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SUSTAINABLE SOLUTION FOR HOUSEHOLD ORGANIC AND FAECAL WASTE MANAGEMENT: A CASE STUDY OF DHAKA CITY

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ABSTRACT

This paper aims to give an innovative solution for the unmanaged organic wastes generated by households and the wastewater from faecal waste in Dhaka city through a low-cost model which will turn those wastes into energy in form of biogas. As Dhaka city is already burdened with a severe load of solid wastes in many forms and poorly served faecal sludge management, this model will be highly effective and sustainable for the environment as well. An anaerobic digester will be used for the treatment of the sewage water mixed with faecal sludge that will ensure a less polluted discharge in the main stormwater drainage of the city corporations. There will be both biogas production, treatment, and storage tank along with a digestor for dry composting to turn the sludges into bio-soil. This model will cost less and will bring a positive impact on the environment and public health.

Keywords: *Solid Waste, Wastewater, Faecal Sludge, Waste to Energy, Biogas, Organic Fertilizer*

INTRODUCTION

Solid waste management is a global concern as rapid urbanization and population increase are generating a massive number of waste products per day which includes domestic, commercial, industrial, municipal, and agricultural wastes (Ilic´ and Nikolic, 2016). According to Okedu et al. (2022), the solid waste output may exceed 2.6 billion tons annually by 2025 because of population growth, urbanization, industrialization, and economic development which have put the sustainability of the environment under great threat (Okedu et al., 2022). The overall solid waste management system of Bangladesh is quite poor (Ashikuzzaman and Howlader, 2020). Abedin & Jahiruddin (2015); Rahman (2017); Shams et al. (2017) demonstrated that Bangladesh's rapid urbanization and population increase are responsible for a significant amount of the country's solid waste generation. It now faces a serious problem with solid waste management, since by 2025 the country will produce 0.75 kg of waste per person per day and 21.07 million tons of waste annually and for the metropolitan regions, it will be approximately 0.6 Kg/cap/day resulting in a daily average waste volume of 57,718 tons (Hoornweg and Bhada-Tata, 2017). Aside from solid waste, managing household organic waste, and faecal waste, this country is also thriving. Although there have been significant investments by the government and NGOs in access to proper sanitation and hygiene over the years (Ashikuzzaman and Howlader, 2020), the disposal of faecal sludge and wastewater into the low-lying areas and lakes and canals within urban areas is causing serious environmental degradation and endangers public health as well as reduces the benefits of an improved sanitation system. It is alarming that, except for about 20% of Dhaka city, all urban areas of Bangladesh are served by on-site sanitation (OSS) system (Mondal, 2018). Also, Dhaka city has very limited vacutug service for pit or septic tank emptying and people normally rely on conventional “Sweeper” service involving a periodic cost for the dwellers. In addition, around 30% of the pits or septic tanks are directly connected to the stormwater drain, which carries the wastewater to the nearby river or water source (Mondal, 2018). However, less than 1% of the sewer waste generated in Dhaka city can be effectively treated through treatment plants (Mansour et al. 2017). Even though Dhaka is the country's capital, it only has one sewage treatment facility, at Pagla, with a 120 ML/d capacity, and only 30% of the city's total area is now connected to the sewer network (DPHE, 2014). Most of the septic tanks in the urban area can function partially only due to their faulty design and can act only as a reservoir rather than treating the sludge. Only a minimal portion is recycled into any useful form of energy (BRAC, 2015). The lack of prior segregation of solid wastes, based on their categories, makes it extremely difficult to recycle in the later stage at the dumping station. Here requires a proper Faecal Sludge Management (FSM) system to deal with on-site sanitation systems (Strauss and Montangero, 2002). Storage, collection, transport, treatment, and safe end-use or disposal of faeces are all included in faecal sludge management (FSM), which refers to all five elements of the sanitation value chain (Singh et al., 2016). The fact that there is no defined division of labour for FSM among utility service providers, City Corporations, Municipalities, and City Development Authorities in large cities is a key contributing factor to the lack of FSM services in these cities and towns (Kabir and Salauddin, 2014). Through a proper FSM and using innovative technologies of Waste-to-Energy (WtE), we can produce energy from a waste source in the form of electricity, heat, or transport fuels (such as diesel). These methods may be used to treat a variety of waste types, including liquid (like home sewage) and gaseous (like refinery gases) waste. Semi-solid waste, such as thickened sludge from effluent treatment facilities, can also be treated using these technologies (World Energy Council, 2013). These technologies can be applied in the case of Dhaka city for an efficient waste management system. This study aims to provide an idea and technical description of developing a mechanism to capture and digest faecal waste along with kitchen and food waste to produce biogas and provide a low-cost sustainable solution.

METHODOLOGY

This paper illustrates a model of low-cost waste to energy-for residential or commercial buildings. This concept can be utilized in slum areas as well. It proposes an anaerobic digester with a water treatment facility for safe discharge to the stormwater drain. The water can be alternatively reused upon its improvement to the potable water standard. This can be placed anywhere on the ground floor or underground of any building. The digester will have a continuous input of faecal sludge and flush water from the latrines of the building through the existing pipelines. It will separate the water from the sludge using its physical characteristics and digest the sludge. Additionally, bio-degradable kitchen and food wastes will also be added in batches for digestion. Another objective of the addition of kitchen waste is to increase gas generation and make the digestion process faster. The output will be biogas with 60-65% Methane content. This gas will be filtered to remove Carbon Dioxide and Sulphur Dioxide contents and improve the Methane content in the product gas to more than 90%. Alongside it will produce organic fertilizer which can be used for household gardening or can be sold to nursery owners.

Waste Collection and Digestion Tank

There will be two digestion tanks, and each tank will be in operation alternatively for 6 months. This tank can be made of brick, concrete, plastic, or steel with insulation wrapped all around to prevent heat loss during the winter season. Each digestion tank shall be of sufficient size to store 6-month solid sludge volume. Inside each digestion tank, there will be a lining of geotextile fabric, which will trap the solid sludges and allow the water to infiltrate through. The accumulated solid will go through an anaerobic digestion process and will produce biogas.

Toilet waste and kitchen waste will be fed to the digestion tanks on regular basis. For the organic kitchen waste, there will be a shredding unit with an inlet. The tank will be facilitated with an integrated agitator which will activate for 5 minutes every 6 hours. This agitation process will enhance gas production and prevent foaming formation. Finally, the tank will be facilitated with a pressure indicator and a pressure relief valve, based on the structural capacity of the tank, for overall plant safety.

Biogas Production, Treatment, and Storage

The produced biogas will come out of the digestion tank in batches once the gas pressure reaches a certain value and then pass through the treatment filters. First, it will pass through a Water Scrubber, which will remove most of the Carbon Dioxide, Hydrogen Sulphide, and Ammonia content from the Biogas. After that, it will pass through the Iron (III) Oxide Unit to remove the remaining Hydrogen Sulphide from the Gas. The produced treated gas will then be stored in a storage bag. The outlet of the bag can be connected to the end users of the gas.

Wastewater Treatment and Discharge to the Stormwater Drain

The infiltrated water from the tank will come out of the tank and will pass through a biological (trickling) filter medium. There will be a grated diffuser plate on top to distribute water equally to the filter. The tank can be filled with packed plastic or porous rock medium to facilitate sufficient bacteria for microbial growth. A transparent top surface will be provided in this tank and a blower will provide sufficient air inside to provide a thriving environment for the microbes. Finally, the tank will be suitably ventilated to prevent any nearby odour pollution. Conservatively considering this trickling filter medium working as a rouging filter, it can be assumed that 40-65% BOD_5 removal efficiency can be achieved (Liu and Liptak, 1997). This water then enters through another grated diffuser plate into a suitably ventilated Slow Sand Filter (SSF) with Schmutzdecke at the top surface which can achieve E. coli removal of 3.23 log and total coliforms removal of 2.98 log, turbidity from 60 to 95%, and apparent colour from 50 to 90% upon the complete development of the layer in the span of 30 to 40 days (Lubarsky et al., 2022). To keep the biological process alive, the Schmutzdecke layer shall always be kept wet (Ranjan and Schmutzdecke, 2018).

An SSF can be built with a fine sand layer at the top, followed by a coarse sand layer, a fine gravel layer, a coarse gravel layer, and a large pebble layer. To achieve the desired water quality or output, multiple SSFs can be connected in series. With the use of effective sand sizes of 0.31 and 0.56 mm, an SSF can remove about 79–92% of BOD_5 and 50–67% of COD (Farooq and Yousef, 1993). In addition, nitrogen removal efficiency will reach 45-67.5% with fine sands (Nakhla and Farooq, 2003). SSF can also satisfactorily remove heavy metals such as arsenic, copper, chromium, lead, and cadmium with more than 90% removal efficiency. In addition, it can also remove recalcitrant pharmaceutical compounds which are either resistant to biodegradation or slowly biodegradable. Propiconazole, Diclofenac, Iohexol, Iopromide, Tebuconazole, Iomeprol, and Propranolol were removed with an efficiency of 21%, 41%, 57%, 58%, 59%, 85%, and 94% respectively (Verma et al., 2017). For the filtration process, biochar can be used as an alternative to the sand media, which has shown better efficiency in terms of BOD, COD, and E. coli (Kaetzl, et al., 2020). All the SSF shall be fitted with a backwashing mechanism to prevent frequent clogging of the sand or biochar pores.

In the final stage, chlorination dosage provision may be added to disinfect the water. For this purpose, a 15% Sodium Hypochlorite solution may be used with a dosage rate of 1 g/m^3. This disinfected water can reach the freshwater standard and may be reused for domestic purposes. This finally treated water can be safely discharged to the storm drain as the standard set by the Department of Environment for Inland surface water if it is not reused.

Digestate Management through Composting

Each digestion tank will be kept uninterrupted for at least 6 months and will act as a dry composting pit beside biogas production. After a tank is closed and stopped from receiving waste input, an additional 1 month is allowed for anaerobic digestion and methane gas production. Then the gas transfer line is closed, and the tank is converted into an aerobic digestion chamber by opening aeration and ventilation.

Throughout the composting process, the organic matter is biologically broken down by thermophilic aerobic microbes. Due to the biological activity of these, the temperature inside can reach 50-70°C under ideal circumstances. This progressively drops to ambient temperature after and is followed by a curing stage of at least 4 months. Then the pile becomes more homogeneous and biologically inactive, with its colour changing from dark brown to black and the texture becoming like soil (FAO, n.d.).

Biogas Treatment

Water scrubbing is a proven technology to filter out Carbon Dioxide from a stream of Biogas (UNIDO, 2017). Water is used as a scrubber to separate Carbon Dioxide by utilizing its comparatively higher value of solubility than Methane in Water. Beside Carbon Dioxide this unit will dissolve Ammonia and Hydrogen Sulfide as well.

In this gas flows from the bottom and water flows from the top of a packing material-filled tower. While getting in contact water dissolves the unwanted elements from the gas stream. The treated gas leaves through the top of the tower, while water moves out from the bottom. This water is sprayed into a reservoir, from which the water can be recirculated. Due to spraying, there is a pressure reduction which results in the gaseous element moving out from the water.

Removal of hydrogen Sulfide with Iron (III) Oxide has been widely popular since the nineteenth century due to its simplicity and low capital cost. This technology can effectively remove Hydrogen Sulfide up to 99.98%. Hydrogen Sulfide output concentrations can go as low as 1 ppm, from a level of 1,000 ppm in the feed gas stream (Laura and Jørgen, 2014).

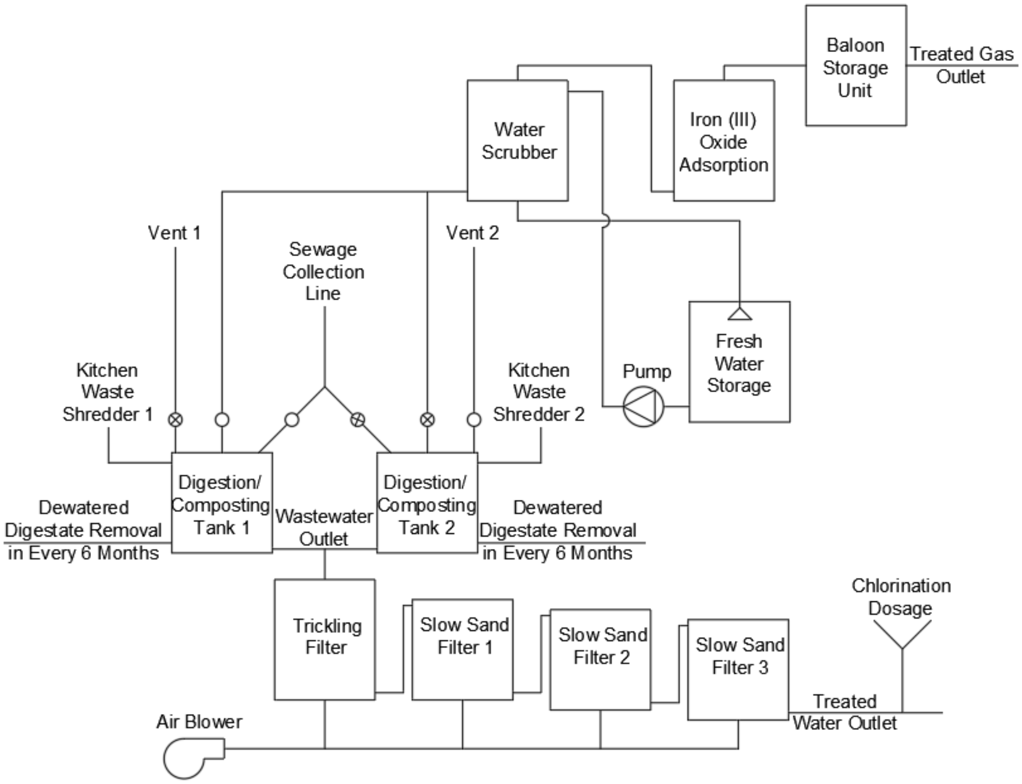

Figure 1: Schematic Diagram of Household Organic and Faecal Waste Management (Source: Author, 2023)

Economic Benefit as a Business Model

- CAPEX (Capital Expenditure) – The plant with a solid waste capacity of 40 kg per day and wastewater capacity of 4000 L per day can be purchased by the consumers at a rate of BDT 2,00,000 if large-scale production can be undertaken.
- OPEX (Operation and Maintenance Expenditure) – the operation cost will limit to BDT 10,000 in a year.
- Cost Saving by Replacing LPG with the treated Bio-Methane Gas – replacement of 275 kg LPG with approximately 350 m³ methane gas (from 590 m³ biogas) will result in an annual cost saving of BDT 32,000, considering the cost of a 12-kg LPG cylinder is BDT 1,400.
- Cost Saving by Eliminating the Need for Septic Tank Cleaning – this may generate a minimum annual cost saving of BDT 10,000.
- Cost Saving by Eliminating the Need for Garbage Collection Service – this may generate an annual cost saving of BDT 3,000.
- Income by Selling Fertilizer – with an annual production of 2,000 kg of organic fertilizer, this may generate an annual income of BDT 20,000 considering the rate of BDT 10 per kg.

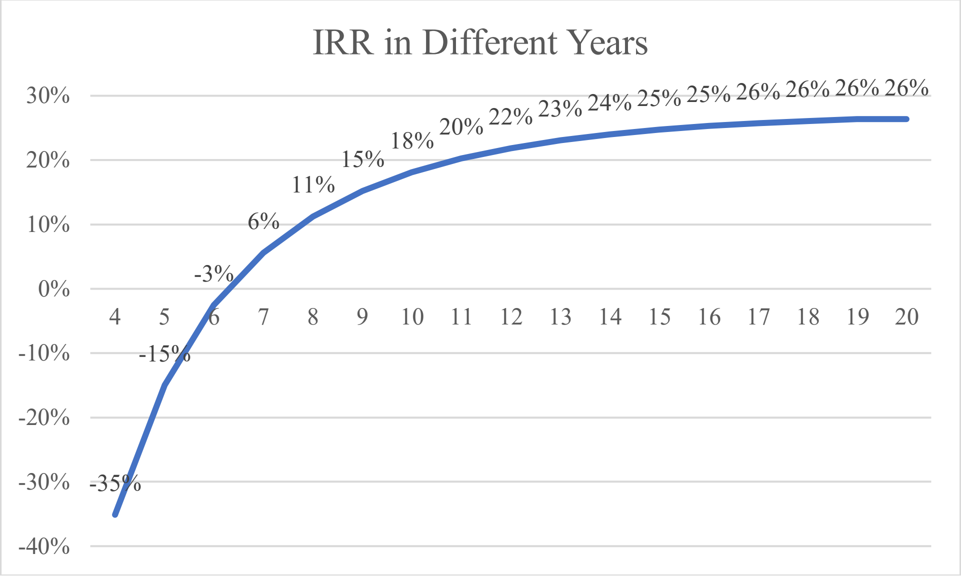

Figure 2: IRR of the proposed solution in different years (Source: Author, 2023)

This project will make breakeven in the fourth year and will have an internal rate of return (IRR) of 26% in 20 years. Hence, it can be considered a beneficial and attractive business model from both the seller and customer or user point of view.

CONCLUSION

With the rapid expansion of the housing and population in Dhaka city, the waste treatment measures are very meagre. There is an urgent need for an effective waste management model to safeguard the environment. This model can result in an annual greenhouse gas emission reduction of 6.32 tonnes, which can result in a social and environmental cost-benefit of BDT 27,000 (Golub et al., 2016) and prevent the pollution of at least 1.46 million litres of surface and groundwater in a year (Tymczyna et al., 2000). Hence, this can be developed as a highly efficient solution for Dhaka city’s waste management.

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