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Future-oriented Waste Management Technology for Ward-6, Bogura, Bangladesh – A Step Towards Sustainability

Abstract: Rapid urbanization combined with high economic growth, industrialization, and changes in socio-economic conditions increase the quantity of municipal solid waste. Cities located in South-Asia are facing serious issues due to waste, with countries like India, Bangladesh, and Pakistan top of the list of bad waste management. The increasing generation of solid waste and also the improper management of waste in Bangladesh leads to environmental degradation. Current waste management practice in Bangladesh is so weak that day by day it is harming the climate and creating a lot of unwanted situations. This research consists of an examination of the current administrative measures and presents another proposition for the executive cycle to decrease ecological contamination. The research study aims to decrease the amount of waste being dumped into municipal sanitary landfill sites & converting the waste into energy which is both financially and environmentally suitable by involving unemployed people in the management system. The results of this study will give an idea of how waste can be utilized as a resource and how this resource can be a capital good as well as how the local level problems can be solved by taking some strategies and making our environment suitable for future generations.

Keywords: sustainable, landfill, pyrolysis, hydrothermal liquefaction, gasification

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1. Introduction

Solid waste means any garbage, refuse, sludge from a wastewater or water treatment plant, or air pollution control facility and other discarded material, resulting from industrial, commercial, mining, and agricultural operations, and community activities [1]. There are various types of waste but essentially solid waste can be divided into three major types:

1) municipal waste,
2) industrial waste,
3) hazardous waste.

In this study, the focus is on municipal solid waste which includes food wastes, garbage, papers, cardboard, plastics, wood, glass, etc. [2]. Yet issues arise when there is mismanagement of municipal solid waste. Countries like Bangladesh are now developing the necessary actions to tackle waste both in the present and the future. Expanding waste age, a wasteful assortment and transportation framework, the elements of waste and climatic conditions should all be considered in solid waste management administration [3]. Here the focus is not only on managing the waste in a better way but also exploiting it so that it can become a resource. For sustainable waste management, equal focuses needed to be given to economic, social, and environmental sustainability for successful outcomes.

2. Study Area

Bogura District is located in the northern part of Bangladesh. The entire municipal area is about 69.25 km^2 [4] making it the largest municipal jurisdiction in Bangladesh; where the selected ward area is 0.71 km^2 [5]. The total population of Ward-6 is 13,794 [6]. The map of study area has been given in Figure 1

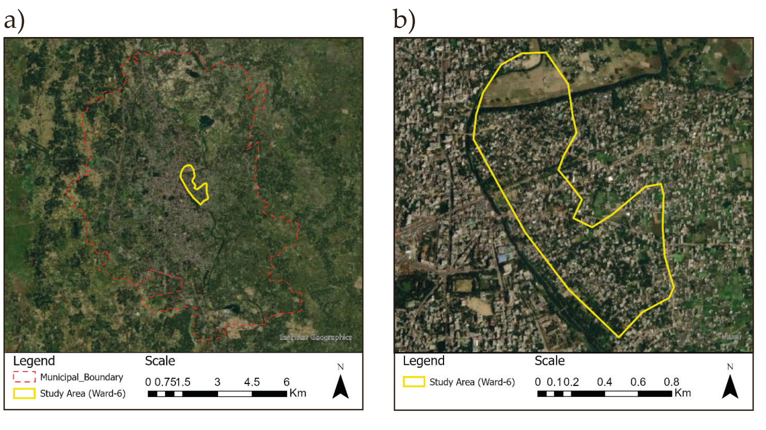

Fig. 1. Study area (a) and its close-up view (b) with municipal boundary

3. Methods and Materials

The article focuses on waste generation and the kind of waste produced within the study area. The initial hypothesis was "There would be enough waste to convert into a resource using thermodynamic processes". Firstly, to support the hypothesis, household surveys were conducted and secondary data related to municipal solid waste obtained. Secondly, to fulfill the aim of the study which is to create a more sustainable waste management practice, the existing situation was analyzed and many issues related to solid waste management were found. Thirdly, to design a modern facility, waste forecasting was conducted and then compared with the service level benchmark provided by the Bogura Municipal Corporation, revealing a gap between the two. Fourthly, as per planning norms and ethics, public participation in plan making is compulsory in Bangladesh and so a ward-wide public opinion survey was conducted to understand citizen perspectives on existing solid waste management practices to ensure that the proposed solid waste management would be both public-oriented and sustainable. Fifthly, in order to further enhance the research, the estimation of energy generation and associated earnings was made using assumptions that are largely focused on electricity, biogas and biofuel production. Lastly, based on the analyzed data, the detailed energy conversion process with costs (for late 2020) and sustainable benefits of the proposed management practice are also discussed.

4. Current Sources of Waste Generation and Existing Status

As per the location of the study area (Ward-6), it is mostly a residential area with a few commercial markets as well. The waste generation and current status data is given below in Tables 1 and 2. Therefore, the existing situation of the Ward-6 solid waste management is not found to be satisfactory based on the service level benchmark provided by the Bogura Municipal Corporation. As a result, many issues were found and which were confirmed by the citizens surveyed.

Table 1. Sources of waste generation

Serial no.	Source of waste	Generation [tons/day]
1.	domestic waste	6.32
2.	commercial waste	2.22
3.	markets	0.48
4.	street sweeping	0.2
5.	bio-medical waste	0.02
Total		**9.32**

Table 2. Current status of solid waste management in Ward-6

Serial no.	Parameters	Current status
1.	total door to door collection [%]	77
2.	total waste generation [tons/day]	9.32
3.	total waste collected [tons/day]	4.86
4.	total number of dustbins	none
5.	total capacity of dustbins [m^3]	none
6.	total number of collection vehicles	25 manual vans
7.	frequency of collection [trips/day]	1
8.	no. of street sweepers [no. of manpower]	4

4.1. Issues Related to Solid Waste Management

There are a lot of issues found in the primary observation and from the local resident's side as well. The main issues are:

a) "All the service-level indicators are poor, which indicates that the service delivery is not as per the benchmark."
b) "Many vehicles are unused as the condition of the vehicles handed over by concessionaire are not in good condition."
c) "Waste is not properly treated and dumped into landfills."
d) "Bogura Municipal Corporation is not collecting user charges properly which is responsible for lower revenue generation."
e) "Riverine communities are throwing their waste directly into the river which is a serious threat to the river ecosystem."
f) "The motivation and awareness of households to segregate waste needs to be increased. Incentives and recognitions can be introduced."
g) "No penalty system is practiced other than that for violating the plastic ban. No penalty or separate incentive is depending on the level of performance by wards."
h) "Currently, solid waste is dumped in the dumping ground and the river without any treatment, creating an environmental nuisance in nearby residential areas."
i) "There are no dustbins in the Ward-6 area. Therefore, the garbage is thrown on the streets and the drains, choking the drainage system and resulting in water logging problems, especially during the monsoon season."
j) "The number of covered vans for the collection and transportation of the solid waste is insufficient. Uncovered Tri-cycle vans with bins are mostly used for carrying solid waste, spilling it onto the roads while moving."

Some of the visual representations of the existing situation are given in Figure 2.

Fig. 2. Visual representation of existing solid waste management

5. Waste Generation Forecasting and Service Level Benchmarking

Waste generation forecasting has been done based on the projected population in 5-year intervals. The waste generation trends has been given below in Table 3.

Table 3. Waste generation trends [tons/day]

	Year					
	2011	2015	2019	2024	2028	2032
Population	13 994	15 624	17 161	19 517	22 313	24 401
Generation	6.32	6.88	7.56	8.27	9.83	10.75

Based on the primary survey and waste generation projection. The service level benchmarking of the existing system has been done as per the guidelines of the Solid Waste Management Plan of Bangladesh, 2016. It gives a better idea of how policy-makers want things to be done and what is the scenario on the ground for that study area. The service level benchmarking is shown in Table 4.

Table 4. Service Level Benchmarks – SWM

Serial no.	Indicators	Output [%]	SWM benchmark [%]
1.	household-level coverage of SWM service	77	100
2.	the efficiency of collection of MSW [t/d] (generated = 6.32 t/d; collected = 4.86 t/d)	80	100
3.	the extent of segregation	0	100

Table 4. cont

Serial no.	Indicators	Output [%]	SWM benchmark [%]
4.	the extent of MSW recovered	0	70
5.	the extent of scientific disposal of MSW	0	100
6.	the extent of cost recovery in SWM service	70	90
7.	efficiency in the redressal of customer complaints	47	80
8.	efficiency in the collection of SWM related user-related charges	65	90

SWM – solid waste management, MSW – municipal solid waste.

Source: [7]

6. Public Opinion and Existing and Proposed Management Practice

A public opinion survey was conducted to get a better view of the situation where the sample size is 5% of the total number of households. Due to the COVID-19 pandemic, the sample is smaller than the original aim of 10 to 15% of the households. In Figures 3 and 4 details are given.

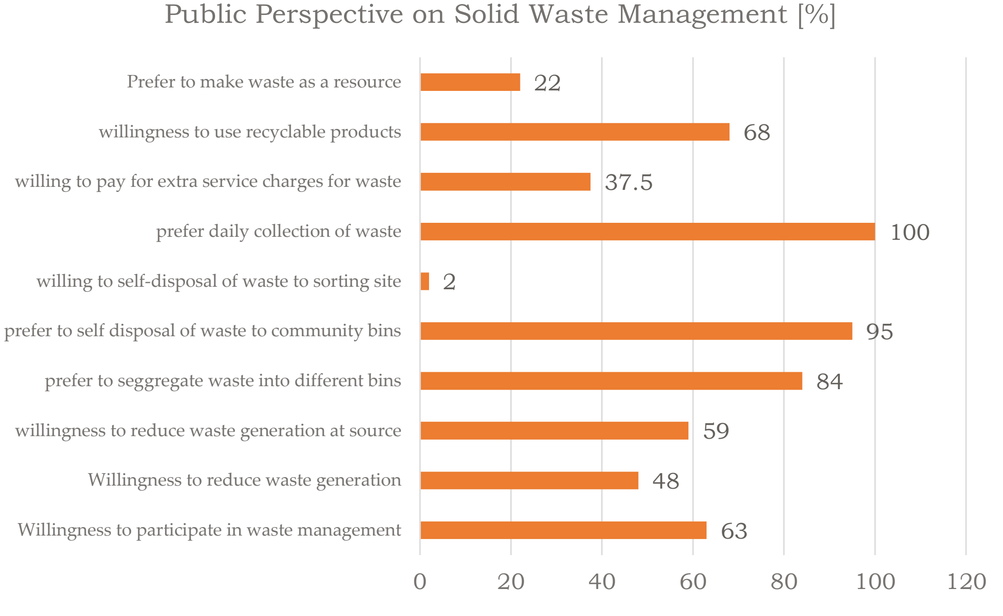

Fig. 3. Public opinion of existing SWM

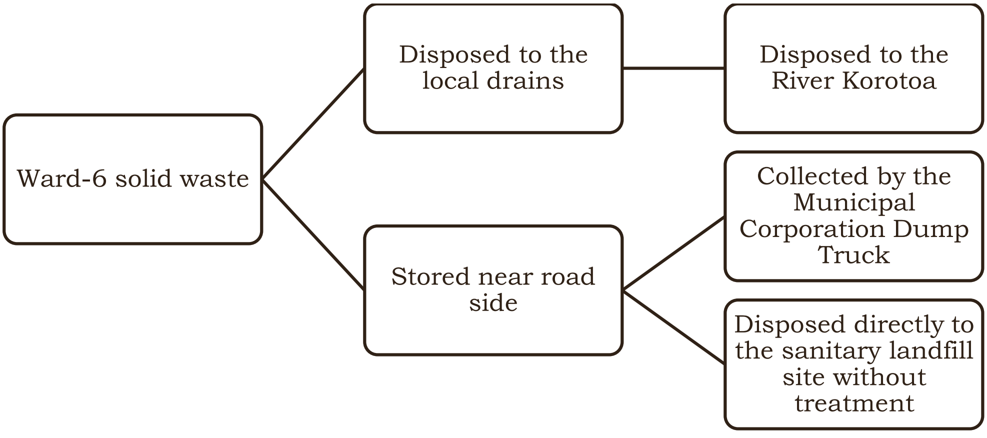

Fig. 4. Flow diagram of the existing management practice

From the above diagram, it is completely clear that the existing practice is not in accordance with the guidelines nor is it sustainable. The existing practice is very harmful to the environment, especially for the river environment near Ward-6. To alleviate this situation, the following management process has been proposed. The proposed solid waste management process is much better and more sustainable since it not only manages solid waste in a better way but also turns the waste into a resource that can meet the three pillars of sustainable development. The proposed solid waste management diagram is given in Figure 5.

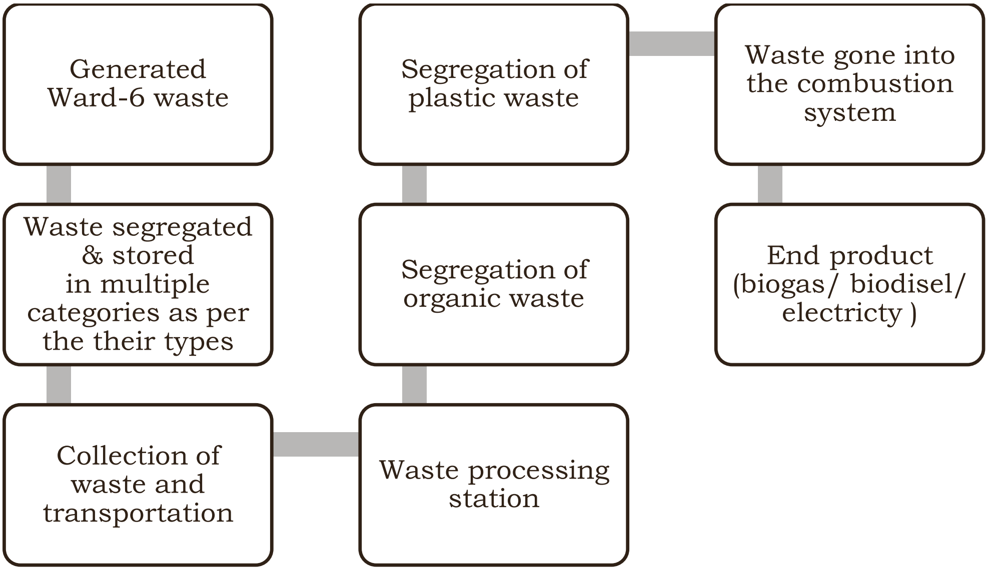

Fig. 5. Flow diagram of the proposed solid waste management

7. Waste to Energy Conversion Process and Sustainable Outcomes

The difference in waste converted into power can be recognized by the different cycles of energy conversion. The immediate burning of waste empowers the most noteworthy recuperation of energy content from the thermodynamic perspective. On the other hand, depending upon the association, the surges of the start cycle can be depicted by the presence of poisonous pollutants, for instance, HCl, HF, NO_x, SO_2, VOCs, PCDD/F, PCBs, and substantial metals [8].

The next stage is the biofuel process, which starts from the deconstruction of biomass. Creating biofuels (e.g., cellulosic ethanol and sustainable hydrocarbon powers) commonly includes a multistep cycle (Fig. 6). To begin with, the extreme unbending structure of the plant cell divider – which incorporates the natural particles cellulose, hemicellulose, and lignin bound firmly together – must be separated. This can be cultivated in one of two different ways: high-temperature deconstruction or low-temperature deconstruction [9].

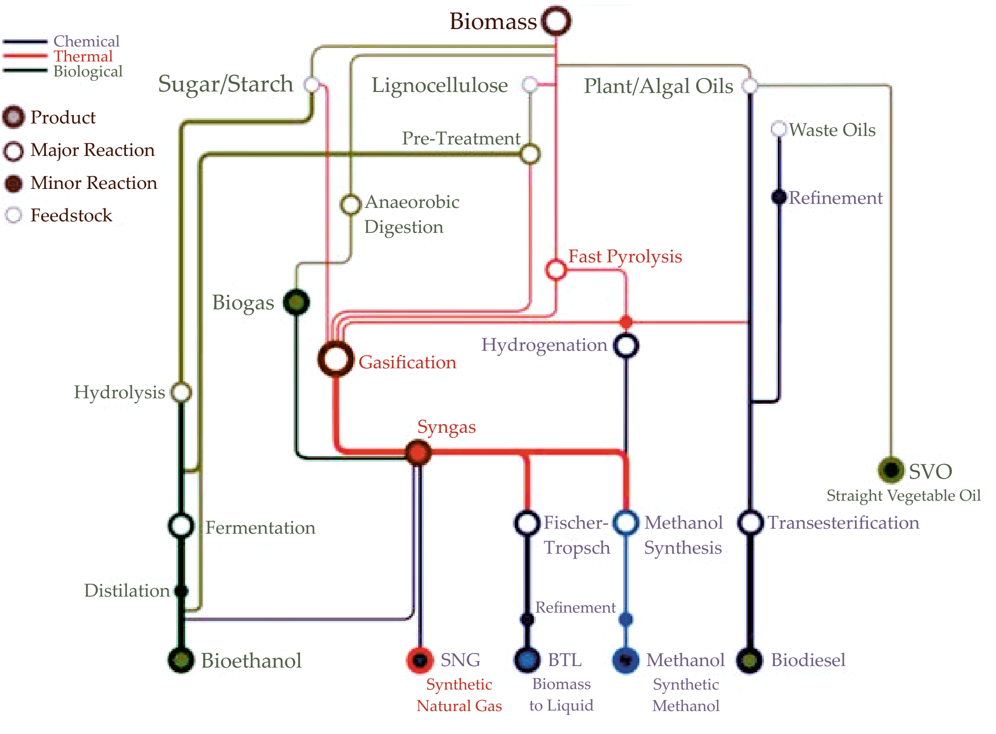

Fig. 6. Biofuel flow diagram

Source: [10]

In this study, a high-temperature deconstruction process has been considered, and three pathways were created:

1) pyrolysis,
2) gasification,
3) hydrothermal liquefaction.

During pyrolysis, biomass is warmed quickly to high temperatures (500–700°C) in an oxygen-free environment. The heat separates biomass into pyrolysis fumes and gas. When the burnt biomass is taken out, the fumes are cooled and condensed into a fluid "bio-unrefined" oil.

Gasification follows a comparative cycle; the biomass is treated in a higher temperature range (>700°C) with some oxygen present to create union gas (or syngas) – a combination that comprises carbon monoxide and hydrogen. Lastly, when working with wet feedstocks like green growth, aqueous liquefaction is the favored warm cycle. This cycle utilizes water under moderate temperatures (200–350°C) and raised weights to change the biomass into fluid bio petroleum [10].

The conversion results were calculated on the following basis:

– 35% of the end product can be achieved from 1 kg of organic waste.
– FROM 1 kg of plastic waste, it is possible to produce 750 mL of automotive-grade biodiesel [11].
– One cubic meter of biogas can generate 1.7 kW of electricity [12].
– The final desired end product could be selected from the said alternatives by the concerned authority as per their requirements.

By taking the amount of generated waste from Ward-6, the energy conversion has been calculated on a yearly basis. Waste to energy conversion with detail costing and earning are listed in Table 5 and 6 below.

Table 5. Waste to energy conversion (Ward-6)

Category	Available waste [kg/year]	End product	Generation
Plastic waste	52,706	biodiesel	39,529.5 L/year
Organic waste	452,600	biogas	249,600 m^3
		electricity	948.48 MW

Table 6. Costing and earning

Category	Production cost [USD/year]	Earnings [USD/year]
Biodiesel	10,723.69	30,307.11
Biogas	20,609.78	287,852.66
Compost	369,253.61	567,329.27
Electricity	61,510.81	78,180.31

The above estimates were made using the following assumptions:

- The dollar conversion rate has been taken on 30.09.2021.
- The cost does not include the operation and maintenance cost
- Per kilowatt electricity production cost is 0.065 USD.
- Per kilogram compost production cost is 0.22 USD.
- Per liter biodiesel production cost is 0.27 USD.
- Here all the production costs have been calculated using technology available in Bangladesh.

Sustainable benefits of the study are given below in Table 7.

Table 7. Sustainable benefits of the study

Environmental	Social	Economic
Reduces the amount of food and garden waste	Renewable substitute for petroleum diesel	Energy independence
Biodiesel lowers particulate matter by 47%, reduces hydrocarbon emissions by up to 67%, and reduces smog	Using biodiesel as a vehicle fuel increases energy security. Using biodiesel as a vehicle fuel increases energy security	Reducing electricity consumption from the public grid
Reduces harmful gases emissions from landfill sites	Biogas system improves sanitary conditions in the locality	Decreases the dependency on fossil fuels
–	Ragpickers can be involved in waste segregation which will give them a job opportunity	–

8. Conclusion

To promote sustainable development in urban areas, management of solid waste is a priority sector to be focused on. Waste has to be treated as a resource and we need to show how waste can be effectively converted into other valuable resources. There are many cities and towns which focus more on landfill sites but, landfill sites are a not sustainable solution and the worst practice used in waste management due to land loss and their impact on surrounding environmental conditions. One of the easiest and best ways to improve a waste management system is recycling and converting waste into resources and energy (e.g., by biogas production, biodiesel production from plastic waste and electricity production). The outcome or end product decisions will be in the hands of the local authority and so depending on the availability of technology, manpower, finance and need, they can easily select the best end product. In this study, the main focus is not only concentrated to waste conversion but also on proposing a new solid waste management practice by showing the scenario on the ground and the existing practice.

To sum up, the following issues have been discussed in the study:

– waste generation and current status,
– service level benchmarking of solid waste management,
– existing management practice,
– proposed management practice,
– waste to energy conversion with costing for the study area,
– sustainable benefits of waste conversion and proposed management practice.

References

[1] United States Environmental Protection Agency (EPA): *Criteria for the Definition of Solid Waste and Solid and Hazardous Waste Exclusions*. https://www.epa.gov/hw/criteria-definition-solid-waste-and-solid-and-hazardous-waste-exclusions#solidwaste [access: 27.12.2020].

[2] Mondol E.F., Hasan M.R., Rahman M.S., Alam S., Rahman S.A.: *Solid Waste Management Strategy & Improvement of Existing Scenario Based on Market Waste*. Global Journal of Researches in Engineering. Civil and Structural Engineering, vol. 13, iss. 4, 2013.

[3] Visvanathan P.C.: *Solid Waste Management in Asian Perspectives*. Asian Institute of Technology, Bangkok 2006.

[4] *Bogura District Action Plan*. District Administration of Bogura, Bogura 2019.

[5] Bhuiya M.B.A.: *Small Area Atlas Bangladesh*: *Bogura Zilla*. Bangladesh Bureau of Statistics (BBS), Dhaka 2017.

[6] *CENSUS of Bangladesh*. Bangladesh Bureau of Statistics (BBS), Dhaka 2011.

[7] Bogura Municipal Corporation: *Annual Municipal Solid Waste Report*. Ministry of Local Government, Bogura 2016.

[8] Electrigaz: *Organic municipal solid waste (OMSW)*. 2017. http://www.electrigaz.com/organicMSW_en.htm [access: 15.12.2020].

[9] Office of Energy Efficiency & Renewable Energy: *Biofuel Basics*. https://www.energy.gov/eere/bioenergy/biofuels-basics [access: 30.12.2020].

[10] Metso: *Sustainability. Enabling sustainable modern life*, https://www.mogroup.com/corporate/sustainability/?r=1 [access: 17.12.2020].

[11] Gao F.: *Pyrolysis of Waste Plastic into Fuels*. University of Canterbury, Canterbury 2010.

[12] Sacher N., Paclijan S.S., Gensch R., Spuhler D.: *Biogas Electricity (Small-scale)*. Sustainable Sanitation and Water Management Toolbox, 2019. https://sswm.info/sswm-solutions-bop-markets/affordable-wash-services-and-products/affordable-technologies-sanitation/biogas-electricity-%28small-scale%29 [access: 9.11.2020].