WASTE TO ENERGY OR BIO-FERTILIZER PRODUCTION: MUNICIPAL SOLID WASTE CHARACTERIZATION IN KHULNA CITY FOR ENGINEERED APPLICATIONS

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ABSTRACT

The research investigates the management of municipal solid waste (MSW) in Khulna City Corporation, Bangladesh, with a focus on waste components, the involvement of waste pickers, and suitable methods for waste-to-energy conversion. The study involves analyzing waste composition and characterization, waste picker roles, and evaluating incineration or composting as a potential waste management measure. The methodology includes field observations, waste analysis, and interviews. Findings reveal that approximately 84.20% of the waste generated is biodegradable, mainly comprising food and vegetable waste. The informal collection by waste pickers significantly influences waste characteristics and alters the composition of waste reaching the Rajbandh landfill. The involvement of waste pickers in resource recovery creates employment opportunities and conserves resources in resource-limited Bangladesh. Considering the high organic content and moisture in MSW and the minor amount of inorganic waste comprising of plastic, paper, cardboard, textile wastes and metals reaching the landfill due to recycling, the study suggests composting as a viable waste management solution. The research highlights the importance of comprehensive waste management strategies to effectively handle biodegradable waste, enhance collection methods, and address environmental issues.

Keywords: *Waste characterization, biodegradable, inorganic, composting, resource recovery*

1. INTRODUCTION

The current population of Bangladesh is 173,554,339 as of November 4, 2023, formulated on World meter elaboration of the latest United Nations data. On the basis of the prevailing population projections, Bangladesh's population will reach its peak in 2053 with a population of 192.78million *(Bangladesh Populati*on, 2024). Waste generation has also increased proportionately along with the growth of population (Mallick, 2017). Waste is an unavoidable product of human activities and this calls for proper waste management practices at public and private initiatives. Inadequate financial resources, inappropriate choice of technology, incompetent manpower and poor institutional structure are the major constraints of waste management in Bangladesh (Abedin & Jahiruddin, 2015; Ahsan et al., 2009; Sujauddin et al., 2008). Additionally, lack of awareness, deficiency in critical thinking, ineffective collection methods and absence of regulation are deteriorating the situation (Malmberg & Olofsson, 2016). The condition is further aggravated by the disposal of wastes in undesignated places and open-air dumping (Abedin & Jahiruddin, 2015). The administration of waste management in Khulna City falls under the jurisdiction of the Khulna City Corporation (KCC). Within the urban confines of Khulna, the conservancy section, operating under the guidance of the Mayor of the Khulna City Corporation, is responsible for the implementation of municipal waste management practices. The disposal of municipal solid waste is facilitated through the concerted efforts of residents, Community-Based Organizations (CBOs), and Non-Government Organizations (NGOs) employing door-to-door waste collection methods, with designated deposition points including roadsides, community bins, container locations, and secondary disposal sites. It is noteworthy that the personnel affiliated with KCC typically abstain from directly gathering municipal waste from various origins such as households, streets, institutions, and markets. Instead, their focus is directed towards the collection of waste from designated community bins or secondary disposal points. Subsequently, the waste undergoes transportation to Rajbandh, situated 10 kilometers west of the city headquarters, which serves as the final disposal site. It is estimated that at present about 490 to 510 metric tons of household solid wastes are generated per day in Khulna City areas with a per capita of nearly 0.3 to 0.5 Kg/day (Hossain et al., 2008). Fortunately, Khulna City Corporation (KCC) is lately considering composting as a sustainable approach. A number of non- governmental organizations (NGOs) namely 'Prodipan', 'RUSTIC' etc., and community-based organizations (CBOs) have been actively participating in order to implement proper waste collection processes from sources. Furthermore, they have been promoting recycling programs and proper waste handling as they are considered to be an integral part of a solid waste management system. 8 functional departments and a conservancy department have been formed by KCC and 6 composting plants have been developed by three NGOs.

This research investigates into examining the attributes of municipal solid waste upon arrival at transfer stations and landfills. It aims to analyse the impact of waste pickers/recyclers on altering the waste characteristics. Furthermore, the study intends to determine the most suitable waste management method—whether incineration or composting—for handling this specific waste stream in Khulna City Corporation.

2. LITERATURE REVIEW

3. Existing condition of Khulna City Corporation

Khulna, situated in the southwestern region of Bangladesh near the Sundarbans, is recognized as the country's third-largest metropolitan area, industrial hub, and port city (Riyad & Farid, 2014). Covering an area of 45.65 square kilometers, Khulna hosts approximately 1.30 million residents, experiencing an annual population growth rate of about 5% (Riyad & Farid, 2014). With the establishment of Khulna as a City Corporation, comprising 31 wards across roughly 47 square kilometers, the population density stands at 67,994 individuals per square kilometer (Islam et al., 2019).

The escalation in solid waste generation aligns with the city's population growth, necessitating a proactive waste management approach. Khulna produces 450 tons of Municipal Solid Waste (MSW) daily, disposed of at the Rajbandh open dump site spanning approximately 20 acres (80937 m²) (Pangkaj et al., 2023). Waste management falls under the jurisdiction of the Khulna City Corporation (KCC), overseen by its conservancy department and eight functional departments dedicated to solid waste management, supervision (Islam & Moniruzzaman, 2019) [21].

Waste disposal involves a door-to-door collection system, where residents, community-based organizations (CBOs), and non-governmental organizations (NGOs) deposit waste at secondary disposal sites. The KCC subsequently transports these wastes to the final disposal sites located about 10 kilometers away from the main city at Rajbandh (Halim, 2021). Studies indicate that roughly 36.84% of generated waste remains uncollected (Riyad & Farid, 2014).. In partnership with the city authority and respective ward commissioners, a total of 22 NGOs and CBOs actively engage in MSW management across various wards of KCC.

Organizations such as PRISM Bangladesh, Prodipan, RUSTIC, World Vision, Muktir Alo, and Bangladesh Resource Improvement Center (BRIC), among others, play integral roles in managing MSW within Khulna.

4. METHODOLOGY

This research embraced a multifaceted methodology to thoroughly examine the existing scenario and recommend suitable actions. The study utilized a combination of quantitative and qualitative analyses to gain a comprehensive understanding of the current conditions. Initially, the characterization of municipal solid waste was conducted by visiting nine transfer stations situated in ward numbers 1, 2, 5, 9, 11, 16, 17, 21, and 24. Additionally, the waste reaching the Rajbandh landfill was also characterized. Focus group discussions and interviews were conducted with waste recyclers/pickers to gain insights into their contributions to resource recovery.

Figure 1: Characterization of Municipal Solid Waste in the Rajbandh landfill

Figure 1: Trucks at KCC used to transfer waste from transfer station to landfill

Information on the total daily municipal solid waste generated by Khulna City Corporation was gathered from the city corporation office and its official website. The tonnage of Municipal Solid Waste deposited at the Rajbandh landfill, serving as the city's landfill, was obtained from the vehicular entry logs of the landfill site managed by Khulna City Corporation (KCC). On average, 105 garbage collection and disposal trucks transport the city's waste daily, with varying capacities ranging from one to twenty tons. Details regarding the trucks' specifications, numbers, and the accurate record of delivered tonnage were acquired from Khulna City Corporation's Mechanical Engineering Section and the landfill's data logs.

Figure 1: Map of Rajbandh Landfill

For waste characterization purposes, distinguishing between biodegradable components such as vegetables, fruits, and papers, and non-biodegradable materials like plastics and polyethylene, representative samples underwent manual sorting. This sorting process involved weighing each fraction to establish their respective proportions. The collected data underwent comprehensive analysis using a spreadsheet, providing mean and standard deviation values for each parameter determined.

5. RESULT AND DISCUSSIONS

6. Composition of the municipal solid waste

The daily average generation of municipal solid waste in Khulna City Corporation concluded in our study was 451 ton/day which matches with the study conducted previously. The transfer stations and in landfill in both cases the percentage of bio degradable waste content was considerable high, higher than 80%. Table 1 and 2 shows the composition and characterization of the municipal solid waste found in the transfer stations and in the Rajbandh landfill.

Table 1: Characterization of Municipal Solid Waste in transfer stations in KCC

Waste composition	MSW Composition (wt %)
Biodegradable Waste	81.25
Plastics	4.47
Paper & cardboard	6.61
Glass	0.69
Textiles & wood	1.20
Electric goods	0.28
Ceramic	1.14
Metals	0.33
Medical waste	0.21
Dust & others	3.55
Total	100

Table 2: Characterization of Municipal Solid Waste in Landfill

Waste composition	MSW Composition (wt %)
Biodegradable Waste	84.20
Plastics	2.99
Paper & cardboard	3.92
Glass	0.67
Textiles & wood	1.34
Electric goods	0.10
Ceramic	1.10
Metals	0.00
Medical waste	0.13
Dust & others	4.18
Total	100

Here we can see the change in the composition of waste finally reaching the landfill. To harness energy from waste, we have to deal with this final waste stream reaching the landfill which has high percentage of biodegradable waste which as a moisture content of 74.68% (Noman et al., 2023) . In addition the heat value biodegradable waste which includes food and vegetables is 957.13 KJ/Kg, dry weight (Worrell & Vesilind, 2011).

7. The role of Waste Pickers

In Bangladesh, there exists an informal resource recovery system that operates without acknowledgment from authorities, yet plays a pivotal role in the city's waste management. Unfortunately, this aspect is often overlooked, despite significantly influencing the characteristics of solid waste reaching disposal or conversion sites. Currently, policymakers base waste conversion decisions solely on generation rates, disregarding the impact of informal resource recovery on both waste volume and composition at Government-operated Municipal Receiving Stations (Khandaker et al., 2023). By studying the involvement of slum dwellers as waste scavengers in nine municipal wards of Khulna City Corporation, this research illuminates the movement and eventual reuse of materials. Drawing a clear picture of this process can aid policymakers in making informed decisions regarding resource allocation in waste management, especially in resource-limited yet developing economies

like Khulna in Bangladesh. We can clearly see the role of recyclers in changing the composition and characterization of MSW in table 1 and 2.

8. Waste to Energy through Incineration or Composting

For Khulna City Corporation (KCC) to thrive sustainably, achieving a socio-ecological balance is imperative. The organization faces several constraints primarily due to internal organizational issues. These limitations involve inadequate internal resources, a lack of professional expertise, and inefficiencies in planning and execution in waste management, potentially posing adverse environmental impacts (Jodder et al., 2022). Compared to other city corporations in Bangladesh, KCC's solid waste management efficiency remains subpar due to neglect in certain operational aspects, leading to systemic imbalances impacting the environment.

Developing comprehensive waste management strategies necessitates critical analysis of waste categorization data. This analysis is crucial for implementing effective measures to minimize waste, establish efficient recycling programs, and optimize costs and resources. Understanding the quantity and composition of municipal solid waste is vital for the municipality's planned solid waste-to-energy conversion facility. Such waste primarily originates from various human activities, with households contributing the majority (55–80%) in developing nations, followed by commercial sectors (10–30%) such as markets, institutions, and other entities, resulting in highly diverse compositions (Noman et al., 2023).

The composition of municipal waste in Bangladesh includes an array of materials like food waste, plastics, wood, metals, papers, rubber, leather, batteries, inert materials, textiles, paint containers, and more. The heterogeneity of these wastes presents challenges in efficient sorting and material utilization. Effective waste management strategies rely significantly on thorough sorting and characterization of these waste streams before any treatment procedures (Jeba & Rahman, 2022). Accurate information regarding the separated waste fractions' quality is crucial for potential utilization. Successful and reliable solid waste management strategies hinge on a comprehensive understanding of waste quantity and characteristics.

9. Incineration or Composting: More Viable measure for KCC

Waste to energy has become a very common way to handle huge streams of municipal solid waste. Incineration is a waste treatment technique that involves burning waste materials to produce energy (Mostakim et al., 2021). Materials suitable for this method encompass plastic, rubber, textiles, diesel engine scavenge scraping, food waste, hospital waste, and feminine hygiene products. The process entails burning waste within a temperature range of 900°C to 950°C, using a fuel gas primarily consisting of CO_2, CH_4, and H_2 (Ali et al., 2020). The energy generated at these high temperatures can be utilized as heat energy, subsequently transformed into electrical energy (Ali et al., 2020), (Tan et al., 2014). The primary aim of incineration is to decrease the weight and volume of waste by using oxygen and air to convert it into energy. Incineration has the potential to reduce approximately 90% of Municipal Solid Waste (MSW) volume (Rahman et al., 2020).

Composting is a natural biological process that involves the decomposition of organic materials such as food waste, vegetables other biodegradable substances. This process occurs under aerobic conditions. Microorganisms, including bacteria, fungi, and insects, break down the organic matter into a nutrient-rich material called compost. Composting requires oxygen, moisture, and the right carbon-to-nitrogen ratio to facilitate the breakdown of organic matter into stable humus-rich compost (Hassan et al., 2023).

In order to make an incineration plant viable, the typical heating value of waste input must range around 8-10.5 Mj/kg (Wilson et al., 2013), with moisture content ideally between 40-50% (Münster & Meibom, 2011). However, in Khulna, the mixed municipal solid waste reaching the landfill consists

of approximately 84.20% biodegradable waste and a high moisture content of 74.68%. To make the incineration plant feasible, it becomes necessary to maintain high heating value wastes like paper, cardboard, textile waste, and electrical goods within the waste stream. This selection would impact the informal recycling sector and the livelihoods of waste pickers. In a resource-constrained country, such as this, resource recovery holds significant importance.

Field observations indicate that non-biodegradable plastics, bags, and bottles are informally recycled manually, with retrieved materials transported to Chittagong for reprocessing and integration into the manufacturing supply chain. This informal process establishes a circular economy that operates independently of the Khulna city authority's design. Similar practices exist in other Bangladeshi cities, where informal scavenging at waste dumps supports local industries by providing raw materials. In summary, the study found that the largest fraction of the waste stream is organic and biodegradable. Consequently, composting emerges as a preferable choice compared to other waste-to-energy conversion processes. The Khulna City Corporation (KCC) has chosen composting as its waste management method, initiating a tender valued at around 76 crore BDT. This decision is supported by data indicating the waste's high organic content, with the biodegradable fraction constituting 84.2%. These findings resonate with earlier studies characterizing Municipal Solid Waste (MSW) in Bangladesh, especially in Khulna City. The evidence emphasizes the waste's substantial degradability, validating the rationale behind adopting composting as the primary waste management strategy for Khulna City.

10.CONCLUSIONS

The major findings of the study are as follows,

- Approximately 84.2% of the total waste volume generated, amounting to 379.74 tons per day, was found to be biodegradable out of 451 ton/day. This signifies a considerable opportunity for employing composting techniques as an effective waste management strategy as the moisture content of the MSW is 74.68%.

- This study highlights the role of recyclers and waste pickers in altering the composition of MSW from transfer stations to landfill.

- The study revealed an informal approach to waste collection, unbeknownst to the Khulna city authority. This unregulated collection significantly impacts the quantity of waste reaching landfills, emphasizing the urgent need for enhanced waste management protocols and regulatory oversight.

These findings collectively emphasize the necessity for adopting comprehensive and formalized waste management practices. This approach aims to address the biodegradable waste component, improve waste collection methods, and mitigate environmental concerns within the study area.

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