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A Proposal for Integrated Market Waste Management in Bangladesh

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Abstract— ***The paper sketches out an integrated market waste management plan where both environmental sanitation and organic waste management of vegetable and fish market are molded together. Two different methods are incorporated to generate methane gas that is fed into a biogas generator to produce electricity and fertilizer. Initially a survey was conducted to measure the frequency of toilet usage among the permanent and semi-permanent vendors and waste generated in Karwan bazar market, Dhaka, Bangladesh. According to the findings of the survey, design of the integrated biogas plant is developed. Architecture of efficient use of electricity and heat is also developed to ensure sustainable usage of available energy.***

Index Terms— **Market waste management, Biogas digester, anaerobic digestion process.**

I. INTRODUCTION

Although power generation is increasing each year, it is always trailed behind the growing demand with the fossil energy resources are exploited and pressed to the highest level possible. Government of Bangladesh has formulated a renewable energy policy for the country to take up renewable energy development programs considering economical and technical performance with minimum environmental effects. Among all the potential interventions, Solid Waste Management (SWM), so far, has been the most ignored and least studied area of environmental management in Bangladesh. But in recent years, concern is growing both at the governmental and private sectors for the effective and economic management of waste. Treating waste as a resource rather than burden is a new concept which has not materialized into viable projects. Recovery and recycling are considered as the most important management tools for SWM. The major impediments to appropriate solid-waste management are deficiencies in awareness, technical knowledge, and legislation. Local Government Bodies like City Corporations and Municipalities act on behalf of the government on the basis of policies, laws, regulations, directives etc. and play a very crucial role. Unlike other renewable energy programs, SWM involves several stakeholders like city corporations, municipalities, NGOs and community based organizations and non-the-less, the investors that aims for sustainable outcomes.

II. CONVENTIONAL MARKET WASTE MANAGEMENT IN BANGLADESH

There is no existing comprehensive waste collection system in the municipalities and city corporations with only exception in Dhaka and Chittagong city. These two city corporations somewhat adopted a reasonable process of waste management. In many cities, market wastes are mostly dumped in open places nearby; some are burnt too. In the most exercised system various waste transfer points are developed around the cities from where motor vehicles carry the waste to nearby landfills or dumping sites. There is no available proper sanitary landfill to manage the generated waste in the country and with the alarming rate of waste generation for last few years the existing dumping sites are at stake. According to Waste Concern and JICA (2005), a total of 12,332.89 ton/day waste is generated which accounts for 2.19 million ton CO2e/year. With the existing waste collection efficiency, 140.99 acre, 4m depth landfill area is required.

The separation of waste at households is not very common, although combustible parts are often burnt. In some areas of the municipality a door-to-door collection system exists especially in Dhaka city. Due to the large amount of waste that is land filled and dumped in improper manner the groundwater contains excessive concentrations of lead and iron. Table I below (APPENDIX) shows the scenario of waste in urban areas of Bangladesh where major portion of waste is generated.

However, the physical composition of market waste as shown in Table II (APPENDIX); indicates a high composition of organic matter in the form of food waste. Although significant increase in food waste is observed from dry to wet season, the composition of market waste enables to establish aerobic or anaerobic digestion that will be elaborated later.

III. PROPOSED INTEGRATED MARKET WASTE MANAGEMENT

The field survey in various vegetable markets of Bangladesh suggests that sanitation facility in these markets is not adequate and in some cases is not present at all. The buyers or the shop owners don’t use existing toilets as they are not maintained properly. Sometimes when required they use

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the toilets of nearby Mosque or go back to their houses or wait till the market closes. This field survey suggests high demand for sanitation facility in the rural and urban vegetable markets. As many of these vegetable and fish markets don't have any sanitation facility, it is possible to build inter-connected sanitation facility with dual purpose of hygiene and biogas generation.

A study was also conducted in Karwan-bazar vegetable and fish market with approximate 1 km^2 area where 996 shops reside. Design is prepared based on the surveyed data which was conducted on Karwan-bazar vegetable market, Dhaka. During the survey, 200 permanent and semi-permanent vegetables shops were interviewed. 35 percent responded positively that they defecate within the market time period. (Field survey by Authors, February 2011).

The design of the integrated plant is developed based on the study conducted earlier in the Karwan-bazar market. However, the plant is can be modified and customized according to the local context. There are two parts of the design-an underground connected central digester from 5 different toilets and an anaerobic digester with market waste as feedstock. According to the survey, 10 ton market waste is available from the market. But considering the future growth and possible inclusion of nearby other markets the design for anaerobic digester is made for 20 ton/day. Excreta based biogas plant is designed to handle 300 users per day.

A. Central Biogas Plant Linked with Distributed Market Toilets

Human excreta fed biogas plant system, especially those who linked with separate toilet complexes, has number of limitations those needed to be addressed prior the design. The toilets are used by people from different socio-economic background with different food and toilet use habit. There is no direct control over the concentration of the feed material, loading rate, hydraulic retention time (HRT), temperature etc. The design criteria have to take all these into account, and the design parameters have to be flexible to accommodate the variations. These issues are discussed briefly below:

1. Human excreta are malodorous and associated psychological and religious taboos.
2. It contains full spectrum of pathogens causing health hazards if not carefully handled.
3. Wide variation in the frequency and quantity of water used for cleaning the pans and toilet floor, although the amount of water used for personal cleaning does not differ much.
4. Energy input in the form of heating, mixing, pumping etc. has to be kept to the minimum.
5. There shouldn't be any direct handling of execreta visible at any stage and should be order-free.
6. Cleaning water should be kept minimum and no use of chemicals or disinfectants for cleaning latrines.
7. Arrangements for the drying of slurry before using it as manure should be made [3].

Basic Parameters and Operational Criteria:

Table 3: Functional design of the human excreta fed digester [3]

Volume of feed material per user per day (Excreta+ ablution and flushing water+ occasional cleaning water)	4 liters
Volume of digested sludge per user per day	0.00021 cum
Average Hydraulic retention time (HRT)	30 days
Cleaning (desludging) interval for digested sludge	Bi-yearly
Expected biogas generation per user per day	30 liters
Diameter: depth ration	1.5: 1.0
Rise of top dome (h1)	D/5
Rise of bottom dome (h2)	D/2
Position of inlet pipe	H/3 below the top beam
Position of outlet pipe	Middle height of the cylindrical wall

Design: Hydraulic Retention Time (HRT) of feed material is maintained as 30 days in the proposed design. One cft of biogas is produced from the human excreta of one person per day. Human excreta based biogas contains 65-66% methane, 32-34% carbon di-oxide, about 1% hydrogen sulphide and trace amounts of nitrogen and ammonia. The digester design maintains a fixed 300 users per day. It can be varied according to the estimated users thus changing the volume of the digester. Biogas is stored inside plant through liquid displacement chamber. The plant is made up of Reinforcement Concrete Cement (R.C.C); therefore, no recurring expenditure is required for its maintenance. Methane is the only combustible constituent which is utilized in different forms of energy [3].

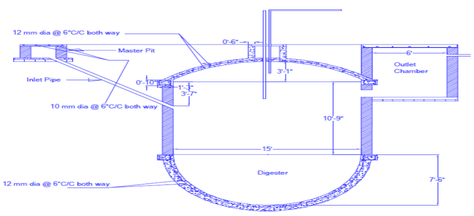

Fig 1: Design of a Biogas plant considering 300 users per day (designed by author)

Reuse of effluent: Effluent contains good percentage of nitrogen, potash, phosphate and other micronutrients, but its aesthetically bad odor, yellowish colour, high BOD and pathogen contents limit its reuse for agriculture/horticulture or safe discharge in water body. In public toilet complexes, linked with biogas plant used by 300 users per day, maximum 1500 litres of waste water is generated per day. The effluent

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could be harmful for the environment if discharged without refining, but it could be used for seeding the anaerobic digester where organic market waste is used as feedstock. Populations of anaerobic micro organisms typically take a significant period of time to establish themselves to be fully effective. Therefore, it is common practice to introduce anaerobic micro organisms from materials with existing populations, a process known as "seeding" the digesters, and typically takes place with the addition of sewage sludge or cattle slurry.

1. *Proposed Market Waste Management Plant*

Choosing an appropriate process for market waste in Bangladesh: As there have been only a few success stories of small scale waste management, meticulous effort has given to identify medium or large scale (in context to Bangladesh) solid waste management. Before choosing a particular waste management option for the purpose of market waste management in Bangladesh, different conventional and current practices all over the world are explored to find out most likely options suited for this country.

Incineration: The main objective of incineration is to reduce volume of MSW so that landfill life span could be extended. Incineration is generally the most costly form of waste disposal and also responsible for emission of many air pollutants including dioxin and furans, a known carcinogen. It requires high technological level in the country which is supported by adequate equipment, infrastructure facility and trained personnel. At larger scale, in context of Bangladesh, incineration is avoided due to the fact that the energy contain of MSW, which reaches the disposal sites is in the range of 1700 to 2100 Btu/lb, is very low to sustain any combustion process. The presence of high moisture and low energy contain makes Bangladeshi MSW unfit for incineration as substantial external energy input would be required to incinerate this MSW.

Sanitary landfill: If properly caped with impermeable liner, sanitary landfill acts as an anaerobic reactor and provides a great opportunity to recover the landfill gas, which is rich in methane and represents an energy reservoir. However, design and operation of a sanitary landfill is expensive and requires a large land area. Even with extreme precautions, odor problem cannot be eliminated in full. If proper engineered sanitary landfill is not constructed and skill fully operated such as at Mautail, beside Dhaka, it can contaminate air, surface and groundwater. Although, it will reduce CH_4 generation by partial aerobic composting and may qualify for a CDM project, but a substantial quantity of CH_4, which can be used as an energy source, would be lost.

Composting: Local municipal solid waste consists of 60% to 80% by weight food wastes and easily could be composted to make humus material to be used as soil conditioner. There are two basic types of organic decomposition that can occur:

Aerobic decomposition: For this process, substantial external energy input is required. Aerobic decomposition (fermentation) will produce carbon dioxide, ammonia and some other gases in small quantities, heat in large quantities and a final product that can be used as a fertilizer. As no CH_4 is generated and released to the atmosphere compared to an open-pit dump, aerobic composting of MSW would qualify as a CDM project. However, a large quantity of CH_4 would be lost in this process.

Anaerobic digestion: Anaerobic decomposition will produce methane (55 to 70%), carbon dioxide (30 to 45%), some hydrogen and other gases in traces, very little heat and a final product with a higher nutrient content than that of in aerobic fermentation. [4] Putrescible materials (food wastes, vegetables, etc.) separated from the recyclables such as metals, glasses, etc. at source will be fed into the digesters. After anaerobic digestion, the residue becomes completely odourless and can be made germ-free. The sorted-out residue can be used as soil conditioner/organic fertilizer and the separated liquid would be used as liquid fertilizer.

Table 4: Composition of solid waste in residential and commercial areas [5].

Constituents (% by wt)	Residential waste	Commercial waste	Mixed waste
Moisture	50	54	59
Carbon (C)	26.06	17.81	12.70
Hydrogen (H)	3.53	1.92	2.25
Nitrogen (N)	1.62	0.46	0.62
Sulfur (S)	0.01	0.02	Minor
Ash	18	22	22
Oxygen (O)	0.78	3.79	3.43
C/N ratio	16:1	39:1	20.5:1
Calorific value KJ/Kg	6048	5243	4578

Source: BCSIR 1998 (Bangladesh Council of Scientific and Industrial Research)

As shown in Table 4, the moisture contents of various kinds of wastes suggest that dry anaerobic process is the best possible option. Aerobic composting is net energy negative, whereas, anaerobic digestion would be energy positive. Dry anaerobic digestion at a decentralized level is more attractive that allows maximum recovery from waste by recycling energy back into the consumers while minimizing not only pollution but also the waste handling and transportation costs associated with localized processing.

Despite the advantages, application of dry anaerobic digestion to MSW has been hindered because of the ammonia accumulation that takes place in dry anaerobic reactors. This issue can be dealt with by assuring the correct proportion of feed waste, which provides a higher carbon: nitrogen (C: N) ratio to avoid ammonia accumulation. The fermentation

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substratum rarely requires pre-treatment. The technology is therefore much simpler and more robust than that of wet fermentation plants.

The major components of waste generated include vegetable wastes (21%), fruit wastes (15%), flower wastes (10%), banana stem and related materials (38%) and packing materials (hay, straw, paper etc. 16%). Materials in the form of stones, plastics, wood etc are present in less than 1% of the waste quantity. Depending upon the season, there are large fluctuations in the quantity and nature of waste generated daily from the market. The total solids content are 25% and 73.7% respectively [6] .Proposed Anaerobic Method for Market Waste Management:

Mode of separation: The mode of separation chosen for compost preparation does have a great effect on the efficiency of the composting process. Studies conducted on composting in developing countries indicate that source separation is the only feasible method for profitable and sustainable composting (Gtz n.d) [7].

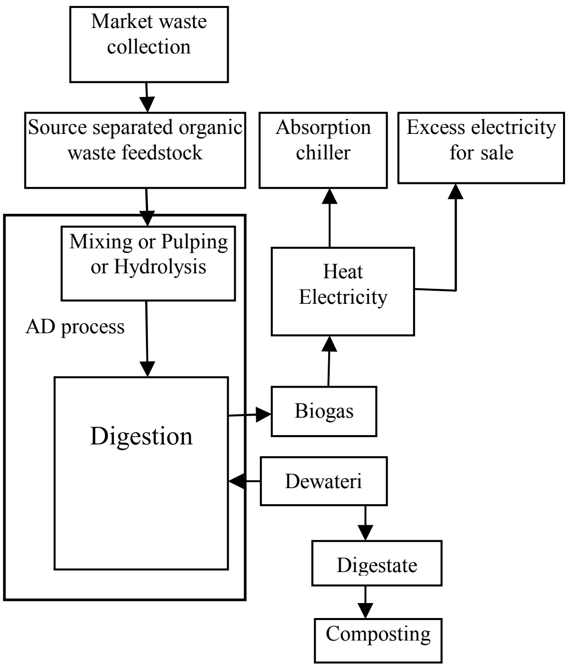

Fig.2. Flow Diagram of Proposed Digestion Process (Regenerated From [8])

Study indicates source seperation for the market waste is feasible with a little adjustment of existing mechanism and training to the current waste cleaners. Other market waste management studies [7] also suggested that coordination with market-based committee would be appropriate with a little awareness raising and training to adopt source separtion technique prior feeding into the digester. Source separation will definitely improve the conversion rate, smooth operation and expenditure cut.

Description of the Technology: Unlike the technologies that are developed in Europe and other parts of developed countries where temperature is controlled at an optimum stage to yield higher biogas from waste, the weather pattern of Bangladesh enables to develop a process with uncontrolled temperature but yet producing substantial amount of gas. In the digester, the temperature will rise to a little over 130^{o}F without any external input. A digester, typically a concrete or steel tank with a 15-20 day retention time, will be used and the feedstock will be separated from source. This eventually minimizes the cost related to shredding, sorting and use of magnetic separator. Water from the dewatering unit is added to the waste in the storage unit, to adjust the feedstock moisture content to 28% dry solids content, 72% moisture content in Kompogas technology.

But in the proposed integrated design, 1500 liter effluent is available from the effluent tank which will minimize the water requirement and also 'seed' the digester. "Dry." systems mix approximately 10 cu ft of water per ton (0.3 cu m per tun) of incoming waste to produce organic slurry of 20-40% total solids. [9] Requirement of water could be met or partially met by the effluent generated from toilet based biogas plant. For example, a 20 ton/per day system will use 6 cum water per day of which 1.5 cum could be met through a 300-user capacity effluent tank. The process is 'Carbon Dioxide Neutral' as there is no net addition of carbon dioxide to the atmosphere by the process. This is quite opposite of what occurs from burning of fossil fuels and coal bed methane, making it one of the most sustainable methods for producing energy in Bangladesh.

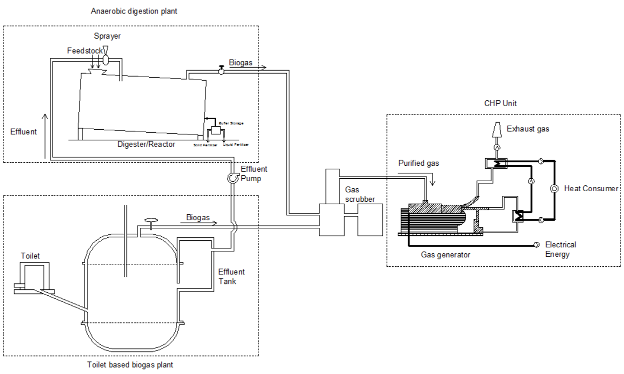

Fig.3. Design of proposed integrated market waste management plant

Biogas Upgrading and Sulphur removal: Biogas from both the AD facilities will be used in the gas turbine, moisture and hydrogen sulphide thus must be removed, to minimize corrosion and other impacts on the equipment, which is designed for natural gas use. Biogas comes out of the digester at about 1psi. But to use in a gas turbine, it must enter the compression equipment at the same pressure as natural gas, which typically is supplied at 200-250 psi. An H_2S scrubber will be used to remove H_2S from the biogas. The scrubber reduces the sulphide concentration by over 90%, and a removal rate of up to 99% is claimed by some manufacturers. [10].

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IV. Daily Biogas Generation From The System

Calculation of biogas generation from toilet: Expected average biogas production per user per day = 30 litre [3] According to the proposed model, per day users will be 300. So, biogas generation from toilet complex = 30*300=9000 litre/day= 9 m^3/dayBiogas from public toilets is not a significant amount but it has multiple benefits-improve sanitation, community health & hygiene, environment, make available quality liquid manure, in addition to uses of biogas for different purposes.

Calculation of biogas generation from digester: According to the thumbs rule of anaerobic digestion, expected biogas generation from 1 ton MSW is in the range of 100-200 Nm^3. This range highly varies due to various parameters like solid content of market waste, temperature inside the digester, digester design etc. Now, given the fact that the solid content measured in market waste, hot weather of Bangladesh and effluent mixture for creating better condition for acid organic bacteria will give higher yield of biogas. The range is expected to be around 160-200 Nm^3/ton of market waste. The digester is designed to take 20 tons of market waste every day. That will give 3200-4000 Nm^3 biogases per day.

V. Electricity And Fertilizer Generation

A Combined Heat and Power (CHP) system is always worth considering for the proposed system. CHP is a good way to gain better efficiency of power use, and it will bring further income to fund the biogas digester operation. As H_2S is almost close to 1% in biogas from human excreta, it'll be dangerous to handle; so cleaning is required before electricity generation. The gas generators tolerate certain amount of H_2S in the biogas. It is recommended to keep the range around 50 ppm for better performance. A gas engine will burn the methane to convert the chemical bond energy of the gas to heat energy expanding the gases within the piston, driving the drive shaft and producing mechanical energy. The mechanical energy in the rotating drive shaft is then coupled into an electrical generator. The mechanical energy is utilized to drive the AC (alternating current) generator for electricity generation.

Besides electricity generation, organic fertilizer is other major product that is generated by the proposed integrated system. The soil conditioners (both solid and liquid) generated are modest in nutrient but positively enhance the productivity of the soil. Unlike chemical fertilizers that adversely affect the productivity of the land in long run, organic fertilizer acts as a slow-release fertilizer that sustains the biological nutrient storage in the soil.

VI. Conclusion

The process of generating electricity and thermal energy from market waste and human excreta accounts real GHG reductions, the productive use of manure and the diversion of organic wastes from landfill. It also offer air quality benefits compared to open burning of waste and coal-fired power plants. Biomass power facilities can benefit local, rural economies by creating jobs and tax revenues. Recycling and reuse of human excreta for biogas generation is an important way to get rid of health hazards from human excreta, besides use of biogas for electricity generation. As the common people are the biggest waste generators, their awareness can lead to a major change in the quantity and quality of waste generated in the country. But knowledge about waste among the common people is inadequate thus requires featured education on various aspects of waste management to have better results.

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APPENDIX

City/town	*WGR (kg/cap/day)	Population** (2005)	Avg. TWG*** (ton/day)	Waste collection rate, %	Landfill area required with 4m depth, acre per year		GHG emission, million ton CO_2e/year
					With existing collection efficiency	With 100% collection efficiency	
Dhaka	0.56	6,728,404	4,634.52	42.00	39.89	94.97	0.76
Chittagong	0.48	2,622,098	1,548.09	70.00	22.21	31.72	0.25
Rajshahi	0.3	468,378	172.83	56.67	2.01	3.54	0.03
Khulna	0.27	967,365	321.26	47.70	3.14	6.58	0.05
Barishal	0.25	437,009	134.38	44.30	1.22	2.75	0.02
Sylhet	0.3	386,896	142.764	76.47	2.24	2.93	0.02
Pourashavas	0.25	15,214,306	4,678.40	54.42	52.17	95.87	0.77
Other Urban Centers	0.15	9,217,612	1,700.65	52	18.12	34.85	0.28
Total		36,042,067	13,332.89	-	140.99	273.21	2.19

Table 1: Waste Scenario of Bangladesh Urban areas [1].

*WGR= Waste Generation Rate
**Including 10% increase for floating population
***TWG= Total Waste Generation

Season	Composition (%)					
	Food waste	Paper	Wood Grass	Plastic	Sand Dust	Other
Dry	53	5	23	3	6	9
Wet	67	3	16	1	4	8

Table 2: Physical composition of market waste [2] Source: JICA 2005