JISR management and social sciences & economics
2025, VOL. 23, NO. 4, 91–110, e-ISSN: 1998-4162, p-ISSN: 2616-7476
https://doi.org/10.31384/jisrmsse/2025.23.4.5

Patterns of Municipal Waste Generation and Composition in Socio-Economic Zones of Clifton, Karachi, Pakistan

Shohaib Ur Rehman[1], Aizaz Ahmed[1], Manzoor Ahmed Sanjrani[2*] and Saira Khan[1]
1-Department OF Environmental Sciences, Sindh Madressatul Islam University, Karachi, Pakistan
2-Department of Operations, Environment & Supply Chain Management, Institute of Business Management, Karachi, Pakistan
*Corresponding Author: manzoor.ahmed@iobm.edu.pk

ABSTRACT

Managing solid waste is a big issue in urban city like Karachi, Pakistan, where economic and social conditions vary. After reviewing already published literature, it was found that very few studies on waste management in Karachi City. To fulfil this gap, this study was conducting on solid waste from different locations in Karachi. This study mainly focusses on its physical features such as composition, average rate of generation, bulk density and moisture content. Three income zones were selected including (1) Shireen Jinnah Colony, (2) Clifton Block 1 and (3) Clifton Block 2. Study result highlighted clear differences in waste generation per person on daily basis. Low-income families generate waste around 0.58 kilograms while 0.69 kilograms waste is generated by middle-income households, and close to 0.83 kilograms of waste is generated by high-income groups. Analysis shows that low-income groups generated mostly organic waste (~50%), middle-income people generate mix of organics and recyclables waste, while high-income families generate less organic waste (≈33%). Study also reveals that high-income groups generate other types of waste also such as paper, plastics, metals, glass, and e-waste (up to 20–25%). These all things reflect differences in generating waste in the study area as socio-economic zone disparities. Solid waste management authorities need to understand the need for zone-specific and income-sensitive approaches for sustainable solid waste management.

Article Type: Original

OPEN ACCESS

Received:
18 September, 2025
Revised:
15 December, 2025
Accepted:
26 December, 2025
Published:
31 December, 2025

Keywords: *Municipal Waste, Solid waste, Physical properties, Solid waste management, Urban area*

JEL Classification: *Q53*

How to cite this article (APA): Rehman, S. U., Ahmed, A., Sanjrani, M. A., & Khan, S. (2025). Patterns of Municipal Waste Generation and Composition in Socio-Economic Zones of Clifton, Karachi, Pakistan. *JISR management and social sciences & economics*, *23*(4), 91–110. https://doi.org/10.31384/jisrmsse/2025.23.4.5

INTRODUCTION

The generation of municipal solid waste worldwide has increased substantially over the past few decades due to rapid urbanization, population growth, industrial expansion, and changing consumption patterns (Maalouf & Agamuthu, 2023). Municipal solid waste (MSW) consists of non-hazardous materials generated by households, commercial establishments, and institutions within urban or designated areas. This category includes treated biomedical waste but explicitly excludes hazardous industrial by products (Dong et al., 2022; Lubello et al., 2025). Rapid population growth and increasing urbanization have significantly intensified solid waste accumulation and greenhouse gas (GHG) emissions. While rural sectors such as agriculture, livestock, and fisheries also play a role in climate change, urban areas disproportionately contribute to carbon emissions due to higher energy consumption and waste generation (Aghabeyk et al., 2025). Improper disposal of solid waste contaminates soil (Njewa et al., 2025), groundwater, and surface water resources through the release of toxic substances and leachates (Aquino et al., 2025; Parvin & Tareq, 2021).

Karachi, Pakistan's is one of the biggest cities, struggles with issue of municipal solid waste management (Afzal et al., 2024; Khatri et al., 2021). Karachi's current population is estimated to exceed 23 million people with a population density of 63,000/ sq. miles. The city produces a substantial volume of municipal solid waste (MSW), exceeding 20,000 tons per day. This equates to an average generation of 1.244 kilograms of waste per person per day and 7.464 kilograms per household per day. As projected the future municipal solid waste generation in the city up to 2030. Their forecast suggests that daily waste production, currently at 20,000 tons, is expected to rise to 25,669.193 tons per day, reflecting an annual growth rate of 2.53% (Afzal et al., 2024; Khatri et al., 2021; Sohoo et al., 2022). Many developing nations, such as Pakistan, face severe limitations in funding and technical expertise required to address their growing waste management challenges. Improper waste management practices, including open dumping, uncontrolled landfilling, and open burning, contribute contributes to significantly to environmental pollution and serious threats to health risks, while sustainable practices support environmental protection and SDG 3 (Kumar & M, 2025; Saif et al., 2025). Many countries have recognized this gap and the fact that the waste management methods currently in use are not capable of achieving the Sustainable Development Goals (Afzal et al., 2024; Dong et al., 2022; Lee & Wong, 2023). In Pakistan, study on energy recovery has been started. Energy from waste can significantly reduce the environmental and public health risks caused by conventional solid waste treatment technologies (Afzal et al., 2024; Khatri et al., 2021; Sohoo et al., 2021).

Prior studies have demonstrated that the development of garbage worldwide is influenced by numerous interconnected elements. According to researchers, the three most crucial elements are social norms and cultural practices, governance frameworks and policy frameworks, and economic conditions (including income levels and consumer behavior). Empirical studies show that socioeconomic factors are among the most important determinants of waste generation in different geographical areas (Sohoo et al., 2022; Song et al., 2024). Key socioeconomic variables influencing solid waste generation include land use patterns, household size, employment sector, income levels, educational attainment, and the age of the primary household member. Additionally, seasonal fluctuations in agricultural activity significantly impact waste composition and volume in rural and peri-urban areas (Nguyen et al., 2020; Óskarsson et al., 2025; Zhang et al., 2024). The literature review indicates that per capita waste generation in cities ranges from 0.20 kg/day to 0.85 kg/day, depending on population size. Waste properties (physical and chemical) differ in regions due to variations in demographics, socioeconomic status, and seasonal factors. Main challenges to current waste management include lack of awareness, skilled personnel and land availability. Another reason is lack of political commitment in urban area. Additionally, gaps in waste composition databases, financial resources, technical capacity, equipment, operational systems, and trained staff pose important obstacles to creating efficient waste management in urban authorities (Cantillo et al., 2023; Páramo-Telle & Vence, 2025; Zhang et al., 2024; Zhu et al., 2025). The increasing challenge of MSW in socio- economically diverse areas of Karachi such as Clifton need urgent consideration due to its serious public health and environmental issues. Furthermore, unmanaged waste creates breeding grounds for disease vectors such as mosquitoes, rodents, and flies, increasing the likelihood of infectious disease transmission.

Existing practices such as inadequate collection, negligible segregation, and open dumping are causing contamination. Air pollution due to burning of waste, groundwater issues due to improper dumping and microplastic causes marine ecosystem degradation. This study emphasizes the importance of conducting a thorough physicochemical characterization of waste, considering its source, seasonal variations, and socio-economic stratification for direct waste analysis; and the need to examine how waste sampling and characterization considering sampling location, material fractions, and specific physicochemical properties affect the design of effective waste handling and management systems. In this research, we present the results with an overall objective to assess the MSW generation rate, composition, and characteristics based on source, socio-economic variations in Clifton, Karachi, Pakistan.

RESEARCH METHODOLOGY

The methodology of the study is based on field work carried out to assess the solid waste generation rate, physical characteristics, and identification of waste management practices in selected low, middle, and high-income areas of Clifton, Karachi.

Study Area

This research was conducted in three socio-economically diverse localities within the Clifton area of Karachi, Pakistan, (1) Shireen Jinnah Colony, (2) Clifton Block 1, and (3) Clifton Block 2, see table 1 and fig 1.

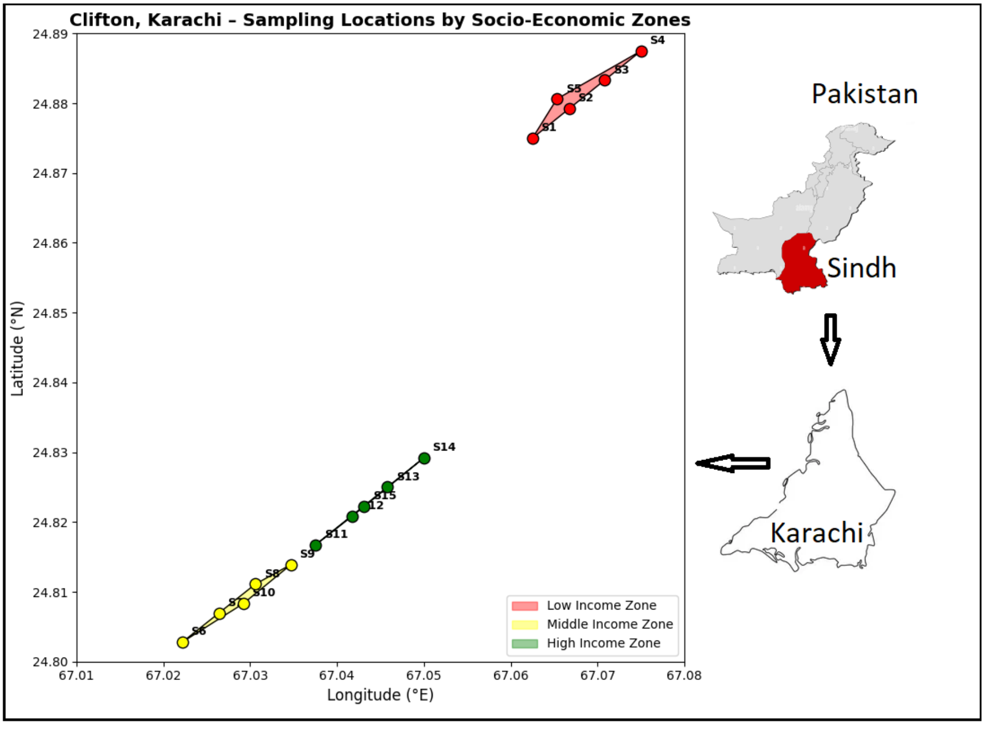

Figure 1: *Study area and Sampling Location*

The methodology of the study is based on field work carried out to assess the solid waste generation rate, physical characteristics, and identification of waste management practices in selected low, middle- and high-income areas of Clifton, Karachi. Household waste samples were collected from five distinct neighborhoods in Shireen Jinnah Colony, Clifton (low-income zone), with six households sampled per neighborhood, totaling 30 households. Household waste samples were collected from five neighborhoods in Clifton Block 1 (middle-income zone), with six households sampled per neighborhood, totaling 30 households. Household waste samples were collected from five neighborhoods in Clifton Block 2 (high-income zone), with six households sampled per neighborhood, totaling 30 households, see Table 1.

Table 1.
Study area information

Zone	Neighborhood	Area (m^2)	Area (ft^2)
Low-Income Zone	Shireen Jinnah Colony, Clifton	256,911.77	2,765,375.30
Middle-Income Zone	Clifton (Block 1)	632,589.00	6,809,131.33
High-Income Zone	Clifton (Block 2)	784,619.00	8,445,568.63

Sample Strategy

In this study, random sampling was done in Clifton's three socio-economic zones, (1) Shireen Jinnah Colony, (2) Clifton Block 1, and (3) Clifton Block 2. Total 90 households, 30 per zone were selected for collecting samples. This selection was based on geographical distribution, and income verification. Sampling was done in five consecutive days during the dry season (March-May) because this period is better to avoid monsoon-related moisture. Household were provided a 20x30 waste collection bags and they were requested to exclude hazardous material. A well-designed questionnaire was filled by households. This methodology balances scientific rigor (ASTM D5231-92 compliance) with policy relevance, capturing income-based, spatial, and seasonal waste dynamics while linking household behaviors to broader municipal waste management systems.

Sample Collection

Sampling Collection from Shireen Jinnah Colony (Low Income Zone)

Collection of household waste samples were conducted from Shireen Jinnah Colony including the Roadside Settlement A, Worker Housing Cluster B, Informal Dwelling Area C, Temporary Shelter Zone D, and Katchi Abadi Sector E, see Table 2. Samples were collected for further analysis such as weighing waste generation, evaluation of composition, moisture content and bulk density, which was later discussed for comparison with middle- and high-income areas.

After collecting samples, the segregation process was conducted. This stage was crucial to ensure completely separated and categorized into several types of materials for accurate assessment of its composition.

Table 2.
Sampling Collection from Shireen Jinnah Colony (Low Income Zone)

S. No	Latitude (N)	Longitude (E)	Neighborhood	HH Samples
1	24°52′30″	67°03′45″	Roadside Settlement A	6
2	24°52′45″	67°04′00″	Worker Housing Cluster B	6
3	24°53′00″	67°04′15″	Informal Dwelling Area C	6
4	24°53′15″	67°04′30″	Temporary Shelter Zone D	6
5	24°52′50″	67°03′55″	Katchi Abadi Sector E	6

Sampling Collection from Clifton Block 1 (Middle Income Zone

Collection of household waste samples were conducted from Clifton Block 1 (the middle-income zone). This zone had mixed waste including food waste, paper, plastics, metals, glass, and other items. Consumption patterns and disposal habits were documented.Table 3 shows the sample collection details.

Table 3.
Sampling Collection from Clifton Block 1 (Middle Income Zone)

S. No	Latitude (N)	Longitude (E)	Neighborhood	HH Samples
1	24°48′10″	67°01′20″	Apartment Complex X	6
2	24°48′25″	67°01′35″	Residential Colony Y	6
3	24°48′40″	67°01′50″	Gated Community Z	6
4	24°48′50″	67°02′05″	Mixed-Use Area	6
5	24°48′30″	67°01′45″	Urban Village	6

Sampling Collection from Clifton Block 2 (High Income Zone

Collection of household waste samples were conducted from Clifton Block 2 (High-Income Zone) such as Gated Villas, Luxury Apartments, High-Rise Towers, Beachfront Residences and Mixed Areas, see Table 4.

Clifton Block 2 (High-Income Zone) generates less organic waste but more other types of waste also such as paper, plastics, metals, glass, and e-waste. The samples were separated into various categories, including organic waste, glass, metals, plastics, paper, and other items. These results were then compared to low- and middle-income communities.

Table 4.
Sampling Collection from Clifton Block 2 (High Income Zone)

S. No	Latitude (N)	Longitude (E)	Neighborhood	HH Sampled
1	24°49’00”	67°02’15”	Luxury Apartments	6
2	24°49’15”	67°02’30”	Gated Villas	6
3	24°49’30”	67°02’45”	High-Rise Towers	6
4	24°49’45”	67°03’00”	Mix	6
5	24°49’20”	67°02’35”	Beachfront Residences	6

Assessment of the Physical Characteristics of Solid Waste

Each household’s waste was weighed and divided by the household size to determine the amount of waste per capita. The given below formula was used to determine the average amount of waste per capita

Equation 1: Average amount of waste per capita

$$Average\ Waste\ Generation\ Rate\ = \frac{1}{m\ x\ n}\sum_{i=1}^{m}\sum_{j=1}^{n}\frac{W_{ij}}{S_j} \qquad \text{(Eq 1)}$$

Where,

m = the total number of days (5 days) in the study period

n = total number of families participating in the study (90)

I = i-th day of waste weighing

j = j-th family

Sj = size of the j-th family

Wij = weight of waste on day i of the j-th family (kg)

Moisture Content

One of the important parameters in municipal solid waste analysis is moisture content, because it affects decomposition, weight, and treatment. High-moisture waste often from low-income zones is better for composting, while low-moisture waste from high-income zones is better for incineration or energy recovery. The formula to calculate moisture content is given below.

Equation 2: Moisture content

$$Moisture\ Content\ (\%)\ = \frac{Wet\ Weight\ of\ Sample\ (kg)\ -\ Dry\ Weight\ of\ Sample\ (kg)}{Wet\ Weight\ of\ Sample\ (kg)} x\ 100($$

Where:

• Wet Weight of Sample (kg) is equal to the waste sample's initial weight prior to drying.

• Dry Weight of Sample (kg) is equal to the waste sample's weight following oven drying.

• The percentage of water in the waste is determined by this computation, which is crucial for organizing treatment, storage, and transportation plans

Bulk Density

Bulk density, or the amount of trash per unit volume, is a key physical measurement of municipal solid waste that reveals its ability to compact and moisture content. It is critical in the design of collection, storage, transportation, and healthcare facilities. The density of the bulk material varies by socioeconomic location due to difference in waste content. For example, low-income regions have damp organic waste, but high-income regions have dry containers.

The following formula is used to calculate the bulk density:

Equation 3: Bulk density

$$Bulk\ Density\ (kg/m^3)\ =\ \frac{Weight\ of\ Waste\ (kg)}{Volume\ of\ Waste\ (m^3)} \quad \text{(Eq 3)}$$

Where:

• Waste weight (kg) = measured weight of collected waste

• Waste volume (m2) is the measured or estimated volume of the waste bag or container.

Questionnaire for the assessment of waste management practices in study area

A structured questionnaire was administered to 90 households across Clifton's three socio-economic zones Shireen Jinnah Colony (low-income), Clifton Block 1 (middle-income), and Clifton Block 2 (high-income) to systematically assess household waste management practices. The survey collected detailed data on household demographics, waste storage and disposal methods, collection service efficiency, recycling and composting behaviors, and environmental awareness.

RESULTS AND DISCUSSIONS

Assessment of the waste generation rate in selected low, medium and high-income areas of Clifton, Karachi

The results analysis shows clear differences in all three zones due to income levels and lifestyle. Waste generation varies in all three zones. In Shireen Jinnah Colony (a low-income group), average 3.53 kg per household per day, or 0.58 kg per person waste was calculated. Clifton Block 1 (middle-income zone) generated the waste higher than Shireen Jinnah Colony, average 4.56 kg per household per day, or 0.69 kg per person. The higher generation of waste was noticed in Clifton Block 2 (high-income families), average 5.14 kg per day, or 0.83 kg per person, with higher proportions of plastic and packaging. Below formula was used to calculate the total waste in kilograms.

Equation 4: Waste Weighted Formula

$$Total\ Waste\ (kg)\ =\ \sum_{i-1}^{n} i \quad \text{(Eq 4)}$$

Low-income areas generate organic waste while to packaging-rich waste in high-income neighborhoods. The results show a clear link between waste generation and income, as wealth increases, the amount and variety of waste increases.

Equation 5: Waste per Person Formula

$$Waste\ per\ Person\ (kg/capita/day)\ =\ \frac{Total\ Waste\ Collected\ (kg)}{Number\ of\ Persons\ in\ Household} \quad \text{(Eq 5)}$$

Municipal Solid Waste Data of Shireen Jinnah Colony Low Income Zone

Result analysis shows that in Shireen Jinnah Colony, the average daily household waste generation is 3.53 kg per household or 0.58 kg per person. This low per capita rate reveals limited consumption and reuse approaches in low-income families.Figure 2 shows low income data, means waste generated by household and other shows waste generation per person, all values are in kilograms.

Municipal Solid Waste Data of Clifton Block 1 - Middle Income Zone

Clifton Block 1 (middle-income zone) generated the waste higher than Shireen Jinnah Colony, average 4.56 kg per household per day, or 0.69 kg per person. Results show that per capita values ranged between 0.55 and 0.93 kg, see fig 3. Overall, middle-income households generate a mixed waste that highlights the need for awareness on segregation and recycling, as well as reliable collection systems to prevent accumulation.Figure 3 shows middle income data, means waste generated by household and other shows waste generation per person,

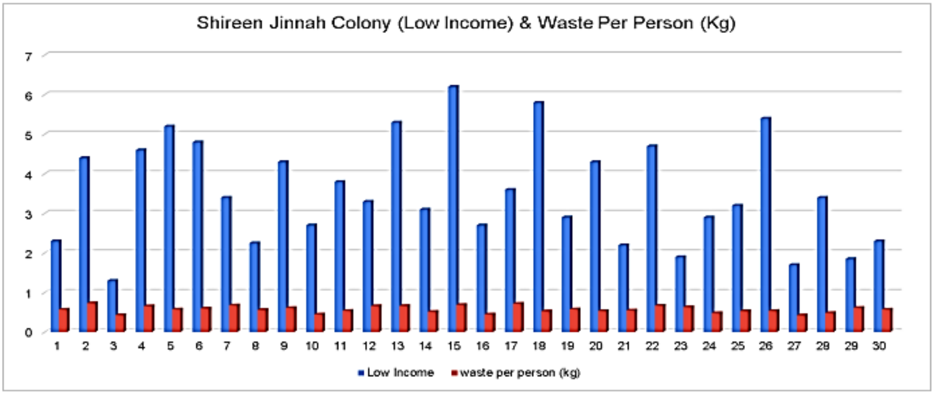

Figure 2: *Municipal Solid Waste Data of Shireen Jinnah Colony Low Income Zone*

all values are in kilograms.

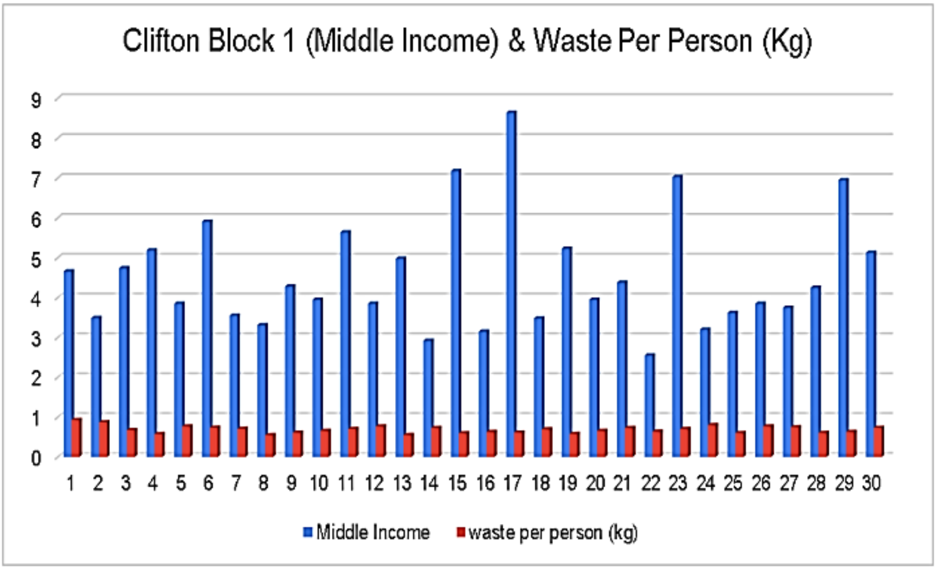

Figure 3: *Municipal Solid Waste Data of Clifton Block 1*

Municipal Solid Waste Data of Clifton Block 2 - High Income Zone

The higher generation of waste was noticed in Clifton Block 2 (high-income families), average 5.14 kg per day, or 0.83 kg per person, with higher proportions of plastic and packaging, the highest among all three zones. Per capita values ranged between 0.61 and 1.37 kg, reflecting wider variability due to differences in household size and food habits.

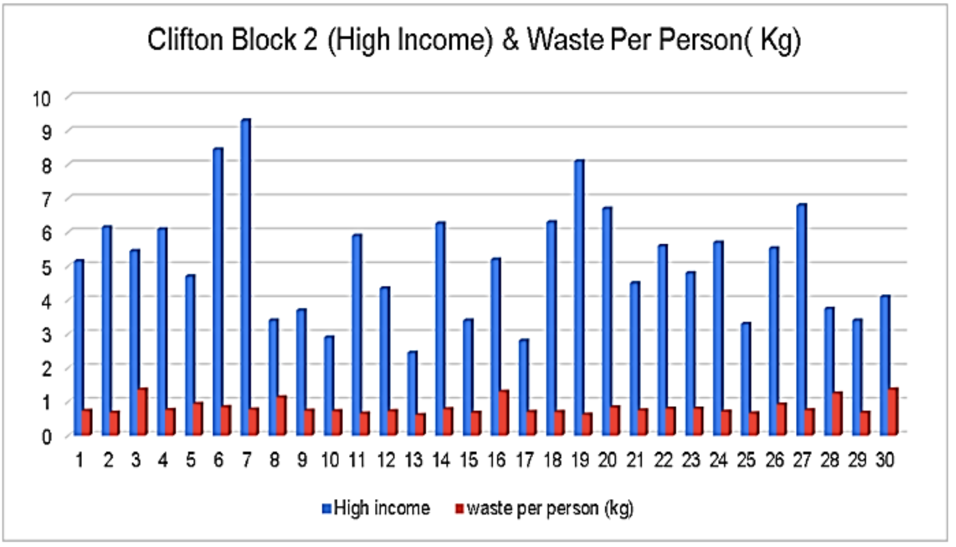

Figure 4: *Municipal Solid Waste Data of Clifton Block 2*

Compared to low-income and middle-income areas, waste has larger share of plastics, paper, and disposable packaging, while organics waste was low. Figure 4 shows high income data, means waste generated by household and other shows waste generation per person, all values are in kilograms.

Assessment of the physical properties (composition, moisture content, generation rate and bulk density) of solid waste in selected low, middle- and high-income areas of Clifton, Karachi

The physical properties of MSW varies a lot in Clifton's socio-economic zones. It reflects differences in household consumption patterns and lifestyle standards. In Shireen Jinnah Colony, organic waste was dominated with high moisture content and a relatively high bulk density. In Clifton Block 1, the mix waste was found such as organics, paper, and plastics with moderate moisture and medium bulk density. In Clifton Block 2, lower organic waste was found than recyclables materials (paper, plastics, glass, and packaging) with less moisture and lower bulk density. The results show that higher-income families generate bulkier but lighter waste that require segregation and recycling-focused treatments, while low-income areas generate dense and wet waste that can be composted.

Average Waste Generation Rate

The results show differences in waste generation by households in three socioeconomic zones of Clifton Karachi. In Shireen Jinnah Colony (a low-income group), average 3.53 kg per household per day, or 0.58 kg per person waste was calculated. Clifton Block 1 (middle-income zone) generated the waste higher than Shireen Jinnah Colony, average 4.56 kg per household per day, or 0.69 kg per person. The higher generation of waste was noticed in Clifton Block 2 (high-income families), average 5.14 kg per day, or 0.83 kg per person, with higher proportions of plastic and packaging, see Table 5.

Table 5.
Average Waste Generation Rate

Income Group	Avg Waste per HH (kg)	Waste per Person (kg)
Low Income	3.5267	0.5761
Middle Income	4.5553	0.6868
High Income	5.1410	0.8338

These results prove a direct link between income levels and waste generation. The rising leads to higher per capita waste output and a shift towards recyclable materials e.g paper, plastics, and glass.

Composition of Municipal Solid Waste in Low, Middle, and High-Income Areas of Clifton, Karachi

In Clifton area, the composition of MSW varies considerably in socio-economic zones, showing differences in lifestyle and consumption, see Table 6.

The organic waste was dominated in Shireen Jinnah Colony, with food and plant waste comprising 38% and 12%, respectively, while only 10% and 8% of plastics and paper respectively. Other waste was negligible such as metals, glass, leather, textiles, ceramics, wood, and electronic. In Clifton Block 1, a more mixed waste was found, with food and plant waste at 32% and 10%, while recyclable plastics and paper at 15% and 12%. Other materials such as metals, glass, leather, textiles, ceramics, wood at (3%) and electronic at (1%). In Clifton Block 2, relatively lower organic waste (food 25%, plant 8%) was found while higher proportions of recyclable, dry, and packaged materials, including plastics (20%) and paper (15%). Other materials such as glass, metals, hazardous, and e-waste (3%).

Table 6.
Composition of Municipal Solid Waste in Low, Middle, and High-Income Areas of Clifton, Karachi

Category	Low-Income (%)	Middle-Income (%)	High-Income (%)
Food Waste	38	32	25
Plant Waste	12	10	8
Recyclable Plastics	10	15	20
Paper/Cardboard	8	12	15
Glass	3	5	6
Metals	2	3	5
Textiles	5	4	4
Leather	2	2	2
Ceramics	4	3	3
Thermocol	3	3	3
Wood	3	2	3
Sand/Dust	5	4	2
Hazardous	0	2	2
E-waste	0	1	3

Moisture Content

The moisture content of MSW was conducted using the standard oven-drying method at a constant temperature of 105 °C for 24 hours. After drying, dry weight was calculated and later moisture content was calculated based on the weight loss during drying. Table 7 shows the moisture content results.

Table 7.
Moisture Content

Zone / Area	Wet Weight (g)	Dry Weight (g)	Moisture Content (%)
Low-Income (Shireen Jinnah)	800	280	65.0
Middle-Income (Clifton Block 1)	1200	328	72.6
High-Income (Clifton Block 2)	1700	374	78.0

Bulk Density

Bulk density is a critical factor for waste collection, transport, storage, and treatment approaches because it represents the mass of waste per unit volume. In this research, household waste from the study area including three socio-economic zones was collected in standardized 30 L (0.03 m^3) containers. The proper method was applied, both weight and volume were recorded to calculate the exact bulk density. Result is given in Table 8.

Table 8.
Bulk Density Across Income Levels

HH No.	Low-Income (kg/m^3)	Middle-Income (kg/m^3)	High-Income (kg/m^3)
1	76.67	155.33	180
2	146.67	116.33	190
3	43.33	158.00	175
4	153.33	173.00	165
5	173.33	128.33	300
6	160.00	197.00	110
7	113.33	118.33	200
8	75.00	110.33	125
9	143.33	142.67	95
10	90.00	131.67	190
11	126.67	188.00	120
12	110.00	128.33	210
13	176.67	166.00	135
14	103.33	97.33	90
15	206.67	239.33	205
16	90.00	105.00	110
17	120.00	288.00	150
18	193.33	116.00	270
19	96.67	174.33	285
20	143.33	131.67	175
21	73.33	146.00	170
22	156.67	85.00	125
23	63.33	234.33	180
24	96.67	106.67	115
25	106.67	120.67	170
26	180.00	128.33	160
27	56.67	125.00	120
28	113.33	141.67	215
29	61.67	231.67	110
30	76.67	171.00	135

The result shows the insights on how socioeconomic factors impact solid waste mixture and density, which is important in setting up tailored waste gathering, storage, and processing solutions for different industries, see Figure 5.

3.6. **Identification of waste management practices in selected low, middle- and high-inc ome areas of Clifton, Karachi**

Figure 5: *Comparison of Bulk Density Across Income Levels*

In Shireen Jinnah Colony, households' size is bigger comprising more than 7 members, and monthly income mostly ranges between PKR 25,000–50,000. MSW is thrown or stored in open sacks (18 households) or uncovered bins (9 households), producing less than 3 kg per day for most families. Segregation is not existed, and waste is collected by informal way. Residents are not satisfied with collection services. They have limited awareness of environmental impacts, and minimal use of recycling or composting. In Clifton Block 1, households' size is not such big, consist of 4–6 members with monthly income ranges between PKR 50,000–150,000. Waste storage system is a little better, covered bins (13 households) and uncovered bins (14 households) but waste generation per day is higher, ranges between 1–10 kg. Collection is a little formal, involving both municipal staff and private companies. In Clifton Block 2, households' size is smaller, monthly income more than PKR 150,000. Waste management system is better, covered bins for storage. Collection is largely managed by private companies, conducted daily, and satisfaction is high. Households have higher environmental awareness and willingness to pay for improved services, but activities such as composting or waste separation remain uncommon.

CONCLUSION

This research assessed waste generation of household including physical characteristics, and management practices across three socio-economic zones of Clifton, Karachi (1) Shireen Jinnah Colony (low-income), (2) Clifton Block 1 (middle-income), and (3) Clifton Block 2 (high-income). The results analysis shows clear differences in all three zones due to income levels and lifestyle. Waste generation varies in all three zones. In Shireen Jinnah Colony (a low-income group), average 3.53 kg per household per day, or 0.58 kg per person waste was calculated. Clifton Block 1 (middle-income zone) generated the waste higher than Shireen Jinnah Colony, average 4.56 kg per household per day, or 0.69 kg per person. The higher generation of waste was noticed in Clifton Block 2 (high-income families), average 5.14 kg per day, or 0.83 kg per person, with higher proportions of plastic and packaging. The organic waste was dominated in Shireen Jinnah Colony, with food and plant waste comprising 38% and 12%, respectively, while only 10% and 8% of plastics and paper respectively. Other waste was negligible such as metals, glass, leather, textiles, ceramics, wood, and electronic. In Clifton Block 1, a more mixed waste was found, with food and plant waste at 32% and 10%, while recyclable plastics and paper at 15% and 12%. Other materials such as metals, glass, leather, textiles, ceramics, wood at (3%) and electronic at (1%). In Clifton Block 2, relatively lower organic waste (food 25%, plant 8%) was found while higher proportions of recyclable, dry, and packaged materials, including plastics (20%) and paper (15%). Other materials such as glass, metals, hazardous, and e-waste (3%). These differences highlight how waste type and compaction affect collection, transport, and treatment needs.

Survey findings revealed wide gaps in waste handling. In Shireen Jinnah Colony, MSW is thrown or stored in open sacks (18 households) or uncovered bins (9 households), producing less than 3 kg per day for most families. Segregation is not existed, and waste is collected by informal way. Residents have limited awareness of environmental impacts. In Clifton Block 1, waste storage system is a little better, covered bins (13 households) and uncovered bins (14 households. In Clifton Block 2, waste management system is better, covered bins for storage. Households have higher environmental awareness and willingness to pay for improved services. Across all zones, segregation at source was entirely absent. The collection fleet (1 tractor, 14 MT rickshaws, 2 armroll trucks, and 1 compactor) ensured coverage but was inadequate for peak demand, especially in dense zones. These gaps contribute to visible pollution, overflowing bins, and irregular collection in poorer neighborhoods.

Findings highlight the urgent need for zone-specific approaches. Low-income areas require need improved bin infrastructure, formalized collection, and organic waste treatment. Middle-income households require better scheduling, integration of recyclables, and community participation programs. High-income areas need stronger recycling systems, source segregation, and greater private sector involvement. This study, based on 90 households across three socio-economic zones, provides an important snapshot of waste generation and management practices in Clifton. While it focused on a specific timeframe, future studies may expand sample sizes, capture seasonal variations, and test pilot interventions to further enrich these findings.

RECOMMENDATIONS

Based on results of this study, it is observed that SWM in Clifton needs improvement based on zone-specific requirements. Policies must be developed to reflect need of these socio-economic zones, including household-level segregation into biodegradable and non-biodegradable fractions. Sindh Government should appreciate public–private partnerships because they can play a critical role in improving collection efficiency and potential for recyclable recovery.

Infrastructure improvements should be carried out for all different economic zones because as results reveals that Shireen Jinnah Colony generate organic, Middle- and high-income zones require proper segregation bins and recycling system. Similarly, the existing fleet of 18 collection vehicles is insufficient, there should be proper collection system for further treatment.

Awareness campaigns should focus on promoting household-level segregation, recycling, and composting practices, involving local associations, schools, and NGOs. Finally, further research is recommended to address existing knowledge gaps. Longitudinal studies capturing seasonal and temporal variations in waste generation and composition would provide a more complete understanding of household waste dynamics. Additionally, assessing the economic feasibility of resource recovery programs, such as composting and recycling, will guide investment decisions. Comparative studies between Clifton and other towns of Karachi could also inform broader, city-wide strategies for equitable and sustainable waste management. Collectively, these measures can support a more efficient, environmentally sound, and socially inclusive waste management system in Clifton.

FUTURE RESEARCH DIRECTION

Detailed study is required to solve waste issue in Karachi Pakistan:

- Conduct similar waste characterization studies in other districts of Karachi to compare waste generation patterns

- Investigate household willingness to segregate waste at the source and assess the feasibility of recycling and composting programs to reduce the volume of waste sent to disposal sites.

• Integrate GIS, population density, and waste generation data to optimize waste collection routes, identify high-waste generation hotspots, and improve the efficiency of municipal waste management services in Karachi.

REFERENCES

Afzal, A., Kausar, A., Lahori, A. H., Pathan, A. P., Sheeba, S. A., Saeed, G., Khan, O. I., Ejaz, F., & Maqsoom, A. (2024). Chapter 19 - Waste accumulation in the environment: case studies of Karachi and Larkana (Pakistan). *Advances in Energy from Waste*, 605–640. https://doi.org/10.1016/B978-0-443-13847-8.00019-1

Aghabeyk, F., Chen, B., Van Zijl, M. B., & Ye, G. (2025). Physicochemical characterization and resource recovery potential of hazardous municipal solid waste incineration (MSWI) fly ash and air pollution control (APC) residues in the Netherlands. *Journal of Environmental Management*, *384*, Article 125579. https://doi.org/https://doi.org/10.1016/j.jenvman.2025.125579

Aquino, L. F., Junior, S. F. S., Kahwage, S., Bila, D. M., Correia, F. V., Saggioro, E. M., Ritter, E., & Mannarino, C. F. (2025). Groundwater contamination and human health risks from leachate at a decade-closed dumpsite: A case study in Rio de Janeiro, Brazil. *Science of The Total Environment*, *1008*, Article 181034. https://doi.org/10.1016/j.scitotenv.2025.181034

Cantillo, T., Notaro, S., Bonini, N., & Hadjichristidis, C. (2023). Assessing Italian household preferences for waste sorting systems: The role of environmental awareness, socioeconomic characteristics, and local contexts. *Waste Management*, *163*, 22–33. https://doi.org/10.1016/j.wasman.2023.03.014

Dong, X., Song, J., & Duan, H. (2022). Prioritizing countries for implementing waste recycling under socioeconomic supports. *Journal of Environmental Management*, *322*, Article 116158. https://doi.org/https://doi.org/10.1016/j.jenvman.2022.116158

Khatri, K. L., Muhammad, A. R., Soomro, S. A., Tunio, N. A., & Ali, M. M. (2021). Investigation of possible solid waste power potential for distributed generation development to overcome the power crises of Karachi city. *Renewable and Sustainable Energy Reviews*, *143*, Article 110882. https://doi.org/10.1016/j.rser.2021.110882

Kumar, H., & M. (2025). Environmental and Health Impacts of Increased Municipal Solid Waste: A Sustainable Management Practice. *Art and Society*, *4*(5), 1–7. https://doi.org/10.63593/AS.2709-9830.2025.06.001

Lee, K. J. L., & Wong, S. F. (2023). Comparative environmental and socioeconomic assessment on mixed plastic waste management: A Singapore case study. *Science of The Total Environment*, *893*, Article 164884. https://doi.org/10.1016/j.scitotenv.2023.164884

Lubello, C., Fiaschi, S., & Notari, G. (2025). Municipal solid waste composition and efficiency of separate collection: A case study in Italy. *Cleaner Waste Systems*, *11*, Article 100272. https://doi.org/https://doi.org/10.1016/j.clwas.2025.100272

Maalouf, A., & Agamuthu, P. (2023). Waste management evolution in the last five decades in developing countries - A review. *Waste Manag Res*, *41*(9), 1420–1434. https://doi.org/10.1177/0734242x231160099

Nguyen, K. L. P., Chuang, Y. H., Chen, H. W., & Chang, C. C. (2020). Impacts of socioeconomic changes on municipal solid waste characteristics in Taiwan. *Resources,* *Conservation and Recycling*, *161*, Article 104931. https://doi.org/https://doi.org/10.1016/j.resconrec.2020.104931

Njewa, J. B., Mweta, G., Sumani, J., & Biswick, T. T. (2025). *The impact of dumping sites on air, soil and water pollution in selected Southern African countries: challenges and recommendations. Emerging Contaminants and Environmental Health*, *4*, Article 3. https://doi.org/10.20517/wecn.2024.71

Óskarsson, G. K., Agnarsson, S., & sdóttir, B. D. (2025). (Vol. 26). Retrieved from https://doi.org/https://doi.org/10.1016/j.indic.2025.100676

Páramo-Telle, Ó., & Vence, X. (2025). Socioeconomic factors explaining municipal solid waste generation in Galicia. Similarities and differences between aggregate magnitudes and fractions. *Waste Management*, *201*, Article 114794. https://doi.org/10.1016/j.wasman.2025.114794

Parvin, F., & Tareq, S. M. (2021). Impact of landfill leachate contamination on surface and groundwater of Bangladesh: a systematic review and possible public health risks assessment. *Appl Water Sci*, *11*(6), 100–100.

Saif, S., Razia, E. T., Khan, M., Hatshan, M. R., & Adil, S. F. (2025). A Comprehensive Introduction to Solid Waste Issues. *In Waste Derived Carbon Nanomaterials*, *1*, 1–16.

Sohoo, I., Ritzkowski, M., Guo, J., Sohoo, K., & Kuchta, K. (2022). Municipal Solid Waste Management through Sustainable Landfilling: In View of the Situation in Karachi. *Pakistan. International Journal of Environmental Research and Public Health*, *19*(2), Article 773. https://doi.org/10.3390/ijerph19020773

Sohoo, I., Ritzkowski, M., Heerenklage, J., & Kuchta, K. (2021). Biochemical methane potential assessment of municipal solid waste generated in Asian cities: A case study of Karachi. *Pakistan. Renewable and Sustainable Energy Reviews*, *135*, Article 110175. https://doi.org/10.1016/j.rser.2020.110175

Song, Y., Liu, D., Zhu, F., Zhang, C., Zhang, S., Li, T., Ji, Y., Dong, Y., Qi, W., Xu, X., Yu, B., Xu, M., & Liu, J. (2024). Urban food waste and socioeconomic drivers in China. *Earth Critical Zone*, *1*(1), Article 100015. https://doi.org/10.1016/j.ecz.2024.100015

Zhang, Z., Wang, J., Li, J., Wang, Y., Yin, K., & Fei, X. (2024). Impacts of regional socioeconomic statuses and global events on solid waste research reflected in six waste-focused journals. *Waste Management*, *182*, Article 113. https://doi.org/10.1016/j.wasman.2024.04.028

Zhu, J., Fei, X., & Yin, K. (2025). Assessment of waste-to-energy conversion technologies for biomass waste under different shared socioeconomic pathways. *Energy & Environmental Sustainability*, *1*(2), Article 100021. https://doi.org/10.1016/j.eesus.2025.100021