Characterization and Sustainable Management of Municipal Solid Waste in Khulna City, Bangladesh: Collection, Recycling, and Resource Recovery Perspectives

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ABSTRACT

In the twenty-first century, it is a global concern to ensure sustainability and environmental friendliness for effective solid waste recycling. The Khulna City Corporation's waste management framework and solid waste collection and recycling practices were examined in this study, which ran from July 2025 to February 2026. Because of its strategic industrial zone and proximity to the Mongla Port, Khulna is an important city in Bangladesh. In the Khulna city region, there are an estimated 785 tons of recyclable solid waste (RSW) available each day, of which 30 to 40 tons are actively processed and recycled. It was discovered that the city's main collection and recycling operations involved about 2,000 individuals, including feriwalas and tokais. There were 310 identified stores for reusable materials and 277 small-scale recycling businesses (dealers) in the Khulna municipality area. The majority of these stores were found in Shiromoni, Fulbarigate, Daulatpur, Khalishpur, Shekhpara, Sonadanga, Gollamari, and Lobonchora. Paper, plastic, glass, bones, and metals (iron, aluminium, and tin) are the main recovered materials. A large amount of these materials is transported to Dhaka, the capital city, for secondary processing and manufacturing into new products, while a small amount plastic is processed in nearby recycling facilities. A vital circular loop is created by the gathering and processing of waste or used materials, which results in the production and usage of recycled commodities. With significant financial, environmental, and social benefits for the city's growing population, this method guarantees Khulna's recycling industry's overall success.

Keywords: Secondary raw materials, Resource recovery, Municipal solid waste, Circular economy, Sustainable urbanism.

1. INTRODUCTION

Waste management is a major environmental problem in Bangladesh and around the world. Rapid urbanization, population growth, industrial development, and changing consumer habits have all contributed to a large increase in the creation of numerous waste categories, including green waste, solid trash, medical waste, industrial waste, and human waste. Because of its poor disposal methods and largely non-biodegradable nature, solid waste has become a major issue among these categories. Solid waste is the broad term for any trash produced by human and animal activities that is no longer usable. Domestic waste, commercial waste, building debris, industrial leftovers, organic waste, and electronic waste (e-waste) are a few examples of this [20, 34]. Although referred to as solid, this group does not include gaseous emissions or liquid sewage, but it may comprise semi-solid pollutants [34]. Serious environmental harm, such as soil contamination, water pollution, air pollution, and elevated greenhouse gas emissions, is caused by inadequate waste management systems. Sustainable solid waste management is becoming more and more difficult in both developed and developing nations worldwide. Approximately 56% of the world's solid trash is produced in developing nations [8]. Developed nations have high rates of individual trash generation, but poor nations have high rates of total waste generation (WGR) [1]. Waste issues are more severe in developing nations than in industrialized ones. In an inappropriate location, solid waste is nothing more than usable material [2]. Due to inadequate infrastructure, a lack of funding, lax policy enforcement, and low public awareness of trash segregation and recycling, these issues are much more severe in developing countries like Bangladesh. In addition to lowering the need for natural resources, effective waste management can generate new employment possibilities [14]. Uncontrolled solid waste disposal and open landfills pose major health dangers to the general public by spreading infectious diseases and creating hazardous living conditions. As a result, effective solid waste management is now crucial for maintaining public health, safeguarding the environment, and promoting sustainable urban growth on a national and international scale. In developed nations, recognized waste treatment techniques like composting, anaerobic degradation, incineration, pyrolysis, gasification, and recycling are used to adequately manage and dispose of the massive volume of solid waste generated every day. The leftover garbage is dumped in contemporary landfills [4]. Furthermore, they are always working to create innovative methods for recycling and recovering valuable resources from solid waste [14]. However, due to a lack of infrastructure, finance, and logistics, many cities in poor nations frequently have inadequate garbage collection systems, which result in unfavorable circumstances that endanger ecosystem integrity and human health as well as unlawful dumping and open burning. Urban sustainability, environmental quality, and human health are all seriously threatened by the increasing volume and complexity of waste. Inadequate waste management and disposal can lead to greenhouse gas emissions, the spread of disease-carrying insects and animals, pollution of the land, air and water, and deterioration of urban living conditions [31, 32]. As a result, efficient solid waste management is becoming a crucial component of global sustainable development. The difficulties experienced by rapidly expanding cities in developing nations are exemplified by Khulna City, the third-largest city in Bangladesh. Despite producing 1100 tons of waste per day, the city lacks sufficient information about the extent of material recovery operations, the social and economic circumstances of waste workers, and the involvement of the informal recycling sector in waste management. In order to develop data-driven policies that can integrate informal recyclers into official waste management systems, boost resource recovery, and promote environmental sustainability, it is critical to comprehend Khulna's current waste collecting and recycling methods. Thus, this study was carried out to investigate the solid waste collection and recycling practices in Khulna City Corporation, with an emphasis on determining the role of individuals employed in the unorganized sector, measuring the flows of recycled materials, and identifying strategies to enhance circular economy practices in Bangladeshi cities.

2. METHODOLOGY

A set of guiding concepts and procedures for analyzing and comprehending research issues in a specific field is known as methodology. A methodology, in contrast to an algorithm, offers a flexible framework for planning research, gathering data, and analyzing it that supports the choice and use of research methodologies. In order for readers to evaluate the study's validity and reliability, the methods section describes the procedures utilized for data collection, processing, and analysis. The informal sector, especially the urban poor, handles recycling and garbage reuse as a primary source of revenue in developing nations. In metropolitan settings with inadequate formal or centralized infrastructure, these decentralized waste management solutions frequently outperform centralized ones, enabling locals to work freely while assisting in resource recovery and service improvement.

2.1. Selection of study area

Khulna's precise city coordinates are frequently given as 22.8426° N and 89.5582° E (Figure 2a). The city is situated at 22.84° N latitude and 89.54° E longitude. It is located in southern Bangladesh, close to the Sundarbans delta and the Rupsha River, according to these coordinates. One of the largest, most significant, and oldest regions of southwest Bangladesh is Khulna. With 31 administrative wards and a population of 718,735 to 719,557, Khulna City Corporation occupies an area of around 45.65 km², situated on the Rupsha and Bhairab rivers in the southwest delta region, it is Bangladesh's third-largest metropolis.

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2.2. Questionnaire survey and data analysis

The Khulna City Corporation, primary garbage collectors, waste recycle stores, and waste recycle factories were the four main stakeholder groups involved in solid waste management that participated in the survey. People involved in the collection and recycling process, including Khulna City Corporation administration, waste collectors, business owners and employees, and recycling factories, were surveyed using a standardized questionnaire about the current recycling process. A set of questions was made to collect data from the stakeholders who were involved in recycling activities and solid waste collection in Khulna City. The questionnaire was prepared according to the focus of the study and included questions related to respondents' characteristics, waste collection practices, recyclable materials, recycling activities, employment, income, and the challenges associated with solid waste management and recycling. The question sheet was used by a field worker for collecting data. However, no formal statistical validation or separate psychometric validation procedure was conducted. Therefore, the findings of the questionnaire have been interpreted as descriptive evidence based on the surveyed respondents and field observations. The collected data were organized and summarized to identify the major patterns of solid waste collection and recycling activities in Khulna City. Quantitative information was presented using descriptive summaries, including percentages, and other relevant numerical descriptions where applicable. Information obtained from open-ended responses and field observations was interpreted in relation to the objectives of the study. A formal thematic analysis procedure was not conducted, but qualitative information was used to support the interpretation and discussion of the quantitative findings.

2.2.1. Primary waste collectors

This method involved two different kinds of garbage collectors. Locally referred to as "feriwala" and "waste pickers," they are house-to-house waste collectors. In the past, the waste pickers would gather trash from a variety of locations, including road dustbins, municipal bins, and streets. Primary garbage collectors, on the other hand, gathered recyclables from homes or trash cans and then sold them to different local waste recycling businesses.

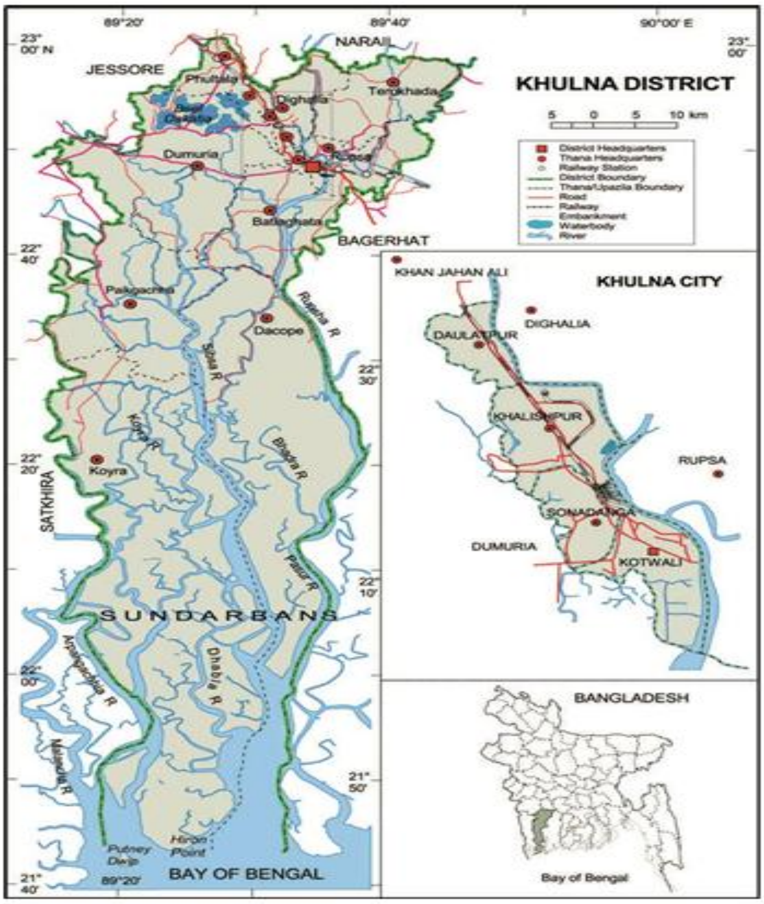

Figure 1. Geographic location of Khulna City Corporation area in Bangladesh [74]

2.2.2. Waste Recycling Shops

Khulna City waste recycling facilities were categorized according to the kinds of garbage they handled, their size, and the number of employees. Only a few sections of Khulna city like Shiromoni, Newmarket, Fulbarigate, Daulatpur, Khalishpur, Shekhpara, Sonadanga, Gollamari, and Lobonchora have stores and industry. Information about the amounts and kinds of waste handled, the number of employees, their pay, their working hours, and the collection procedure were all recorded in the questionnaire survey conducted in recycling shops.

2.2.3. Waste recycling Factories

In Khulna City, waste recycling facilities are an essential part of the circular economy. According to field surveys, there are about 35–40 formal and informal plastic recycling facilities operating in important locations like Daulatpur, Fulbarigate, Khalishpur, Sonadanga, and Shiromoni. Together, these facilities employ about 400–427 people and process an estimated 27.70 tons of plastic waste every day, or 7.2–7.65% of the city's total solid waste. High-demand polymers, such as PET (polyethylene terephthalate) from beverage containers, PE (polyethylene) packaging, and PP (polypropylene) items, are mostly handled by the factories. About 25–30% of processing materials are processed locally, and the remaining 70–75% are shipped to Dhaka for final manufacture. The industry gives low-income people a means of subsistence while producing a substantial amount of economic value, estimated at roughly BDT 15–20 million each month. However, there are a number of difficulties, such as restricted access to contemporary technology, erratic material supply, a lack of quality standards, and environmental issues from wastewater discharge, and little interaction with KCC's official waste management system.

2.2.4. Strategy of sampling and size

The study conducted a stakeholder-based sampling design to ensure a description of the four groups. They were directly involved in waste collection and recycling, i.e., Khulna City Corporation (KCC) personnel, primary waste collectors (including feriwalas and waste pickers), waste-recycling shops or dealers, and recycling factories. KCC personnel and recycling-facility operators were selected consciously because they possessed operational knowledge of collection, material handling, transportation, and processing. Primary collectors were approached across different areas of the city and selected to capture variation between feriwalas and waste pickers. Recycling shops were sampled purposively from the main activity clusters identified during the reconnaissance survey. Average daily waste generation was 1100 tons per day, but 900 tons per day were collected by Khulna City Corporation (KCC) personnel, primary collectors including feriwalas and waste pickers, recycling shops, and recycling factories.

2.3. Rate of Waste Generation

One of Bangladesh's largest cities, Khulna, has seen tremendous urban expansion and growing difficulties with municipal trash management. Under normal circumstances, the city produces between 700 to 800 tons of solid garbage each day, with daily creation increasing during peak times, according to current estimates. Depending on lifestyle and economic level, the city's daily trash generation rate per person has been estimated to be between 0.47 to 0.75 kg. In certain wards, for instance, household surveys revealed an average generation rate of roughly 0.476 kg/person/day, with higher rates in higher-income groups. There were around 719,557 people living in Khulna City Corporation as of the 2022 census (Wikipedia) [69]. Khulna City produces between 300 to 400 tons of solid trash per day, with organic (biodegradable) wastes making up the majority of the waste stream, according to published per capita generation rates. According to physical composition studies, food and kitchen trash make up the majority of Khulna's municipal solid waste, which is mostly organic in nature.

3. COLLECTION OF SOLID WASTE

Khulna City Corporation (KCC) uses both human and automated methods to collect solid trash in the city. Waste is delivered to disposal and treatment facilities after being gathered from homes, businesses, public trash cans, and streets. The average daily garbage generation, collection, transportation, and treatment facilities in Khulna

City are compiled in **Table 1**.

Table 1. Daily generation, collection, and management of different types of waste in Khulna City.

Type of Waste	Average Daily Waste Generation (Tons/days)	Average Daily Waste Collected (Tons/days)	Collection Method	Transport Vehicles	Disposal / Treatment Facility
Solid waste	785	636	Manual & mechanized	60 vans/trucks	Shalua, Rajbandh, Mathavanga landfills
Green waste	100	50	Manual & mechanized	6 vehicles	Composting (limited scale)
Medical waste	10	10	Manual & mechanized	6 private vehicles of 2 NGOs.	Controlled treatment (under process)
Polythene & plastic waste	4.5	3.5	Manual & mechanized	1 vehicle	Recycling shops & factories
E-waste	0.5	0.5	Manual & mechanized	1 vehicle	Informal recycling
Human waste	200	200	Mechanized	6 vehicles	Dedicated treatment plant
Total	1,100	900		80 pieces	

Source: KCC

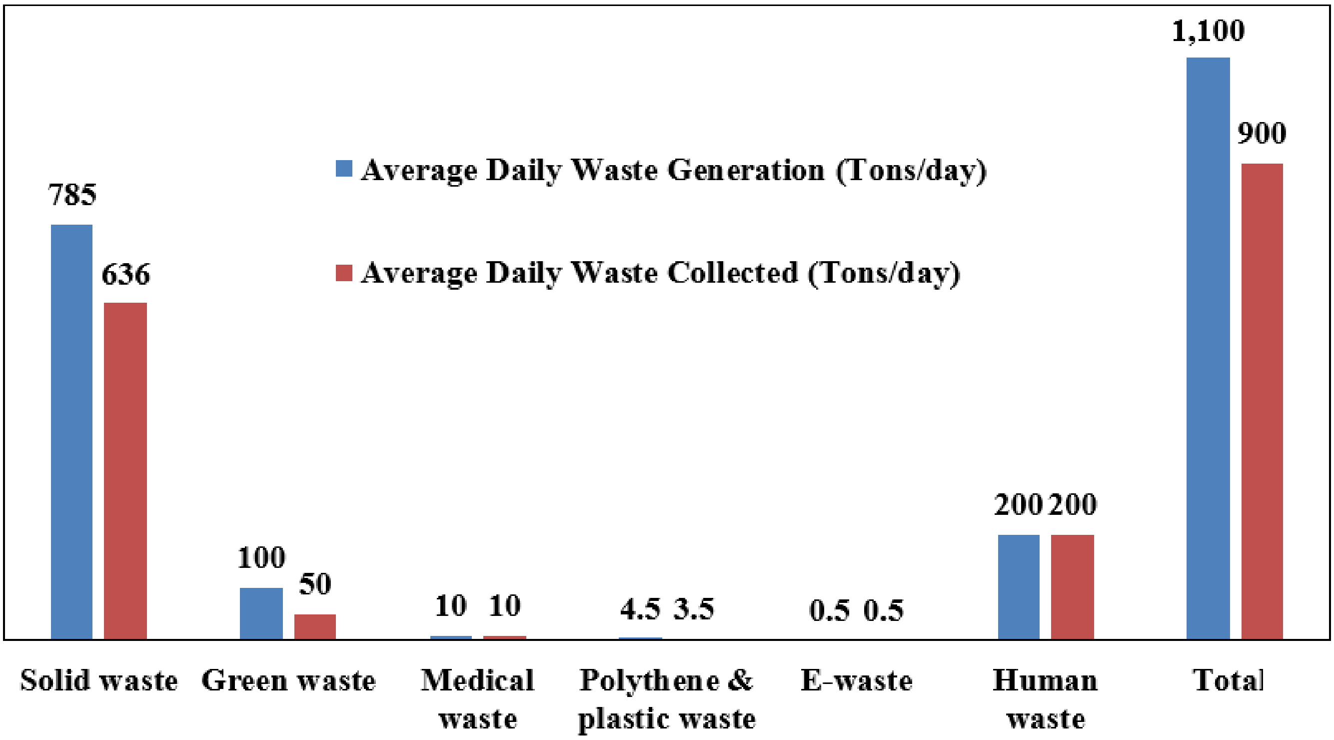

Figure 2. Average daily generation (tons/day) and collection (tons/day) of different types of waste in Khulna city.

4. RESULT AND DISCUSSION

4.1. Primary waste collectors

According to the field survey, feriwalas waste and pickers were mentioned as the principal primary collectors in the informal recycling chain. Waste pickers were searched, recovering recyclable materials from roadside and municipal bins, while feriwalas gathered recyclable materials directly from households and sold them to recycling shops. Table 3 describes the KCC workforce separately and does not interpret the sample size of informal primary collectors.

4.2. Waste recycling shops

Waste recycling stores serve as intermediaries between recycling facilities and primary collectors. Plastics, bottles, cardboard, paper, metals, glass, and other recyclable materials are all handled by these stores. There are numerous stores in some parts of Khulna City, which facilitates and improves collection and transportation. However, issues such a lack of storage space, fluctuating recyclable material market prices, and inadequate oversight can lessen its efficacy. The majority of recycling shops have poor pay, hazardous working conditions, and informal working circumstances.

4.3. Estimated of recycled waste

Recent empirical evaluations of trash flows and recycling shop operations were used to estimate the amount of recyclable solid waste managed through recycling activities in Khulna City. In Khulna City, recycling stores and unofficial collectors handle between 30 and 40 tons of recyclable material per day. The gross plastic inflow into recycling shops in the city was estimated to be around 27.70 tons per day based on data gathered from 35 recycling shops, most of which were located within and around the city boundary, according to a direct field survey of recycling shops carried out over a six-month study period. In addition to the 6.9 tons of non-recyclable plastic handled by the same, this translates to an observed total of 830.5 tons of recyclable plastic garbage processed each month. These recycling initiatives complement the Khulna City Corporation's official municipal waste management system, which only collects and processes a portion of the waste generated. All things considered, this estimate emphasizes how important recycling actors are in lowering the quantity of garbage transferred for final disposal and assisting in the recovery of valuable resources inside the city.

4.4. Estimation of recyclable solid waste

The data shown in Table 01, which includes recyclable components including paper and paper products, polythene and plastics, metal, glass, and ceramic materials, is used to estimate the potential recyclable solid waste in Khulna City. In terms of recycling, this information was crucial. Thus, the amount of recyclable solid trash in Khulna City was calculated using the 785 tons of rubbish generated every day.

4.5. Waste Quantification and Disposal Infrastructure in Khulna City Corporation

The municipal solid garbage generated in the Khulna City Corporation (KCC) area is handled by about 80 collection vehicles every day. KCC garbage pickers start the waste management process with primary collection. They next deliver the materials to nearby secondary transfer stations (Figure 4a), such as Moylapota, Shibbari, Boyra, etc. Waste is moved from these locations to three primary disposal sites: Mathavanga (24.70 acres), Rajbandh (22.00 acres), and Shalua (17.00 acres). Together, these locations offer 63.70 acres of land for the final disposal of solid garbage. 1635 workers with a variety of employment arrangements make up the workforce supporting these operations, as shown in Table 3. Permanent employees make 24,000 BDT a month, master roll workers make 21,650 BDT per month, and outsourced workers make 700 BDT per day (for a 22-day working month), every employee works a typical 6 to 8-hour workday according to KCC report. The current staff and infrastructure are crucial for keeping the city clean, but the significant reliance on large-scale landfilling indicates a pressing need for improved resource recovery techniques to prolong the life of the city's constrained disposal capacity.

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4.6. Plastic recycling factory

The majority of the waste that medium-sized and large stores collected was shipped to Dhaka, where sophisticated recycling and manufacturing facilities are concentrated, in order to produce various new materials [54]. Local factories processed very little garbage. The local factories or medium-sized and major retailers purchase the plastics and bottles from the small businesses. Therefore, presenting a thorough picture of plastic waste recycling in Khulna City in figure 4e to 4k requires an awareness of the operational characteristics of local plastic recycling factories. According to field survey, there are roughly 35 to 40 formal and informal plastic recycling stores or small recycling facilities in the Khulna City Corporation (KCC) area, according to current studies and research on trash management. Khalishpur, Sonadanga, Shiromoni, Fulbarigate, Daulatpur, Shekhpara, Gollamari, and Lobonchora are the primary locations of these factories. The Khalishpur and Sonadanga regions are home to the majority of the stores. The stores mostly deal with PET (bottles), PE (polyethylene), and PP (polypropylene), and the industry directly employs between 400 and 427 people. These private-sector stores, which handle between 7.2% and 7.65% of the city's total solid garbage, are primarily responsible for plastic recycling, despite KCC being the official entity in charge of waste management.

4.6.1. Processing of plastic wastes in local factories

The processing of plastic wastes involved several sequential steps to prepare the materials for reuse in factories (Figure 3) , firstly in sorting the plastic wastes were sorted based on their physical characteristics, such as hardness, color, and thickness, because different types of plastics were sent to different factories. (Figure 4k). Secondly in separation, unwanted materials like dust and other particles were removed during the separation process. (Figure 4m). Thirdly in cutting, the plastic wastes were cut into smaller pieces, usually between 6 mm and 12 mm, to make further processing easier. (Figure 4h). Fourthly washing, the small plastics pieces were washed with water and detergent to remove pollutants, impurities, toxins, dirt, filth, adulterants, foreign bodies, and poisons. (Figure 4g). Fifthly, in this case of drying washed plastic chips were dried under sunlight. In some cases, they were mixed with colors before drying. Finally, the dried plastic chips were packed and sent to Dhaka or local factories for the manufacture of new products. (Figure 4j)

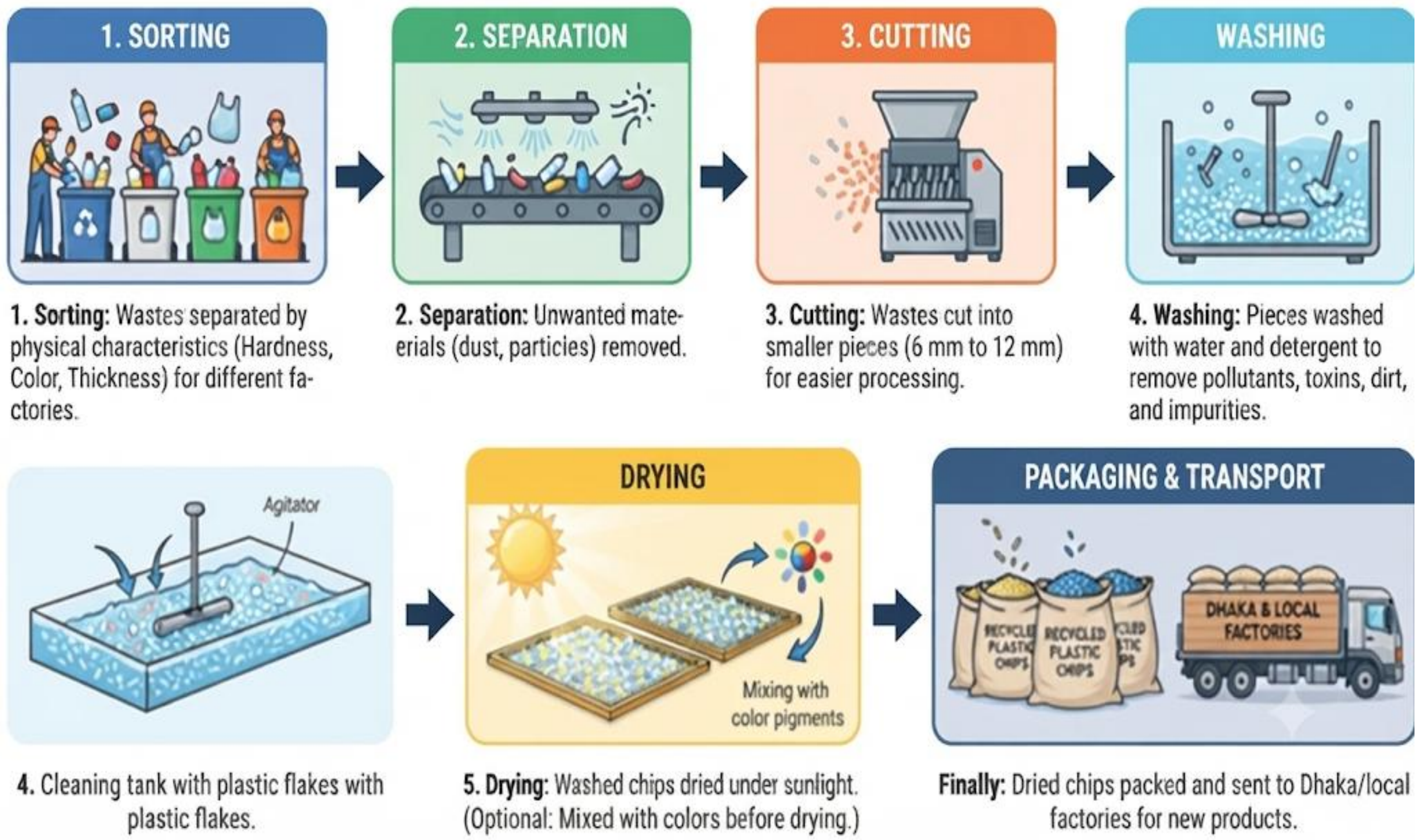

Figure 3. Sequential processing of plastic wastes for factory reuse.

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Figure 4. (a) Transportation waste by KCC, (b) Central waste bin of ward 16, (c) Central waste bin of KCC ward 22, (d) Central waste dropping spot of KCC.

Figure 4. (e) Sorted waste in waste factory, (f) Packaging after recycling, (g) Washing, (h) Cutting.

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Figure 4. (i) Packing after drying, (j) Drying, (k) Sorting in factory, (l) Separating unwanted things after washing.

Figure 4. (m) Solid waste collecting by waste picker, (n) Transporting recycled waste to Dhaka.

Table 02. List of regular, master roll, outsourcing and external worker in KCC waste management department.

Category		Regular	Master Roll	Outsourcing	External	Total
Conservancy department	Male	141	282	105	174	702
	Female	31	41	21	22	115
	Supervisors	19	19	0	4	42
	Dustmen	30	41	21	22	114
	Sewage	65	138	70	42	315
Van workers		26	69	35	20	150
Truck workers		26	36	0	76	138
Spray men		5	20	2	32	59
Total workers		**343**	**646**	**254**	**392**	**1635**

Source: Khulna City Corporation

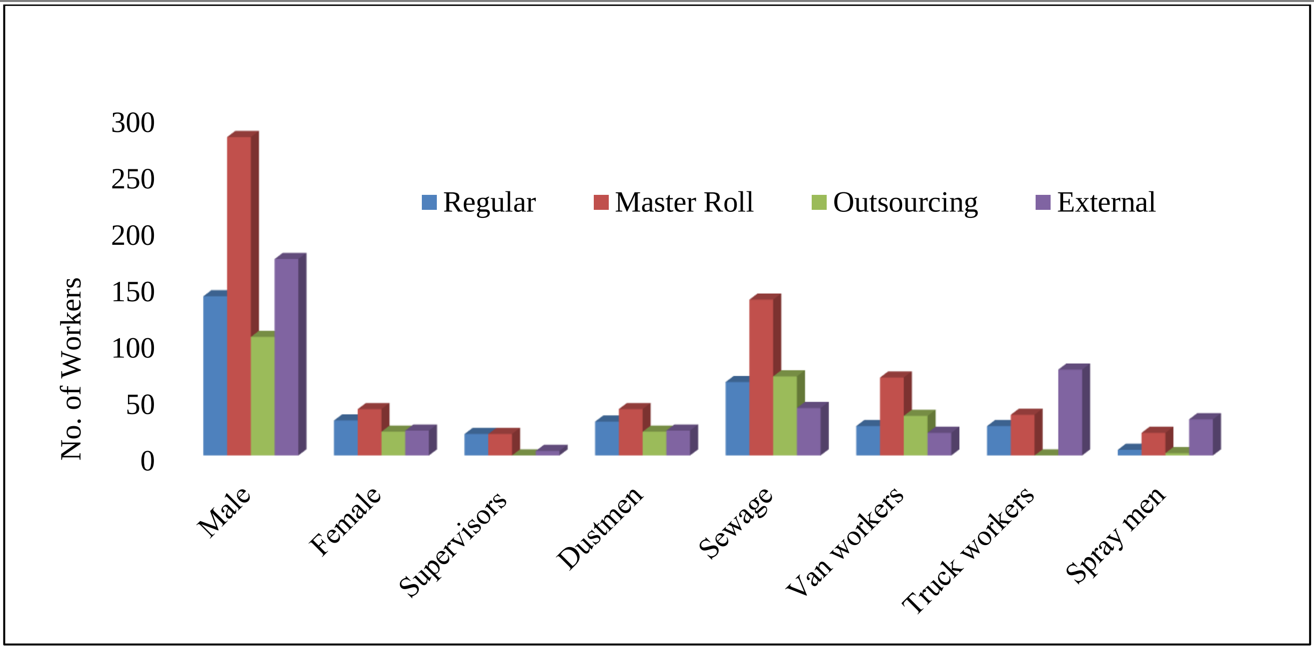

Figure 5. Bar diagram of worker & laborer in KCC waste management department.

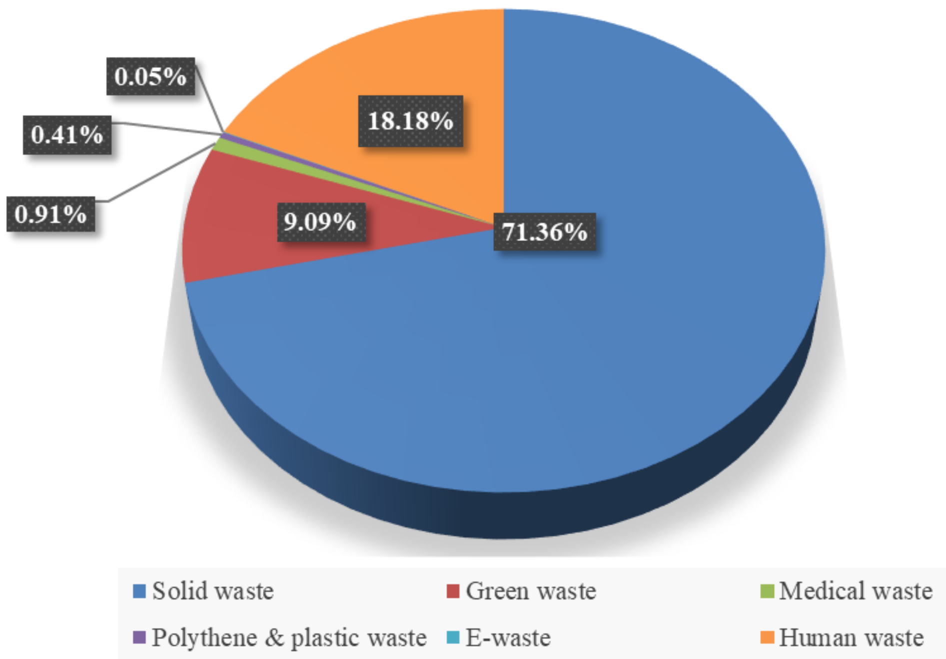

Figure 6. Pie chart of percentage of waste generation in KCC area.

4.7. Estimation of number of people involved in waste department in KCC

Table 02 provides comprehensive labor data for Khulna City Corporation's (KCC) garbage collectors. Regular, master roll, ward-based outsourcing, and external employees who are directly or indirectly engaged in conservancy and waste-related tasks are included in the statistics. KCC employed 1635 people in various categories. Approximately third-fourths of the workforce was engaged in waste collection, transportation, and sanitation services, as evidenced by the 1288 employees who were directly employed by the conservancy department. There is a glaring gender disparity in waste management labor, with 702 of these conservancy employees being men and 115 being women. The conservancy department employed 286 out of the 343 regular employees. There were 31 female employees and 141 male employees in this category. Additionally, 30 dustmen, 65 sewage workers, 26 van laborers, 5 spray men, and 26 truck workers made up the operational personnel, while 19 supervisors were in charge of overseeing conservancy operations. With 646 employees, including 521 who work in conservancy services, the master roll category is the largest group of workers. There were 41 female employees and 282 male employees in this category. This group had 19 supervisors, 41 dustmen, 138 sewage workers, 69 van workers, 20 spray men, and 36 truck workers. 217 out of the 254 outsourced ward-based employees were employed by the conservancy department. There are no managers for the 105 male and 21 female employees in this group. A small number of them worked as spray men (2 workers), but the majority of them were employed in sewage work (70 workers) and van garbage collection (35 workers). Furthermore, KCC's waste management system employed 392 outside personnel, 264 of them were involved in conservancy operations. With the assistance of 4 supervisors, this group had 174 male employees and 22 female employees. They were heavily involved in secondary waste transportation, with 22 dustmen, 42 sewage workers, 20 van workers, 32 spray men, and 76 truck workers among their tasks. Overall, Table 02 demonstrates that KCC's waste management system necessitates a sizable workforce with a significant reliance on external, outsourced, and master roll staff. Waste management labor in Khulna City is physically demanding, as evidenced by the fact that the majority of workers are men and that most of them handle sewage and perform transportation duties. In the Khulna City Corporation area, this personnel structure is crucial to maintaining daily waste collection, sanitation, and environmental cleanliness.

4.8. Involvement of the gender disparity in waste-management

There are 702 men and 115 women indicates substantial gender segregation in formal waste management employment. The current study did not directly test the causes of this disparity but several credible descriptions emerge from the work-related structure observed in the field, many jobs involve physically demanding collection, sewage handling, loading, and shipping, work may begin early into evening hours, exposure to smells, sharps, pathogens, traffic, and other occupational hazards may dishearten female involvement, and usual social prospects may channel women away from highly visible or physically demanding sanitation occupations. Informal recycling can also be socially denounced, which may emphasize occupational exclusion. These factors are consistent with broader evidence that occupational health and safety conditions are vital blocks in informal recycling schemes [24]. The consequence is not only an equity issue. A constricted gender composition reduces the pool of potential workers, may limit access to formal employment and social protection for women, and can reproduce the inconspicuousness of women's contributions to household-level sorting and recycling.

4.9. Concentration of recycling activities in particular wards

Recycling shops and factories are concentrated in certain area like Shiromoni, Fulbarigate, Daulatpur, Khalishpur, Shekhpara, Sonadanga, Gollamari, and Lobonchora rather than being evenly distributed across the 31 wards. The study did not conduct a formal spatial backsliding, so these explanations remain illustrative. The clustering is nevertheless consistent with the recycling economic geography, businesses benefit from proximity to large sources of recyclable substances, vans and trucks road access, existing networks of trader, available low-cost field for storage and sorting, and small connections between collectors, dealers, and processors. For cluster forms, search and transaction costs can be reduced by buyers and sellers, which can support further concentration. Comparable clustering has been reported for two other Bangladeshi cities one is Rajshahi where recycling shops were concentrated around the Stadium Market area, another one is Jashore where recycling shops were clustered around major transport/market locations [76,77]. So, ward-level pattern in Khulna city seems to partly generalizable to secondary-city recycling economies, especially, the concentration in industrial and transport-linked parts of Khulna influences the city's own spatial and economic structure.

4.10. Implications for the circular economy

The findings reveal that the Khulna city recycling system is not simply a residual activity occurring outside the system of municipal; it is a medium of functioning material-recovery that reclines the quantity of recyclable materials entering final disposal. However, the network remains weakly unified with KCC, and maximum of the recovered material leaves Khulna for secondary processing in Dhaka. This creates an inconsistency; the city captures the labor and other environmental benefits of collection but loses part the high value processing activi-

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ties. Formal acknowledgment of collectors and dealers, definite material-recovery areas, professional safety support, transparent information, and incentives for local processing could therefore shift the informal toward a more inclusive circular-economy model. Evidence from other cities also suggests the formal–informal partnerships can develop service provision and worker inclusion when they are designed to preserve the livelihoods and agency of existing recyclers [28].

5. SIGNIFICANCE OF WASTE MANAGEMENT

Solid waste management has evolved from a little service to a crucial component of public health, urban sustainability, and economic expansion. In addition to contributing to greenhouse gas emissions and plastic pollution in the ocean, improper disposal still contaminates soil, water, and air and incurs significant expenses for local governments and communities. However, waste also presents a significant economic opportunity for the urban poor when it is managed inclusively, with informal recyclers integrated into formal systems. According to this study, Khulna City produces 785 tons of solid garbage every day, 1.09 kg per person each day. Approximately 30–40 tons of recyclable material are removed from landfills every day by the unofficial recycling sector. Despite its tiny percentage, this diversion offers significant environmental benefits, such as less soil and groundwater contamination, less methane emissions from decaying garbage, and the preservation of new raw materials including plastics, metals, paper, and glass. On the basis of field survey, 310 reusable material outlets, 35–40 plastic recycling companies, and 277 small recycling businesses support the roughly 2,000 waste pickers and feriwalas engaged in primary rubbish collecting, creating a functioning circular economy that primarily functions without official acknowledgement. Waste pickers make between Tk 150 and Tk 300 a day, while feriwalas make between Tk 500 and Tk 700. These jobs are simple, require little initial investment, and are crucial in helping those who are economically challenged escape poverty. The subsector of plastic recycling alone has an estimated monthly economic benefit of BDT 15–20 million. Despite this crucial role, recycling is not addressed by KCC's official waste management strategy. Approximately 70–75% of recovered materials are shipped to Dhaka for processing, which raises transportation costs, produces carbon emissions and limits chances for local employment and value creation. In addition to helping Khulna transition to a circular economy in line with SDGs 11 (Sustainable Cities), 12 (Responsible Consumption and Production), and 13 (Climate Action), the establishment of processing facilities within the city will close this gap. It is also crucial to integrate waste collectors into the formal system with inclusive employment practices for all genders, health support, and safety training. The gender disparity that now exists (702 male conservancy workers compared to 115 female workers) demonstrates a blatant exclusion that can be addressed by policy reform. In addition to investing in infrastructure, moving forward necessitates acknowledging that the unorganized sector is currently performing vital tasks and needs the right assistance to do so in a safer and more efficient manner. Figure 7 presents a theoretical framework for integrating the informal recycling sectors into the formal economy via the circular economic system of Khulna City. This framework compares the existing informal recycling system with a proposed modern formal integrated system. In the informal system, waste pickers and feriwalas collect recyclable materials from households and streets and then sell them to informal recycling parties and, for further processing, transport those to Dhaka. The proposed modern system seeks to formalize waste-picking activities, establish the facilities of local recycling and processing, and also make employment opportunities that will be supported by health and safety training and appropriate policy reforms. Again, the framework describes how local processing and resource recovery can contribute to a circular economy through value addition, local job generation, and a decrease of gender parity. As a whole, the modern proposed integrated system can build up a more resilient and sustainable recycling system in Khulna by contributing to environmental benefits, economic opportunities, and the reduction of poverty.

5.1. Comparison with secondary cities in South Asia

Khulna shares several features with other non-capital South Asian cities, dependence on labor-intensive collection, a significant informal recycling economy, limited local processing capacity, and the movement of recovered materials toward larger industrial markets. For example, Rajshahi, has been reported to have a distributed recycling chain involving collectors, shops, and a small number of processing factories, with considerable material flows ultimately linked to Dhaka [76]. Jashore similarly shows assembled recycling shops, a large informal workforce, and dependence on Dhaka and other cities for further processing [77]. Pokhara, Nepal, delivers a

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comparable example of a secondary city where municipal waste management is constrained by collection capacity, landfill dependence, and occupational risks for waste-management staff [78]. What is unique in Khulna is the combination of a large KCC collection workforce with a sizeable informal recovery network, the attention of plastic-processing facilities in specific wards, and the strong downstream dependence on Dhaka even though Khulna's industrial and port-related position. The generalizable lesson is that secondary cities can build effective material recovery systems by linking municipal collection with existing casual networks; the Khulna-specific challenge is to preserve more processing and value addition locally while improving worker safety and insertion. This comparison should be construed as contextual rather than as a statistically controlled cross-city comparison.

Figure 7. Current and proposed plan for building a resilient KCC.

CONCLUSION

This study contributes to the literature in three main ways. Firstly, it updates observational picture of Khulna's recycling sequence by linking municipal collection, primary collectors, recycling shops, and plastic-processing facilities within perspective flow of single material. Secondly, it documents the coexistence of formal municipal waste services and an economically meaningful informal network of recovering, showing that the latter performs resource-recovery works that are not fully determined in the statistics of official waste-management. Thirdly, the study indicates specific clusters, worker categories, and downstream material flows that can be used to design more selective interventions than a city-wide 'collect-and-dispose' structure. The findings therefore support a regenerate social economy approach in which informal participants are treated as stakeholders and partners of service rather than marginal participants. There are several limitations for example the analysis relies on reported quantities, business information, and field calculation from informal actors, whose records are not consistent. Again, informal collectors and small recycling businesses are tough to itemize, so the study does not mention actors' number accurately who operate intermittently. Then the fieldwork cannot cover full seasonal change in waste generation, collection and recycling flows it only covered from July 2025 to February 2026. Moreover, the study is elementary descriptive and does not show statistically test and best explanations for imbalance of gender, clustering and activities of recycling. These drawbacks do not invalidate the findings but interfere definitely. Besides of these, the limitation of methodological is that the questionnaire was not involved in formal statistical validation, and the qualitative information was not analyzed through a formal coding-based thematic analysis. Prospective studies should establish a longitudinal material-flow of dataset covering all season's variation; carry out GIS mapping of ward-level collectors, shops, transfer points, roads, markets, and recycling facilities; and use statistical-based sampling where a sound sampling skeleton can be built. A hybrid approach study should inspect gender, age, income, occupational health, and access to social safety among waste workers. Again, specific studies of material should gauge plastic, paper, metal, glass, ceramics, organic waste, and e-waste flows from source to final processing zones. The evaluation of cost efficiency between local processing and transport to Dhaka, while intervention studies could test source segregation, formal registration of recyclers, cooperative models, producer-responsibility strategy, and recycling. Cross-city comparative study involving Khulna, Rajshahi, Jashore, and other secondary cities of Asia would further distinguish structural patterns from Khulna based on specific conditions. With an emphasis on the function of the unofficial recycling industry in waste management, this study looked at the solid waste collection and recycling systems within Khulna City Corporation, Bangladesh. The study, which was carried out in all 31 administrative wards between July 2025 and February 2026 using field surveys, structured questionnaires, and direct observation, yields a number of significant conclusions. The primary conclusion is that Khulna's waste management system still relies on a straightforward collect-and-dispose approach that fails to fully utilize the economic and environmental benefits of recyclable materials. Investing in local processing infrastructure, including informal recyclers in the formal system, creating markets for recycled goods, and enforcing stricter laws and regulations are all necessary to make the shift to a circular economy approach. Policymakers, urban planners, and development professionals working to improve waste management systems throughout rapidly expanding cities in Bangladesh and other developing nations can benefit from this study's demonstration of the environmental, economic, and social significance of the informal recycling sector.

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