Muhammed Alamgir, S.M. Tariqul Islam, N.J. Pollen (Eds.)
ISBN: 978-984-35-7297-4

Full Paper of the WasteSafe 2025 – 9th International Conference on
Sustainable Solutions for Waste Management in Developing Countries
22-23 February 2025, Dhaka, Bangladesh

THE STATE OF MUNICIPAL SOLID WASTE MANAGEMENT IN KHULNA CITY: CURRENT CHALLENGES AND ENVIRONMENTAL IMPACTS.

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***Keywords**: municipal solid, greenhouse gases, biodegradable, waste management*

ABSTRACT

Urban areas in Bangladesh generate an estimated 4.86 million tons of waste each year, with projections indicating an increase to 17.2 million tons annually by 2025. The daily per capita waste production in 2019–2020 was 0.72 kg. In Khulna City, Bangladesh, approximately 1,000,000 kilograms of solid waste including 450 ton municipal solid waste are produced daily. In such a scenario, standardized management of this vast quantity of waste becomes essential. In Khulna, Bangladesh, the waste management sector grapples with various obstacles while also witnessing some initiatives for sustainable enhancements. The city produces approximately 1,000,000 kilograms of waste each day, with the majority being organic matter—roughly 78.9% is biodegradable food waste, and about 14.2% consists of recyclable materials. Nevertheless, insufficient waste sorting and a scarcity of recycling facilities result in a substantial dependence on landfills, which account for nearly 86.5% of waste disposal in standard scenarios. This conventional reliance on landfilling significantly contributes to the emission of greenhouse gases (GHGs) and other environmental risks in the area. The management process of waste often employs open dumping Process as a common method. This Review article examines different approaches to waste management, including open dumping systems, recycling methods, and a comparative analysis of the environmental and health impacts associated with these processes. This open dumping approach to disposal of waste in confined and unprotected areas, leading to several environmental and health issues. In near future, it is possible to create a cleaner and greener world by proper management of waste.

INTRODUCTION

Effective management of urban waste is essential for promoting sustainable growth and safeguarding public health in regular life. However, for a developing nation such as Bangladesh, the process of managing city waste is likely to be more challenging and open to scrutiny. Daily, Bangladesh produces an estimated 25,000 to 30,000 tons of municipal solid waste, with urban areas contributing a substantial portion.Khulna city, located in the southeast region of Bangladesh and ranking as the country's third-largest city, is responsible for a significant percentage of this municipal solid waste. With a population of 1.13 million and spanning 45 square kilometers, Khulna ranks as Bangladesh's third-largest metropolitan area, industrial center, and Sea port city.(Murtaza .G. 2002.)Based on existing data, the daily garbage production exceeds 250 tons, with the Khulna City Corporation (KCC) managing to collect and dispose of just 42% of the generated solid waste.(Salequzzamanet al.,2005).Among this vast amount of wastes approximately (55-80)% Municipal solid waste is generated by domestic uses while only (10-30)% of Municipal solid waste is generated by commercial areas and markets with the daily total waste generation of 1000000 kg per day (Nomanet al.,2023). According to various sources, 85.87% of municipal waste originates from households, 11.60% from business premises, 1.02% from factories, 0.55% from street cleaning, and 0.96% from others. Over a

ISBN: 978-984-35-7297-4

one hundred million tones of waste manufactured annually eighty million tones are either disposed of in landfills or left unattended urban sites (A. Ahsan et al.,2015).This variety and vast amount of municipal waste must be scientifically managed otherwise it will be threatening for human health by water contamination, spreading of diseases, Methane Emissions, Soil and Food Chain Contamination,Long-Term Chronic Effects and others.The environmental consequences of solid waste are substantial and pose serious threats to human well-being. The mismanagement of solid waste significantly impacts environmental factors and community health. This critical issue has been the subject of several research studies. Solid waste releases various harmful gases, including Sulfur Dioxide (SO_2), Nitrogen Oxides (NOx), Carbon Monoxide (CO), Respirable Suspended Particulate Matter (RSPM), and Suspended Particulate Matter (SPM). Elevated levels of particulate matter can result in both short-term and long-term respiratory issues, as well as damage to human lungs. (Prakash & Kumar, 2020).On the other hand Excessive levels of chemical or physical substances in water that can harm living organisms are considered water pollutants. Common chemical hazards include copper, manganese, lead, cadmium, phosphate, and nitrate. The direct release of untreated waste into aquatic ecosystems leads to the buildup of toxic substances in the food chain, affecting the flora and fauna that rely on these water bodies for their existence. (Prakash & Kumar, 2020).Besides that,The degradation of land stems from complex interactions between biophysical and socio-economic factors, particularly in arid regions. Human activities and climatic influences such as drought, excessive grazing, unsustainable land ownership, and economic pricing failures contribute to this issue. Desertification, defined as land degradation in arid and semi-arid areas, occurs due to these factors. The loss of vegetation accelerates soil erosion and reduces soil fertility, resulting in decreased land productivity. This process is often considered a human-induced problem that depletes soil nutrients and biological productivity. (Glover et al,2013).Changing rainfall patterns increase the likelihood of extreme weather events, such as extended droughts and hurricanes, which can damage infrastructure and complicate solid waste management. (Gichamo T &Gökçekuş H,2019).Climate change-induced temperature variations are increasing average and maximum temperatures, as well as the frequency of heat waves. Higher temperatures accelerate waste decomposition, impacting worker health and waste management infrastructure. (Gichamo T &Gökçekuş H,2019).Elevated sea levels and stronger storm surges increase the flooding risk for low-lying coastal waste management sites, intensifying erosion and the potential for seawater intrusion into landfills. (Gichamo T & Gökçekuş H,2019).The 2006 IPCC guidelines outline that solid waste management includes disposal, incineration, wastewater treatment, and biological treatment. Methane, produced from the anaerobic decomposition of organic waste, drives greenhouse gas emissions, which depend on the organic content in waste. (Gichamo T & Gökçekuş H,2019).Furthermore, Improper handling of solid waste poses potential risks to both the environment and public health. Direct health risks primarily affect workers in this field, who must be protected from contact with hazardous waste. Specific dangers are associated with handling medical waste from healthcare facilities. For the general public, the main health risks are indirect and arise from the proliferation of disease vectors, particularly flies and rats. Moreover, the uncontrolled mixing of hazardous industrial waste with municipal waste presents significant threats to human health. (Alam& Ahamde,2013).Accumulation of domestic waste that remains uncollected poses a great health risk for the entire city as it leads to drainage system blockage and contamination of water bodies. This is very acute during the rainy season especially in the congested unplanned neighborhoods where roads are very narrow, and waste collection trucks cannot access (World Bank 2000).There are still some lack of knowledge and application of modern waste management system of Authority and manpower though it had improved from past few years.In advanced nations, contemporary waste handling systems are engineered to reduce environmental consequences, enhance resource reclamation, and safeguard public well-being. These systems encompass ten primary components: Source-based Waste Separation, Pickup and Conveyance, Material Reuse and Recovery, Biological Waste Processing and Composting, Power Generation from Waste, Disposal Site Administration, Regulatory Frameworks and Guidelines, Community Education and Involvement, Cutting-edge Technological Advancements, and Worldwide and Regional Collaborative Efforts.

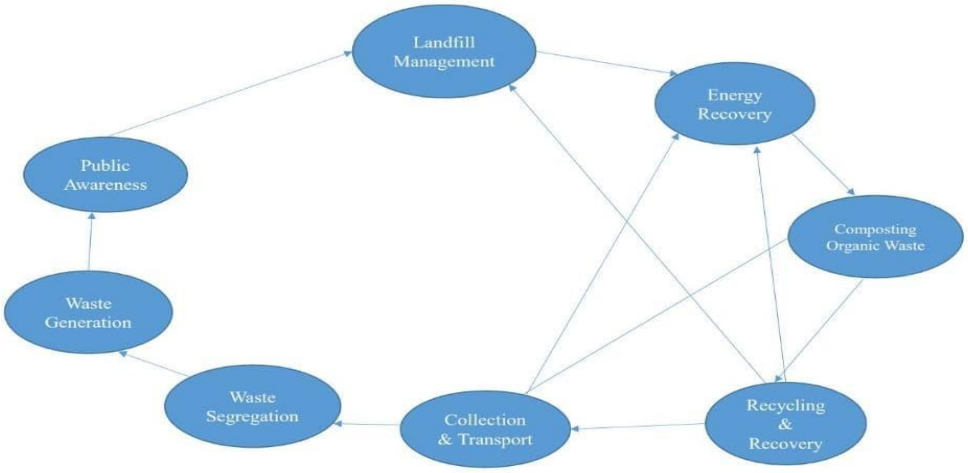

Figure 1 Flowchart of Modern Waste Management System

Selecting, implementing, and utilizing contemporary waste management practices in developing nations has become a contentious issue due to numerous societal and structural obstacles. The ecological footprint serves as a useful metric in this context, primarily quantifying the natural resources consumed by an individual, group, or activity in relation to the Earth's regenerative capacity. This indicator illustrates the land, water, and other resource requirements necessary to sustain a particular lifestyle or activity, encompassing aspects such as food consumption, energy usage, and waste handling (Salequzzamanet al.,2005).Typically, Khulna City Corporation (KCC) staff are not responsible for collecting municipal waste from various sources like homes, streets, institutions, or markets. Instead, this task is primarily carried out by third-party individuals or occasionally NGOs, who gather waste door-to-door and deposit it in designated bins provided by the city corporation. Subsequently, KCC workers collect these accumulated wastes by collection truck and transport them to Rajbandh, the final disposal site located 10 km west of the city center(Nomanet al.,2023).According to Rajbandh employees, between 70 to 100 trucks of waste are received daily from the entire Khulna City. This summarizes the Traditional waste management process in Khulna City. Effective waste management and sustainable practices rely heavily on the segregation of waste at its source. This is particularly crucial for recycling efforts. Furthermore, it primarily encourages the classification of waste into several categories, including flammable, biodegradable, non-biodegradable, and miscellaneous materials. Such categorization plays a significant role in reducing the adverse effects on the environment.By this separation of waste, the collection, transportation, and processing of these materials become more streamlined and economical. (Nomanet al.,2023).To develop an effective municipal solid waste management plan in line with the Sustainable Development Goals (SDG), multiple studies have been conducted examining the quantity and characteristics of household waste in Khulna City. Noman's research established a robust link between waste production rates and income levels (r =0.997) using survey data from Khulna City. The study examined MSW generation rates across various socioeconomic groups and the impact of weekdays versus weekends on waste characteristics and categories (Nomanet al.,2023).Alamgir and Ahsan examined the physical composition and daily waste generation in six major Bangladeshi cities: Dhaka, Khulna, Chittagong, Barisal, Sylhet, and Rajshahi. Their study involved collecting municipal solid waste samples from diverse sources, including residential, commercial, institutional, and open areas.(A. Ahsan et al.,2015). Shams' research introduced KCC's conventional wastemanagement approach and highlighted its shortcomings in reducing waste generation. The study also proposed potential solutions, such as Barrel Type Domestic Composition and Local Level Recycling (S. Shams et al.,2009). Islam's study provided an overview of Khulna city's current waste management system, focusing on the quantity of managed municipal solid waste, daily driven distance, and fuel consumption of collection and transportation vehicles (M. Islam et al.,2019).Moniruzzaman investigated the solid waste recycling practices in Khulna city, examining the quantity of recycled waste and its economic impact. The researcher also suggested a model to assess the potential for organizing informal waste recycling practices to enhance the efficiency of the existing recycling process (S.M. Moniruzzamanet al.,2022).Salequzzaman's research primarily concentrated on the Ecological Footprint of Waste

Generation for the KCC Area (0.088 hector per capita), including the composition of household wastes (Salequzzamanet al.,2005).Hossain explored the generation, characteristics, and disposal system of municipal solid waste in Khulna city. The researcher conducted a household survey to gather opinions and information about municipal waste management in the city. There is limited research in Khulna City that reveals the actual amount of waste generation by different socioeconomic groups (E. Hossain et al.,2017).Golder's study focused on the health issues of people working and living near dumpsites in Khulna City. The research identified various parameters affecting these individuals, including diseases, educational quality, poverty, gender, age, and other factors.(Golderet al.,2023).

METHODOLOGY

Selected Study Areas:
Khulna (22.8456° N, 89.5403° E) is Bangladesh's third largest city, in the south western part of the country, on Rupsa and Bhairab Rivers; it covers an area of 45.65 sq. Km (Area, Population and Literacy Rate by Paurashava, 2001) with population 7,18,735 (Population and Housing Census 2022 National Report, Volume 1, Bangladesh Bureau of Statistics). Through online and offline inquiries 12 different areas of Khulna (Fultala, Shiromoni, Fulbarigate, Khalishpur, Daulatpur, Boyra, Sonadanga , Nirala, Batiaghata, Dumuria, Tutpara, Rupsha) were selected for the study.

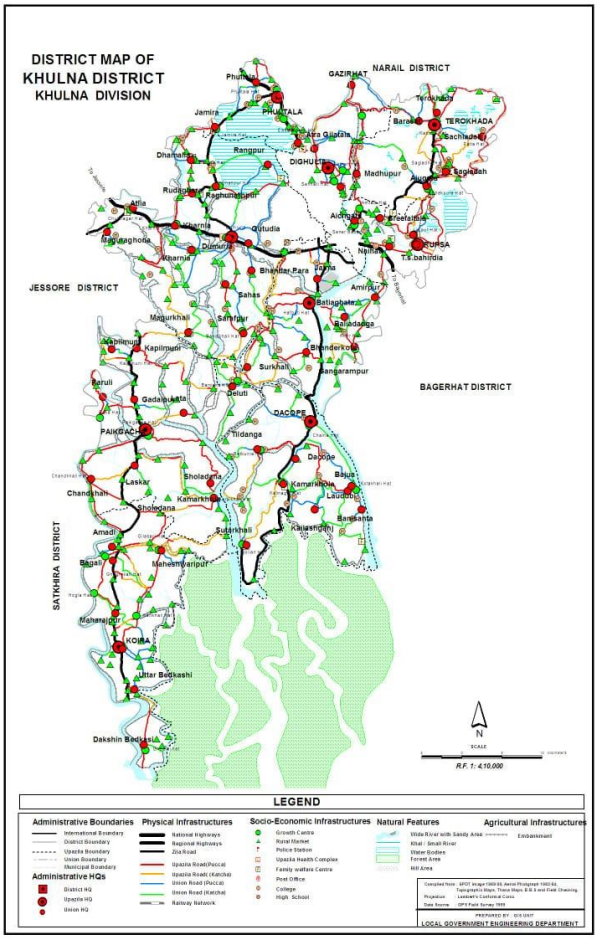

Figure 2 Map of Khulna City of Bangladesh

Key Informant Interview:
As an important and powerful tool of the research, key information review has been conducted with a view to gathering relevant information, opinions, suggestions of the respondence. Initially an extensive interview survey was conducted to find relevant information on different aspects of solid waste and its management in Khulna city. In this interview we have collected information from household respondents, employes of Khulna city corporation, the owner of the shop for reusable materials and the people who are directly involved in solid waste management in Khulna city. The respondents have been asked about the presence situation of solid waste management in Khulna city area, the root causes of poor waste situation, major problems and limitations in the waste

management system, the activity of KCC authority and their expectations in case of waste management. During this interview it was found that some respondents did not show interest to provide information about solid waste management.

Field Survey in Selected Areas:
We have conducted a reconnaissance survey in the selected 12 areas of Khulna city. It was difficult to gather information because the population varies from place to place, as does the economic status and waste type. We visited the selected area to observe the collection, transportation, disposal, and management processes of household, industrial, and commercial waste, as well as public opinions on these matters. We also visited dumping sites and recycling shops in certain areas. However, some shop owners were unwilling to provide data because they were concerned about potential increases in taxes.

RESULTS AND DISCUSSION

Solid Waste Generation in Khulna City:
Khulna, the third-largest city in Bangladesh, generates a substantial amount of solid waste due to its growing population and urbanization. The generation of solid waste in Khulna City, Bangladesh, has seen significant challenges and developments. Currently, the city produces approximately 300-600 tons of waste daily, with a per capita waste generation rate of around 0.33 kg per day. This rate is expected to increase annually by 1% due to population growth and urbanization. However, about 40-50% of the total waste remains uncollected, highlighting inefficiencies in waste management. Most of the collected waste ends up in open dumping sites or inadequately managed landfills, contributing to environmental degradation (JICA, 2023; Khulna University Studies, 2022).Studies show that food and vegetable waste make up the largest portion of the city's waste, followed by plastics, paper, and other materials. Socio-economic factors significantly influence waste generation rates, with middle- and high-income households producing more waste than low-income groups. For instance, average household waste generation rates range from 1.47 kg/day for low-income groups to 2.14 kg/day for middle-income groups, while per capita rates vary from 0.29 to 0.63 kg/day depending on income levels and wards within the city (Khulna University Studies, 2022). Efforts to improve waste management include initiatives like composting, recycling, and integrated landfill facilities. For example, the proposed Integrated Landfill and Resource Recovery Facility in Khulna aims to handle up to 375 tons of waste daily, with improved recycling and composting to reduce reliance on landfills and decrease greenhouse gas emissions (JICA, 2023).

Sources of Solid Waste in Khulna City:
The sources of solid waste in Khulna, Bangladesh, stem primarily from domestic, commercial, and institutional activities, with household waste being a significant contributor. Here's a breakdown of major sources:

Household Waste: The composition of waste encompasses organic materials from kitchens, plastics, paper products, glass items, textiles, and metallic objects. The amount of waste produced correlates with household income levels, with higher and middle-income families generating more waste than their lower-income counterparts (Muhammed Alamgir, Werner Bidlingmaier).An investigation into Khulna's solid waste management practices was conducted, focusing on the analysis and quantification of household municipal solid waste. The research offers valuable information regarding waste generation rates and composition across various income brackets (A.A. Noman et al.,2023).A study examines possible municipal waste management strategies for Khulna City, with an emphasis on treating waste as a valuable resource rather than simply disposing of it. The research discusses methods to enhance environmental outcomes through efficient waste management techniques (Reazul Ahsan et al.,2009)

Commercial and Market Waste: Commercial areas and markets generate waste that is primarily organic in nature, with vegetable and food waste making up about 79% of the total waste produced (Minhajur Rahman Khan,&Md. ShakilAr Salan,2024). A large portion of organic waste, including fruit and vegetable remnants, comes from markets, along with packaging materials such as plastics and cardboard. Non-biodegradable waste is also produced by small-scale businesses and shops (PankajKantiJodder).

Institutional Waste: Khulna City's industrial sector generates various types of waste, including solid, liquid, and hazardous materials from jute mills, tanneries, and fish processing facilities. The improper

ISBN: 978-984-35-7297-4

management of this waste leads to contamination of rivers, soil, and air, negatively impacting both ecosystems and human health. Additionally, institutions such as hospitals, schools, and offices contribute to the waste stream, producing paper, food, and medical refuse. Certain waste products, particularly those originating from healthcare facilities, require specialized handling procedures due to their hazardous nature (World Bank).

Open Dumping and Scavenging: Inadequate waste management systems lead to open dumping in drains, roadsides, and vacant lands, exacerbating environmental and public health risks (World Bank)

General Composition of Solid Waste in Khulna City:

Biodegradable Waste: Comprising 60–70% of total waste. Includes kitchen scraps, plant debris, and yard clippings. Generated by homes, marketplaces, eateries, and food manufacturers.

Plastic Refuse: Makes up 8–12% of waste. Consists of shopping bags, product wrappings, and various containers. Originates from residential areas, shopping districts, and manufacturing facilities.

Paper and Cardboard Materials: Account for 5–10% of waste. Encompasses periodicals, shipping boxes, and wrapping supplies. Produced by households, workplaces, and commercial entities.

Fabric Waste: Represents 2–4% of total waste. Includes garments, cloth remnants, and discarded textiles. Comes from homes and industrial settings.

Glass Items: Constitute 1–3% of waste. Comprises bottles, containers, and shattered glass pieces. Sourced from residences, businesses, and industrial sectors.

Metal Objects: Form 1–3% of waste. Includes food tins, kitchen implements, and miscellaneous metal products. Primarily from households and commercial zones.

Building and Demolition Debris: Makes up 2–5% of waste. Consists of masonry, cement, and construction remnants. (Source: Construction activities.)

E-Waste and Hazardous Waste: Percentage: 0.5–1%Examples: Batteries, electronics, and medical waste.Source: Households, healthcare facilities, and industries.

Other Inert Materials: Percentage: 3–5%Examples: Ash, dust, and ceramics.Source: Various.

Figure 3 Local Open Dumping Practice in Khulna City

The current state of solid waste management in Khulna City:

Collection and Management: In select areas, KCC has established door-to-door waste collection services, with gathered refuse being placed in nearby waste receptacles. Khulna generates roughly 300 tons of waste daily, but only 40-50% is collected. The uncollected waste is often discarded improperly, creating environmental and health risks. Non-governmental organizations handle waste collection for approximately 10% of households. (CDIA, JICA)

Figure 4 Collection and transportation vehicle.

Existing Infrastructure: Khulna City Corporation oversees three landfill locations (Rajbandh-1, Rajbandh-2, and Solua), but most rely on open dumping with minimal sorting. Initiatives like the City Region Development Project (CRDP-2) aim to establish integrated landfill and resource recovery facilities, focusing on increasing recycling and improving waste recovery management. (JICA,WORLD BANK) .To enhance waste management, the Second City Region Development Project (CRDP-2) proposes constructing an Integrated Landfill and Resource Recovery Facility. This facility is designed to process 40-50% of the 300 tons of waste collected daily, thereby improving waste handling and minimizing environmental impact. (Hossain et al., 2014)

ISBN: 978-984-35-7297-4

Figure 5,6 Final disposal of waste in Rajbandh

Recycling and Resource Recovery: In Khulna, approximately 7.2% (37.23 tons/day) of the total waste produced is recycled daily, representing 53.2% of the recyclable solid waste (RSW). The recycling of materials such as paper, glass, plastic, aluminum, iron, tin, bones, and tires is primarily managed by the private sector. It's worth noting that, with the exception of bones, paper, iron, plastic, and tires, the other recovered materials are sent to industries in Dhaka for additional processing. Khulna City grapples with several issues, including insufficient infrastructure, absence of official guidelines, and minimal public understanding of waste separation. Research suggests that to boost recycling and resource recovery efforts, it is crucial to legitimize the informal sector, upgrade waste collection methods, and encourage greater community involvement. The implementation of sustainable waste management strategies that incorporate both formal and informal sectors could lead to improved efficiency and better environmental results.(Moniruzzaman et al. 2011). Initiatives are in progress to enhance recycling efficiency, with a target of 32-40% by 2041. Planned facilities will concentrate on producing compost, generating biogas, and recycling plastic, along with implementing leachate treatment systems to reduce environmental effects. (JICA, WORLD BANK).

Figure 7 Collection of reuseable solid waste.

Collaboration and Regulatory Alignment: While NGOs and informal recyclers are vital to the current system, their efforts lack coordination. The city is working to establish a more organized approach by aligning with national regulations such as the Environment Conservation Act, 1995, and the Draft Solid Waste Management Rules, 2020 (CDIA, JICA).

Waste disposal method in Khulna city:
Khulna, a major Bangladeshi city, is transitioning from traditional waste disposal methods to more sustainable practices. The current waste management system includes:

Primary Waste Collection
Household Pickup: NGOs, community organizations, and municipal employees collect waste directly from residences.Neighborhood Receptacles: Residential and small commercial entities dispose of waste in strategically placed community containers.

Transportation: In Khulna City, solid waste disposal primarily involves transportation to the Rajbandh open dumping site. The city's waste management system is overseen by the Khulna City Corporation (KCC), which collects about 220 tons of waste daily, though only about 46% reaches the landfill. Collected waste is transported using rickshaw vans, carts, and small trucks to designated secondary transfer points or directly to landfill sites.

ISBN: 978-984-35-7297-4

Figure 8 Solid waste transportation vehicle.

Final Disposal Landfill: Waste is dumped in designated landfill sites. The primary site for Khulna city is the Rajbandh landfill, which operates as an open dumping site with minimal management. Waste at the Rajbandh site is leveled and compacted but lacks advanced landfill management features like soil covers or engineered liners, leading to environmental concerns such as groundwater contamination and unregulated informal recycling activities.

Figure 9 Landfilling process in Rajbandh.

Open Dumping: In some areas, waste is still dumped in open spaces, roadsides, and water bodies, leading to environmental and public health concerns. Open Burning of Solid Waste: Open burning of solid waste is a significant environmental and public health concern in Khulna City. This practice often arises due to inadequate waste management infrastructure, lack of awareness, and improper disposal habits. Residents and informal waste collectors burn mixed waste, including plastics, paper, organic matter, and hazardous materials, in open spaces, streets, or near residential areas.

Figure 10 Open burning of solid waste.

Recycling and Reuse: The city's waste composition is predominantly organic (79%), with compostable materials underutilized. Recycling rates are low, and over half of the waste remains uncollected, often ending up in open areas or waterways. Efforts by NGOs promote composting and limited recycling, but challenges persist due to resource constraints, public awareness gaps, and inadequate infrastructure (SUSTAINABLE ENVIRONMENT RESEARCH, DEVELOPMENT ASIA). Informal waste pickers recover recyclable materials like plastics, metals, and paper for resale. Some NGOs promote composting at the household or community level, focusing on organic waste.

Environmental Impact of Improper Solid Waste Management in Khulna City:

The inadequate management of solid waste in Khulna city has resulted in substantial environmental deterioration and health hazards. The city's ineffective waste handling system contributes to various negative consequences affecting air, water, soil, and public health.

Air Contamination: A primary environmental issue in Khulna is the open combustion of solid waste. This practice emits dangerous gases, such as carbon dioxide, methane, and particulate matter, which exacerbate air pollution and contribute to climate change (Islam et al., 2020). Moreover, the breakdown of organic waste produces unpleasant smells, diminishing the overall living conditions for nearby inhabitants (Hossain & Rahman, 2019).

Water Contamination: The pollution of water resources due to improper waste disposal is another crucial concern. Leachate, a toxic fluid generated by decomposing waste, frequently infiltrates groundwater or adjacent water bodies. This contamination presents a considerable risk to drinking water quality and aquatic life (Rahman et al., 2018). The release of untreated waste into rivers and canals, including the Bhairab River, has further intensified water pollution, endangering both human well-being and local fish populations (Ahmed et al., 2021).

Soil Pollution: Improper waste management also results in soil contamination, especially with hazardous materials like heavy metals and chemicals from electronic or industrial waste. These pollutants can decrease soil fertility and impede agricultural productivity in the neighboring regions (Rahman & Rahman, 2020). As time passes, these contaminants build up in the soil, rendering it unsuitable for cultivation.

Health Hazards: Improper waste disposal and accumulation in public spaces create breeding grounds for vectors like mosquitoes, flies, and rodents, which spread diseases such as malaria,

dengue, and cholera (Rahman et al., 2019). Additionally, informal waste pickers, often without protective gear, are at risk of exposure to hazardous materials, putting them at increased risk of illness (Hossain et al., 2020).

Aesthetic and Social Issues: The accumulation of waste in public spaces not only impacts the city's visual appeal but also contributes to urban blight. Blocked drainage systems, especially during monsoons, result in waterlogging, which worsens the situation (Ali et al., 2022). This waste mismanagement further strains the city's infrastructure, affecting daily life for residents. Contribution to Climate Change The decomposition of organic waste in landfills without proper management produces methane, a potent greenhouse gas that significantly contributes to climate change (Islam et al., 2020).

Comparison of Solid Waste Management: Khulna City vs. Developed Countries: Solid waste management (SWM) in Khulna, Bangladesh, significantly differs from practices in developed countries due to disparities in resources, infrastructure, and enforcement mechanisms. This comparison highlights key aspects of SWM in Khulna and developed nations.

Waste Generation and Segregation Khulna City: Waste segregation at the source is almost non-existent. Mixed waste, including organic, recyclable, and hazardous materials, dominates. Public awareness and enforcement of segregation practices are minimal (Alamgir & Ahsan, 2007). Developed Countries: Source segregation is highly prioritized. For example, Germany's strict recycling laws enforce household-level separation of waste, achieving a recycling rate of over 60% (BMUV, 2023).

Collection and Transportation Khulna City: Waste collection is irregular and largely reliant on informal workers. Manual handling and limited coverage mean that only 50–60% of waste is collected (Islam et al., 2020). Developed Countries: Mechanized systems ensure efficient and regular waste collection. For instance, in the United States, waste collection vehicles equipped with GPS optimize routes and improve collection efficiency (EPA, 2023).

Treatment of Organic Waste Khulna City: Organic waste, constituting a major portion of the waste stream, is typically disposed of in open dumps, leading to environmental hazards (Zia et al., 2015). Composting is minimal and limited to a few small-scale initiatives. Developed Countries: Composting is widespread. The Netherlands, for instance, processes a significant share of organic waste into compost or biogas, reducing landfill dependency (European Commission, 2023).

Recycling Khulna City: Recycling is informal, driven by waste pickers who recover materials like plastics and metals for resale. There is no formalized system or significant public participation (Rahman et al., 2019). Developed Countries: Recycling is an institutionalized process. Japan, with advanced recycling technologies, achieves recycling rates exceeding 80%, particularly for electronic waste (OECD, 2023).

Waste Disposal Khulna City: Open dumping is the primary method, as the city lacks engineered sanitary landfills. This causes environmental pollution, including water contamination and methane emissions (Ahsan et al., 2014). Developed Countries: Sanitary landfills are designed to minimize environmental harm. The U.S., for example, uses methane capture systems and leachate treatment in modern landfills (EPA, 2023).

Waste-to-Energy (WTE) Khulna City: There are no operational WTE facilities, and infrastructure for such technology is absent. Developed Countries: WTE technologies are prevalent. Sweden incinerates over 50% of its municipal waste to generate heat and electricity, reducing landfill use to less than 1% (AvfallSverige, 2023).

Policy and Regulation Khulna City: Policies exist but are poorly enforced due to limited institutional capacity and funding (Alamgir& Ahsan, 2007). Developed Countries: Comprehensive policies, such as the European Union's Waste Framework Directive, enforce stringent waste management standards, promoting a circular economy (European Parliament, 2023). Challenges of Solid Waste Management in Khulna City Khulna, one of Bangladesh's largest cities, faces significant challenges in solid waste management due to rapid urbanization, inadequate infrastructure, and environmental concerns. The following issues highlight the most critical obstacles in managing solid waste effectively.

Inefficient Waste Collection and Transportation
A significant portion of the waste generated in Khulna remains uncollected, primarily due to a lack of resources and poor operational efficiency. Irregular collection schedules often result in waste accumulation in public spaces, leading to environmental degradation (Islam & Huda, 2022).

Inadequate Infrastructure
The city suffers from insufficient waste bins, collection vehicles, and transfer stations. The Rajbandh landfill site operates as an open dumping ground without proper management, posing severe health and environmental risks (Zaman et al., 2020).

Lack of Source Segregation
Waste segregation practices are almost nonexistent in Khulna. Organic, recyclable, and hazardous wastes are mixed, reducing the potential for recycling and composting while increasing the environmental burden (Chowdhury & Roy, 2021).

Environmental Pollution
Improper waste disposal, such as open dumping and burning, significantly contributes to air, water, and soil pollution. Uncollected waste often clogs drainage systems, exacerbating flooding during the monsoon season (Dasgupta et al., 2021).

Limited Awareness and Community Engagement
Public awareness regarding waste management practices is low in Khulna. Informal settlements often resort to indiscriminate dumping due to the lack of access to proper disposal facilities, worsening the situation (Ahmed et al., 2019).

Resource Constraints
The Khulna City Corporation (KCC) faces financial and human resource limitations, which impede the adoption of modern waste management technologies. Dependence on outdated equipment further reduces efficiency (Haque et al., 2020).

Governance Challenges
Weak institutional coordination and ineffective policy enforcement hinder solid waste management. Collaboration between government agencies, NGOs, and private organizations remains insufficient (Rahman & Akter, 2023).

Table 1 Prices for reusable waste materials.

Serial No	Waste Item	Price (Tk)	Serial No	Waste Item	Price (Tk)
01	Plastic Bottle	35 /kg	05	Plastic Bag	3 / nos
02	Electronics	40 /kg	06	Cartons	10 /kg
03	Cement Bag	4 /nos	07	Papers	10-15 /kg
04	Jute Bag	9 /nos	08	Old Cloths	60-180/kg

Climate Change Impacts
Being a low-lying coastal city, Khulna is highly vulnerable to climate change impacts, including rising sea levels and flooding, which further complicate waste management (World Bank, 2021).

Strategies to Improve Solid Waste Management in Khulna City:

Improving solid waste management in Khulna City requires a multifaceted approach, incorporating policy reforms, infrastructure development, public awareness, and partnerships. Below are strategies backed by global practices and studies relevant to urban waste management.

Strengthening Waste Collection and Segregation
Implement Door-to-Door Collection: Regular collection reduces littering and ensures better hygiene (Hoornweg&Bhada-Tata, 2012). Encourage Waste Segregation at Source: Educating residents about separating waste into biodegradable, recyclable, and non-recyclable categories can enhance

recycling rates (World Bank, 2018).
Increase Collection Points:Placing labeled bins at strategic public locations makes disposal more convenient and organized (UNEP, 2020).

Developing Recycling and Composting Facilities
Establish Recycling Centers: Collaboration with private recyclers can foster the effective processing of materials like plastics and metals (Chowdhury, 2019). Promote Composting: Community-based composting initiatives can turn organic waste into valuable fertilizer, reducing landfill burden (Islam et al., 2016).

Expanding Infrastructure
Build Modern Landfills: Sanitary landfills with proper leachate management reduce environmental contamination (Zurbrugg et al., 2012). Introduce Waste Transfer Stations: These stations improve efficiency by streamlining waste transport from collection sites to disposal facilities (ADB, 2019).

Utilizing Technology
Smart Waste Monitoring: Using GPS and IoT-based systems can optimize waste collection routes and prevent overflowing bins (Singh et al., 2021). Mobile Apps for Citizen Engagement: Apps allowing residents to report uncollected waste encourage accountability and participation (UN-Habitat, 2020).

Promoting Public-Private Partnerships (PPP)
Partnerships with private firms enhance service delivery and introduce innovative practices in waste management (Asian Development Bank, 2019). Incentives for private waste management companies foster investment and efficiency (World Bank, 2018).

Enhancing Public Awareness and Participation
Campaigns on the 3Rs (Reduce, Reuse, Recycle) can foster behavioral change (UNEP, 2020).
School programs instill environmental responsibility in younger generations (Chowdhury, 2019).

Enforcing Policies and Regulations
Strict penalties for littering and illegal dumping discourage such behavior (Islam et al., 2016).
Compliance requirements for businesses ensure adherence to waste management policies (World Bank, 2018).

Reducing Waste Generation
Promoting reusable alternatives to plastic bags and containers minimizes single-use waste (UNEP, 2020). Zero-waste events and green practices can encourage eco-friendly urban living (Hoornweg &Bhada-Tata, 2012).

Adopting Circular Economy Practices
Waste-to-energy plants and upcycling businesses create economic value from waste materials (Singh et al., 2021). Local entrepreneurs can turn waste into products, contributing to sustainable development (Islam et al., 2016).

Partnering with NGOs and International Organizations
NGOs and international donors provide funding, training, and technology to strengthen municipal waste management systems (UN-Habitat, 2020).

CONCLUSION

The urgent necessity for sustainable practices and modern systems in Khulna City is underscored by the difficulties and consequences of managing municipal solid waste. Research indicates that current inefficient waste management methods, including open dumping, insufficient infrastructure, and a lack of waste separation, contribute significantly to environmental deterioration and health concerns. Tackling these issues requires a comprehensive strategy encompassing enhanced waste collection, sorting, recycling, and community involvement. Environmental impacts can be reduced by implementing sustainable techniques such as composting, waste-to-energy technologies, and constructing state-of-the-art landfills with leachate control. Crucial elements for ensuring systematic waste management practices in line with international standards include policy amendments, reinforced institutional structures, and collaborations between public and private sectors. Additionally, enhancing public awareness and involvement in waste management processes can encourage

enduring behavioral shifts and promote a cleaner urban setting. By implementing these strategies, Khulna City can effectively address its growing waste challenge and establish a model for sustainable urban growth, contributing to the broader Sustainable Development Goals (SDGs) of environmental sustainability and enhanced public health.

ACKNOWLEDGEMENT

Our team wishes to convey our heartfelt thanks to all individuals who played a role in completing this research on solid waste management in Khulna City. We are particularly indebted to the Khulna City Corporation (KCC) for supplying crucial data and insights regarding the current waste management situation in the city. Their assistance was vital in collecting precise and pertinent information. We extend our appreciation to Khulna City residents and key informant interview participants who shared their experiences and views on waste management practices. Their contributions significantly enhanced the study's findings. We owe special recognition to the Civil Engineering Department at Khulna University of Engineering & Technology (KUET) for their constant support, direction, and provision of resources that facilitated this research. Additionally, we recognize the input from non-governmental organizations (NGOs) and community-based groups actively involved in Khulna City's waste management. Their endeavors and perspectives offered essential context for comprehending the challenges and prospects in this field.

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