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Municipal Solid Waste Landfill in Dhaka: A Sustainable Approach for Energy Generation

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Abstract: ***The failure of respective authorities to properly collect and treat municipal solid waste leads to unpleasant urban surroundings, posing serious threat to health and the environment. The capital of Bangladesh, Dhaka, is one of the most densely populated cities in the world. The predicament of poor solid waste management and energy crisis will, if not already, have a crippling effect on this metropolis of around 15 million residents. With a high rate of increasing urban population and consumption, Dhaka city produces approximately 3500 tons of solid waste per day, of which only 51% is collected for disposal and inefficiently treated. On top of that, the energy sector fails to produce electricity according to its demand, resulting in routine load shedding occurrences. The concept of a sustainable urban landfill will be a model of maximum solid waste collection and management while promoting green practices as well as generating energy in the form of electricity, heat and methane.***

Keywords: Bangladesh, energy, geomembrane, municipal, landfill, sustainability, waste

1. Introduction

Bangladesh is a country of over 160 million people, making it the 9th most populous country in the world. Its capital, Dhaka, spreads over 127 square kilometers with around 15 million people – almost 10 percent of the total population [1].

According to the World Bank, Bangladesh is classified as a lower-middle income economy [2]. A country that is based on agriculture and export, with instabilities in environment issues and national politics, it can be observed how technology and sustainability do not play a major role in the daily lives of the people. Two major examples of such tribulation are the management and treatment of urban or municipal solid waste (MSW), and the lack of resources to generate renewable energy. Unlike major metropolises around the world, Dhaka falls behind when it comes to generating simple and effective ideas to overcome barriers and achieve greener environment and clean energy.

Advancement of technology and experimentation in the world has led to many scientific breakthroughs in the field of solid waste management over the years. Waste is no longer a burden, rather a "resource" to safely produce energy, compose fertilizer and/or generate recyclable material. The major challenge however, is its collection, separation and transportation [3]. Due to the growing rate of urbanization, global MSW generation portrayed a double increase just only within 10 years from 0.68 billion tons per year in 2000 to 1.3 billion tons per year in 2010. It is expected to reach 2.2 billion tons per year by 2025 and 4.2 billion tons per year by 2050 [4].

The proper treatment of such high volumes of generated waste into electricity, heat or fuels is known as the waste-to energy approach, and is considered a sustainable method for solid waste management. The country's energy generation capacity is around 12, 365 MW. The current power demand is around 10, 000 MW against a production of around 9, 000 MW, with a system loss of about 13.5%. Using urban-generated waste can produce significant amounts of biogas to contribute in the high energy demand of the country.

2. Background

The current land area of Bangladesh is about 147, 570 square kilometers [5]. The major land use types are agricultural, forestry and urban area. The urban area of the country is almost 1.16 mha. The average temperature ranges from 21 to 31 degrees Celsius with a relative humidity of 78%. The average annual rainfall varies from 1200 mm in the west to 5800 mm in the east and north-east.

The amount of biomass production mainly depends on the climate, temperature, soil condition and the area of available surplus land [6]. A developing country, Bangladesh, produces a lot of solid waste, mostly from the urban regions in Dhaka, Chittagong, and other major cities. The lack of recycling practices mean almost all of the generated waste finds itself dumped in open-air landfills. Landfills are one of the oldest forms of waste treatment. It is usually a site for open dumping or burial of wastes: a method practiced all over the world since ancient times. Dhaka has two sanitary landfill sites in Matuail and Amin Bazar.

The city's waste collection methods are mostly operated by the Dhaka North and South City Corporations, with non-governmental organizations (NGOs) taking care of slums and lesser municipal areas.

Waste collected from households is mostly open dumped in constructed sites around the city. The time, unlike parts of the modern world where waste is assembled at night, is early

morning – coinciding with the morning rush-hours. Much of the collection and separation is done by hand as there are no strict regulations to segregate waste at domestic levels. Hence, recycling practices are neglected. This leads to mixing of organic and inorganic waste which is difficult to deal with. A study shows that the percentage combinations of the collected waste is about 75% organic matter, followed by paper, plastic, textile and wood, metal, leather and rubber, and glass, respectively in smaller fractions [7].

A major factor in the increased rates of MSW in Dhaka is the constant growing population of the city, which is credited to increasing jobs and migration to cities from rural parts for better standards of living. This poses a serious threat from a waste management point of view, as not only is waste different in each city, different types of waste require different methods of treatment – eventually leading to more costs.

Table 1: Growth rate of urban population causing increased waste generation

Year	Urban population	Total urban waste generation (kg/day)	Per capita waste generation rate in urban areas (kg/cap/day)
1991	20.8 million	6, 493, 000	0.31*
2005	32.76 million	13, 332, 000	0.41**
2025	78.44 million	47, 000, 000	0.60***

Source: *World Bank, 1998; **Waste Concern, 2005; ***UMP, 1999 [8]

3. Solid Waste in Dhaka

A demographic study of the capital city, Dhaka, will illustrate the area divided among sections that differ in levels of infrastructure, habitat and economy. The city produces different kinds and forms of waste each day from each part of the city. It is expected and experimentally proven that a developing country that is based on agriculture with a high rate of poverty would produce the highest percentage of organic waste.

The waste is collected by municipal authorities on a daily basis, and that is where the mismanagement begins to appear. Lack of general public awareness stimulates more littering on the streets, sewer, ditches, lakes and canals on or beside the streets. The collected waste that is taken to the open-dumping site via trucks and vans rarely segregate the waste according to moisture content, size, or type.

Table 2: Percentage composition of solid waste in Dhaka city

Materials	Quantity (%)	
	Residential	Commercial
Food waste (Organic)	84.37	79.49
Paper/Cardboard	5.68	7.22
Textiles	1.83	1.59
Plastics	1.74	1.48
Glass/Metals and construction debris	6.38	10.22

Source: Shariar and Al Bustam, 2012 [9].

Table 3: Composition of MSW in Dhaka city

Waste composition (%)	Per capita waste generation (kg/day)		
	Mia, Dijkstra & Solaiman, 2015 [10]	Huda, Mekhilef & Ahsan, 2014 [11]	Average
Food waste/ Organic	69.00	68.30	68.65
Paper	6.70	10.70	8.70
Plastic	5.07	4.30	4.69
Textile and wood	9.58	2.20	5.89
Leather and rubber	1.40	1.40	1.40
Metal	1.84	2.00	1.92
Glass	2.37	0.70	1.54
Others	7.72	10.40	9.06

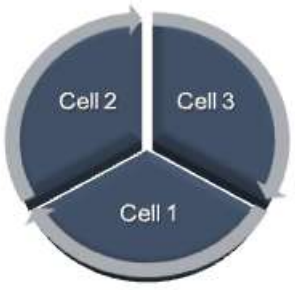
4. Methodology

In order to create a systematic approach for urban waste management and treatment in Dhaka, four areas can be selected for development:

1. Collection and transportation of waste from collection sites to the landfill site
2. Separation of waste into organic and inorganic fractions for treatment
3. Deposition of waste in the landfill
4. Generation of different forms of energy and by-products

The ability to produce different forms of energy will make the planned landfill site a “multipurpose” facility. It will be equipped with the latest technology and machineries in waste management industry. Some fundamental assumptions regarding the facility and its operations are listed below.

a. The landfill site will be divided into grids or “cells”
b. Each cell will be used for a year (e.g. Cell 1 for year 1 of operation, and so on), making it re-usable and hence sustainable as shown below



After year 3, Cell 1 is labeled as Cell 4.

c. The landfill site management authority will take on initiatives and public/private partnerships to collect waste from households
d. Untreated waste will be disposed of in the most effective and safe way possible
e. The facility shall be used to produce maximum energy and cause least environmental deterioration
f. The community will actively participate in recycling methods and be aware of the facility operations
g. It can be assumed that consumption and waste genera-

tion habits will continue as per present rate

h. The fate of the landfill site will be eco-friendly and aesthetic in nature

Granted, such a massive undertaking will require land and large scale investment. In the following sections, the concept of a sustainable landfill facility is made clearer, with practical examples and prospects of its implementation in modern day Dhaka.

5. Features

The site for the conceptual landfill is the old airport located in Tejgaon, surrounded by residential, military/VIP and commercial areas. The area is presently under the supervision of the Civil Aviation Authority, Bangladesh (CAAB). It is mostly used as an airfield nowadays, containing hangars and a runway that served as the only airport of Bangladesh prior to the construction of Hazrat Shahjalal International Airport in 1981.

The idea and design of the proposed urban landfill facility was inspired by the presence of an unused space in a metropolis like Dhaka, added to the frequent tribulations over waste collection, management and treatment. With the availability of such a vast area under the jurisdiction of the government authorities, it is expected that the responsible parties can come together to utilize and work for better urban waste solutions.

New landfill developments as well as significant changes to the existing site would enhance the productivity of the current airstrip that has not been in use commercially since 1988. The area is just under 2 square kilometers and promises development and usage of both small and large scale operations.

Figure 1: Conceptual design of the urban solid waste management facility, with landfills, photovoltaic panels, incinerator and establishments on site created using Google MyMaps.

For the plan of the landfill site, Figure 1 portrays the optimum capacity of the site, with options for further future expansion if required. The design includes:

1. Central waste collection point
2. Separation-segregation-recycling zone
3. Incinerator
4. Integrated leachate collection system
5. Surface drainage control using channels and gutters
6. Methane collection system and cleaning plant
7. Electricity generating power station
8. Grid lines
9. Administrative establishments
10. Roads
11. Landfill cells

5.1 Waste processing

Waste collection trucks will be used to transport the waste from local collection points, arriving at the site and emptying onto the tipping floor of the separation zone. This zone will incorporate a shredding area, which will help increase the surface area of the waste. The waste will be then placed on conveyor belts, to be separated manually into organic and inorganic fractions.

Recyclable materials can be separated in bales. The bales will be stockpiled at the site until there is sufficient quantity to ship to markets, or dumped directly into the landfill. Current research also suggests dry waste can be used as aggregates for concrete production. The inorganic fraction will be sent to the incinerator; the organic will go to the landfill.

5.2 Development sequence

The landfill site will have to be developed in stages. An adequate dimension of each cell is necessary to accommodate the accumulated waste from future population growth and a constant increase in waste generation. The idea proposes a sustainable, long-term and re-usable solution as each cell can be used repeatedly over years. The site will contain 3 cells, each to be filled in one fiscal year. The organic waste will be deposited every day on one landfill, covered with top soil and then compacted with a roller. The same operation is to be repeated daily for a year, until the process is moved on to another cell after a year.

5.3 Leachate collection

Each cell will be drained for leachate storage, extraction and treatment. The leachate collection system will consist of a network of perforated pipes bedded in graded rock contained within ditches surrounding the cell, like a moat. The production of leachate will be monitored by using a pressure transducer that rises up to the surface. The liquid will be obtained by using pumps and transported to a treatment facility.

5.4 Stormwater management

The location that is proposed is flat as it houses a runway. This risks stagnation of stormwater, considering high precipitation levels of Bangladesh round the year. Stormwater and surface drainages must be managed to control water accumu-

lation and to manage the water that is in contact with the waste. The water from rainfall will flow into the surrounding moat ditch used to store and remove surface water from over the pit.

5.5 Landfill gas

Landfill gases will be generated as part of the process of waste decomposition. Landfill gas is composed of a mixture of hundreds of different gases. By volume, landfill gas typically contains 45-60% methane and 40-60% carbon dioxide along with small amounts of several other gases.

The volume of gas produced at landfills will require studies and tests. It will be possible to collect the gas in order to run it through to a gas collection and cleaning system to generate electricity for the grid or for heating requirements.

5.6 Incinerator

The landfill site will host an incineration zone to treat the separated inorganic fraction of the incoming solid waste. After segregation, the dry waste will be dropped into a storage bunker, from which large clawed clamps will be used to pick it up and placed in the incinerator.

After burning at a very high temperature of around 800-1200 °C, the waste is "thermally treated" to produce ash and flue gases. The ash is carried on a conveyor belt to the landfill site as it has the necessary properties to be used as a component of cover material.

The flue gases will rise up and divide into effluent gases and steam, with the latter being used to propel a steam-turbine generator and supplying electricity in the range of megawatts (MW). The effluent flue gas will undergo several steps of pollutant filtering and particulate matter removal system and the cleaned, warm air will be released into the environment.

5.7 Solar power

The introduction of solar photovoltaic cells on the landfill will be the very first of its kind in Bangladesh. Having acquired a large, flat land, it can be used to produce a lot of energy using multipurpose methods. Bangladesh receives an average daily solar radiation of 4-6.5 kilowatt-hours per square meter (kWh/m^2) [12]. The introduction of solar energy at a waste sanitary landfill site will add another feather to its cap, in addition to the energy produced from burning of dry, inorganic material at the incinerator and collection and process of landfill gas (methane).

Solar photovoltaic panels that are easy to assemble can be installed over the 2 allocated cells of landfill sites while the other cell is being used to dump wastes in. This will already have produced electricity by the time cell 1 is fully covered at the end of one year. This will make the facility both a solar power farm and a sanitary landfill site, hence living up to its multifaceted attribute with the purpose of waste management as well as power generation.

An alternative and futuristic approach to making this happen could be the use of solar geomembrane covers to cover the area once it is in full capacity. Integrated photovoltaic arrays are placed in these covers which contain flexible solar laminates. Use of such material also helps in controlling the infiltration and erosion, as precipitation can easily run off its surface into the moats or channels to be piped away. The heat trapped due to the thick material of the membrane also helps a quicker decomposition rate of the waste under it, requiring minimum top soil.

Furthermore, photovoltaic panels present the risk of reflecting sunlight. It would be unwelcome for an urban setting, as a sustainable waste management system should not only be environmentally sound but also socially acceptable. Geomembrane covers do not reflect sunlight and can be spread over large, flat lands. The feature will play an important role in generating electricity as well as reducing carbon dioxide emissions as no vegetative top soil is required.

The Hickory Ridge Landfill in Conley, Georgia, USA produced around 1.3 million kWh of electricity from a 1 MW facility [13]. A landfill in Dhaka can generate more power to rectify its energy crisis, predicted to reach 60000 MW by the year 2040.

6. Advantages

Other than the sole purpose of collecting and treating solid waste that generates in huge amounts in densely populated areas, the landfill site incorporates various kinds of advantages.

The location, albeit visible from nearby neighborhoods, provides support in the form of accessibility. There are roads along the 4.98 kilometer perimeter that make it easier for collection trucks to enter from various entry points into the facility.

As mentioned, the fact that it is an airport provides evidence that the land is flat with minimal gradient. This will help in doing engineering and excavation work on the ground. Being in close vicinity to the Dhaka Cantonment and Ministry of Agriculture in Khamar Bari can act as an advantage, as specialists can monitor the operations and put in their valuable input.

7. Disadvantages

Establishing a large scale project at the heart of a bustling city that deals with solid waste, poses a good amount of threats and risks to the daily life of a citizen. Aesthetically, it may be undesirable, but recent advances in technology and engineering make it possible to undertake such operations with minimal adversity to scenic beauty.

Moreover, the odor created over the long period of time may raise concerns, apart from the frequent smoke from the incinerators. It only means that serious considerations need to be made regarding the hygiene policies coupled with stringent measures to adhere to them.

Undertaking such large-scale projects will require an environmental impact assessment which in turn should stipulate public participation and dialogue. Moreover, the local envi-

ronmental agencies can come forward to magnify the benefits of such a facility to help in gaining support from its beneficiaries.

8. Conclusion

The aforementioned idea, attached illustrations and figures show a concept for a versatile urban landfill facility in the heart of Dhaka.

The public and respective authorities can take a step forward to combat the imminent hazards of a failed waste management system, as well as provide for much needed energy for a country that is heavily dependent upon traditional, non-renewable energy sources. Such a landfill facility promises to be not only a clean source of energy for the localities, but a landmark in engineering and design.

The landfill attributes the capability to rotate use of cells for waste treatment over a lifespan of over 50 years. Beyond that, based on the topography and location of the landfill site, it can be renovated into a park or recreational center. Initiatives as such will result in reducing carbon footprint and fighting climate change as well; harboring green and sustainable methods to rejuvenate a city's environment will prove to be exemplary to the world.

The development of new landfill facility is a major step in the quest to attain sustainability and a green future for Dhaka city. Following down the road from trash to treasure will no longer be a dream but a reality.

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