr.	Megagrams/yr.
2002	599,000	92.0	184	126
2003	1,190,000	180	361	247
2004	1,790,000	265	531	361
2005	2,390,000	347	694	470
2006	2,990,000	425	851	574
2007	3,590,000	501	1000	672
2008	4,190,000	573	1140	766
2009	4,790,000	643	1280	856
2010	5,390,000	710	1420	940
2011	5,990,000	774	1540	1,020
2012	5,990,000	743	1480	971
2013	5,990,000	714	1420	924
2014	5,990,000	686	1370	879
2015	5,990,000	659	1310	836
2016	5,990,000	633	1260	795
2017	5,990,000	609	1210	756
2018	5,990,000	585	1170	719
2019	5,990,000	562	1120	684
2020	5,990,000	540	1080	651
2021	5,990,000	519	1030	619
2022	5,990,000	498	997	589
2023	5,990,000	479	958	560
2024	5,990,000	460	920	533
2025	5,990,000	442	884	507
2026	5,990,000	424	849	482
2027	5,990,000	408	816	459
2028	5,990,000	392	784	436
2029	5,990,000	376	753	415
2030	5,990,000	362	724	395
2031	5,990,000	347	695	375
2032	5,990,000	334	668	357
2033	5,990,000	321	642	340
2034	5,990,000	308	617	323
2035	5,990,000	296	592	307
2036	5,990,000	284	569	292
2037	5,990,000	273	547	278
2038	5,990,000	262	525	264
2039	5,990,000	252	505	251
2040	5,990,000	242	485	239
2041	5,990,000	233	466	227

Source: Analyzing by E-PLUS version 1.0 software

Table 2: Range of LFG compositions from MSW landfills

Parameter	**Unit**	**Range of variation**
Methane	CH_4 %	30-65
Carbon dioxide	CO_2 %	20-40
Nitrogen	N_2 %	5-40
Hydrogen	H_2 %	1-3
Oxygen	O_2%	0-5
Argon	Ar %	0-0.4
Hydrogen sulfide	H_2S %	0-0.01
Total sulfate	S %	0-0.01
Total chloride	Cl %	0.005
Temperature	^0C	10-40
Moisture content	% Relative humidity	0-100
Mass	Kg/m^3	1.1 – 1.28
Lower energy level	MJ/Nm^3	10.8 – 23.3

Source: [3] Johannessen, L. M., p-6, 1999

Summary Result (Analyzed by E-PLUS Software**)**
Project Start Year: 2002
Project Lifetime: 20
Electricity Capacity: 4,644 kW for electricity sales
Average Electricity Price: $0.0624 per kWh, averaged over the life of the project
Financial Results:
Capital Costs: $ 6,967,078
O&M Costs: $ 1,073,112 per year, averaged over the life of the project

Landfill Characteristics
Open Year: 2002
Close Year: 2012
Current Year: 2002
Waste in Place: 599,040tons, in 2002
Waste Acceptance Rate: 599,040 tons per year, from current year onward
Depth: 20 feet (6.1 m), maximum during landfill lifetime
Area: 202 acres, maximum during landfill lifetime
Gas Generation and Collection
Gas Generation During the Project: 2002 to 2022
Annual Average: 534 mmcf/year of methane
1,068 mmcf/year of landfill gas
Maximum: 774 mmcf/year of methane
1,549 mmcf/year of landfill gas
Gas Collection Efficiency: 85 percent
Electricity Production and Sales Summary
Total Capacity: 4,644 kW
Average Generation: 25,457,534 kWh/year over the life of the project
Engine Load Factor: 62.58 percent over the life of the project
Average Electricity Price: $0.0624 per kWh, averaged over the life of the project
Financial summary:
Total capital costs = 6967078 US$
Annual benefits = 1588137 US$
Annual operating and maintenance costs = 1073 112 US$
Average electricity price (with escalation price) = 0.062 US$/kWh
Average electricity price (base year) = 0.045 US$/kWh
Therefore, Total electrical energy over 20 years (electric power plant life)
= 25457534 kWh * 20 = 509150680 kWh
Total waste in landfill site is = 5990400 ton
Electrical energy per ton of waste = 85 kWh/ton
Total operating and maintenance cost (over life time) = 1073112 * 20 = 21462240 US$
Total revenue from electrical energy sale
= Annual benefits * 20 = 1588137 US$ * 20 = 31762740 US$.