Sindh Solid Waste Management Board

WASTE AMOUNT CHARACTERIZATION SURVEY IN DISTRICT CENTRAL AND DISTRICT KORANGI OF KARACHI

Final Report

July 2021

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Preface

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The report is developed in compliance with the Terms of Reference set for the Waste Amount Characterization Survey for Central and Korangi District. The findings, conclusions and recommendations set out in the report are solely those of the consultant and or not binding on SSWMB or on any other organization.

The consultant would like to thank all those who assisted in the survey, particularly the Managing Director, Deputy Directors of Central and Korangi, staff of SSWMB, and the residents of the Union Councils who consented to participate in this survey.

Executive Summary

Efficient and sustainable management of solid waste is getting more attention at national and local levels. Sindh Solid Waste Management Board (SSWMB) collects and disposes of municipal solid waste in its jurisdiction. The amount of solid waste collection and disposal is based on the quantity of waste carried by each vehicle to the dumping site. However, the exact waste generation, according to the population estimate, has not been carried out. Similarly, the physical and chemical Characterization of solid waste has not been determined.

The general objective of the waste amount and characterization survey (WACS) is to obtain data on waste amount and composition of municipal solid waste generated in Karachi. The results/analysis of WACS shall be used as basic data to formulate the waste collection, 3R (reuse, recycle and recover) policy, intermediate treatment and waste disposal plans addressing inefficiencies of the existing solid waste management system.

An open-ended exploratory methodology was adopted for conducting the Waste Amount Characterization Survey in District Central and District Korangi. There are currently no internationally agreed-upon standards for waste stream analysis or Waste Amount Characterization Survey. However, many European countries have their national procedures.

The Environmental Protection Agency, Ireland Method for Waste Amount Characterization Survey was selected for the survey and sample size determination. A total of 1,767 households took part in the survey.

A total of 2,078.705 kg of solid waste was collected from 4,615 persons living in 756 households during the survey. The residential solid waste generation rate ranges from 0.368 to 0.491 kg/capita/day. The average residential solid waste generation rate is 0.450 kg/capita/day in District Central, Karachi.

Similarly, a total of 2,672.356 kg of solid waste was collected from 5,984 persons living in 1,011 households during the survey. The residential solid waste generation rate ranges from 0.397 to 0.495 kg/capita/day. The average residential solid waste generation rate is 0.447 kg/capita/day in District Korangi, Karachi.

Overall, in residential areas of District Central, Karachi, the highest percentage was found out to be of the kitchen or food waste at 56.00%, followed by Plastic at 16.30%, Pamper / Diapers / Sanitary Pads at 12.42%, Paper at 4.62%, textile at 3.65% and residue material remaining on the sheet at 1.59% and rest of the items were below 1%.

Overall, in residential areas of District Korangi, the highest percentage was found out to be of the kitchen or food waste at 52.56% followed by Pampers at 14.30%, Plastic at 13.86%, Textile at 4.01%, Paper at 3.72%, Dust at 2.89%, Residue material at 1.84%, Domestic Hazardous Waste at 1.32% and Leather and Rubber at 1.25% and rest of the items were below 1%.

The commercial waste generation rate of shops is 1.608 and 1.956 kg/day in District Central and District Korangi, respectively. Major components included plastic and papers indicating the recycling potential of commercial waste.

The density of residential solid waste (District Central) at high, middle & low incomes is 281.92 kg/m^3, 267.56 kg/m^3 and 266.97 kg/m^{3,} while the average density is 272.15 kg/m^3.

The density of residential solid waste (District Korangi) at high, middle & low incomes is 248.83 kg/m^3, 257.05 kg/m^3 and 251.57 kg/m^{3,} while the average density is 252.48 kg/m^3.

Based on the Waste Amount Characterization Survey findings, the potential uses of the waste stream as a resource have also been considered. The total number of recyclable materials is 21.76%. There is a potential for the establishment of Material Recovery Facilities at Garbage Transfer Stations.

The percentage of biodegradable wastes, i.e. kitchen waste, grass, wood, hairs and bones, accounts for 54.95% of the solid waste generated in residential areas. Kitchen waste also has a high percentage of moisture, i.e., 50~70%; therefore, composting has a high potential. Further, the average carbon-nitrogen ratio was found out to be 21.5, which is near to the recommended range, suitable for composting, which is 25 - 40. Combustible waste takes 26% of the residential waste. This shows potential for RDF and incineration treatment.

The energy content of District Central is 2339 kcal/kg, and for District Korangi, it is 1020 kcal/kg. Whereas the energy content (average LCV_{wb}) of Central and Korangi districts is 1680 kcal/kg. In general, the average lower calorific value of waste should be at least 1671 kcal/kg (7 MJ/kg) and must never fall below 1433 kcal/kg (6 MJ/kg). Without this value, there would be a need to constantly supply auxiliary fuel, which would increase the viability of an MSW incineration facility at risk.

Seasonal factors also play an important role in the determination of constant high calorific value evaluation throughout the year. Therefore, for District Central and District Korangi, the waste to energy option will be completely evaluated after a seasonal survey on Waste Amount Characterization Survey is conducted in District Central and District Korangi. The Waste Amount Characterization Survey needs to be carried out at least twice a year or preferably quarterly to obtain year-round results.

The Waste Amount Characterization Survey has provided necessary input data for the Solid Waste Management System design for Central and Korangi Districts of Karachi Division.

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Abbreviations & List of Units

%	Percentage
ASTM	American Standards for Material Testing
EPA	Environmental Protection Agency
GHG	Greenhouse Gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoS	Government of Sindh
GPS	Geographical Positioning System
GWP	Global Warming Potential
ISWA	International Solid Waste Association
IUCN	International Union for Conservation of Nature
kg	Kilogram
kg/c/day	Kilogram per capita per day
KP	Khyber Pakhtunkhwa
m^3	Cubic Metre
MJ/kg	Mega Joule per kilogram
mm	Millimetre
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
PET	Polyethylene Terephthalate
PKR	Pakistani Rupees
PPI	Project Procurement International
RDF	Refuse Derived Fuel
Rs.	Pakistani Rupees
sec	Seconds
Sq. km	Square kilometre
Sr. No	Serial Number
SGS	Société Générale de Surveillance (SGS)
SWM	Solid Waste Management
SSWMB	Sindh Solid Waste Management Board
UC	Union Council
WB	World Bank
WGR	Waste Generation Rate
WHO	World Health Organization

1 Introduction

1.1 Background

Karachi is one of the largest metropolitan cities in the world. Having a 16.05 million (2017 Census) population, the city has expanded exponentially over the last 30 years. In 2015, the built-up area of Karachi amounted to about 379.09 square kilometres, up from about 328.56 square kilometres in 2000.[1] Thus, the authorities responsible for maintaining and managing the municipal services face challenges in delivering public service to the citizens.

A very high demand scenario always existed specifically for improving rates of integrated waste reduction, reuse recycling and conversions systems for the entire metropolis while addressing health, environmental, climate change and safety concerns against the substantial probability of environmental disasters.

Sindh Solid Waste Management Board is mandated to perform municipal service within the municipal jurisdiction of any local council (after approval from the competent forum) through outsourcing, SSWMB since its inception, has outsourced Front End Collection of solid waste in four out of six Districts of Karachi Division, Presently, contractual arrangements of the solid waste management have not been successful in providing desired performance in providing core services of door-to-door collection of garbage, manual and mechanical sweeping, timely and efficiently lifting and cleaning of garbage, sorting and segregation of the collected and finally transportation to the designated landfill sites.

Current contract agreements also lack proper incentives for the improvement of service delivery and operational performance. Contacts also fail to include value recovery activities such as monetization of recyclables which may help offset public spending on the sector.

SSWMB is collecting and disposing of municipal solid waste in its jurisdiction. The amount of solid waste collection and disposal is based on the quantity of waste carried by each vehicle to the dumping site.

This Waste Amount Characterization Survey (WACS) provides information about the types and amounts of the materials that are in the waste stream. The analysis enables local authorities to gather information on the range of materials in their waste stream and the amount of each of these materials, and their relative proportions in their waste.

This study has focused only on municipal solid waste generation rate and the physical and chemical Characterisation of solid waste produced in SSWMB jurisdiction.

1.2 Scope of Work

The scope of work Waste Amount Characterization Survey is as follows:

- Estimate per capita waste generation rate (Kg/cap/day).
- Quantify the solid waste amount and Characterisation from various sources, i.e., commercial (markets) and residential (lower income group, middle-income group, and higher income group)

[1] https://www.statista.com/statistics/911665/pakistan-built-up-area-karachi/#:~:text=The%20statistic%20shows%20the%20built%20up%20area%20of,Pakistan%20from%201975%20to%202015%20%28in%20square%20kilometers%29 retrieved on 3rd July 2021

- Parameters used for testing and analysis will be physical and chemical characterization, moisture content, and ash.
- Find out the density of the municipal solid waste at the primary collection stage.
- Compare the findings of this study with previous studies conducted by any other institute/organization.
- Formulate recommendations based on findings of the study for the potential use of waste stream as a resource.

1.3 The objective of the Study

The general objective of the waste amount and characterization survey (WACS) is to obtain data on waste amount and composition of municipal solid waste generated in Karachi. The results/analysis of WACS shall be used as basic data to formulate the waste collection, 3R (reuse, recycle and recover), intermediate treatment and waste disposal plans addressing inefficiencies of the existing solid waste management system.

The specific objectives of the WACS are:

- To estimate per capita waste generation rate (Kg/cap/day).
- To determine the waste components and measure their fractions (percentage by weight).
- To determine the variation of solid waste generation in social classes of the households (low, middle, and high income).
- To estimate the fractions of recyclables, compostable and combustibles.
- To carry out chemical analysis to determine C/N ratio, Moisture content, Ash, and combustible components.
- The study will analyze the Waste to Energy (WtE), RDF and MRF potential of waste generating in the Central and Korangi districts of Karachi.

1.4 Organization Preparing the Report

M/s Project Procurement International, an Environmental and Management Consultancy Firm, Islamabad, has carried out the Waste Amount Characterization Survey of District Central and District Korangi.

The list of names, qualifications and roles of team members carrying out the WACS and the brief profile of PPI has been provided as **Annexure-1**.

1.5 Significance of the Study

The study provides a research-based Waste Amount Characterization Survey in the SSWMB jurisdiction area. The results will help SSWMB to improve its solid waste management operation and determine the revenue potential of its various waste stream.

SSWMB understands that improper solid waste disposal and management can cause all types of pollution: air, soil, and water, leading to a variety of adverse impacts. The U.S. Public Health Service identified 22 human diseases that are linked to improper SWM. Exhaust fumes from waste collection vehicles, dust gusting from disposal practices and the open burning of waste also contribute to overall health problems.[2]

The main impacts due to waste mismanagement of solid waste lead to the major environmental and health risk issues as follows:

- Accumulation of wastes in the street increases contact possibilities. It offers perfect conditions for propagating germs, insects, rats, and other disease vectors such as cholera and dengue fever.
- Burning of waste causes the emission of toxic substances to the air, such as dioxins and furans.
- Uncollected wastes often clog drains and cause the stagnation of water, the breeding of mosquitoes, or water bodies' contamination.
- Respiratory disorders may result from inhaling particulate matter, bio-aerosols, and volatile organic compounds (VOCs) during collection and disposal.
- Sanitary workers and waste pickers are prone to Punctures or injuries caused by pieces of glass, needles, or other objects, which is very common. This can lead to infections, tetanus, hepatitis, or HIV, especially if the wastes contain hazardous and medical materials.
- Health and safety issues to the population also arise from improper solid waste management, such as greenhouse gases are generated from the decomposition of organic wastes in landfills, and untreated leachate can pollute surrounding soil and water bodies.[3]

Possible environmental and health risks due to waste open burning and open dumping for municipal solid waste includes

- The leachate generated is released to the soil, polluting groundwaters mainly used for drinking and household purposes. The risks concern the health of the population through direct and indirect (agriculture) intake.
- The generation of methane and other GHGs increases global warming, the risk of local fires and the pollution of the atmosphere surrounding the final disposal sites
- The breeding of animals around the disposal sites and rodents and insects increases the risks of diseases transferring to the population through bites and direct contact with the animals.
- The uncontrolled disposal causes the release of waste fractions, mainly plastics, into water bodies, contaminating the rivers, lakes flowing to the oceans and the seas, causing marine pollution.

The emissions due to uncontrolled waste fires produce significant amounts of contaminants that affect the overall health of the population. Respiratory illnesses, especially in children, are common in areas with open burning practices. The generation of Carbon Monoxide, Carbon dioxide and other Greenhouse Gases affects the Global Warming Potential (GWP) more than the anaerobic degradation of organic waste.[4]

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[2] The Sustainable World 381 www.witpress.com, ISSN 1743-3541 (on-line) WIT Transactions on Ecology and the Environment, Vol 142, © 2010

[3] The Sustainable World 381 www.witpress.com, ISSN 1743-3541 (on-line) WIT *Transactions on Ecology and the Environment, Vol 142, © 2010*

[4] Un-Habitat. (2010). *Solid waste management in the world's cities*. UN-HABITAT

1.6 General Overview of Solid Waste Management Practices

Solid Waste Management is the generation, separation, collection, transfer, transportation, and disposal of waste in a way that considers public health, economics, conservation, aesthetics, and the environment and is responsive to public demands.[5]

Aside from a technical issue, solid waste management is strongly influenced by political, legal, social, cultural, environmental, economic, and available resources. All these issues need to be addressed to reach a sustainable solid waste management action.

The contradiction between increasing waste-generation rates and decreasing waste-disposal capacities is very important with the rapid socio-economic development. In response to this concern, the development of effective MSW management strategies with satisfactory economic and environmental efficiencies are highly desired.[6]

The financial cost of the MSW should be considered, as Asian countries alone spent about US$25 billion on solid waste management per year in the early 1990s; the figure is expected to rise to around US$50 billion by 2025.[7] Land disposal is the most common method adopted. In developed countries, well-managed landfills are governed by local councils that provide regular construction and maintenance.[8]

On the other hand, the waste in less legislated regions is disposed of in open dumps, which leads to severe environmental degradation and results in the loss of natural resources.

The comparison of practices in solid waste management between high, middle & low-income countries is shown in **Table 1.1**. Similarly, waste management practices in different studies of Pakistan are mentioned in **Table 1.2**.

[5] Iliyas, M. (2008). Disposal of Waste. Eds.: Iliyas M, Shah KS. Public Health and Community Medicine. 7th edition. Karachi: Time Publisher, 261-273.
[6] Al-Maaded, M., Madi, N. K., Kahraman, R., Hodzic, A., & Ozerkan, N. G. (2012). An overview of solid waste management and plastic recycling in Qatar. *Journal of Polymers and the Environment*, *20*(1), 186-194.
[7] Hoornweg D, Thomas L (1999) What a waste: solid waste management in Asia. World Bank Urban waste management working paper series no. 1, Washington
[8] Department of Energy (DOE/EIA) (1999) Report of greenhouse gas: methane emission from energy end use. EPA, USA

Table 1.1: Comparison of Solid Waste Management Practices in high, middle, and low-income countries

Activity	Low Income	Middle Income	High Income
Source Reduction	No organized programs, but reuse and low per capita waste generation rates are common.	Some discussion of source reduction, but rarely incorporated into an organized program.	Organized education programs emphasize the three 'R's' Policy — reduce, reuse, and recycle.
Collection	Sporadic and inefficient. Service is limited to high visibility areas, the wealthy, and businesses willing to pay. A high fraction of inert and compostables impact collection—overall collection below 50%.	Improved service and increased collection from residential areas. Larger vehicle fleet and more mechanization. The collection rate varies between 50 to 80%. Transfer stations are incorporated into the solid waste management system.	Collection rate greater than 90%. Compactor trucks and highly mechanized vehicles and transfer stations are common. Waste volume is a key consideration. Ageing collection workers are often a consideration in system design.
Recycling	Although most recycling is through the informal sector and waste picking, recycling rates tend to be high for local as well as international markets and imports of materials for recycling, including hazardous goods such as e-waste and ship-breaking. Recycling markets are unregulated and include a number of 'middlemen'—large price fluctuations.	The informal sector is still involved; some high technology sorting and processing facilities. Recycling rates are still relatively high. Materials are often imported for recycling. Recycling markets are somewhat more regulated. Material prices fluctuate considerably.	Recyclable material collection services and high technology sorting and processing facilities are common and regulated. Overall, recycling rates are higher than low and middle income. Informal recycling still exists (e.g. an aluminium can collection.) Extended product responsibility is common.
Incineration	Not common, and generally not successful because of high capital, technical, and operational costs, the high moisture content in the waste, and a high percentage of inert material.	Some incinerators are used but experiencing financial and operational difficulties. Air pollution control equipment is not advanced and often bypassed—little or no stack emissions monitoring. Governments include incineration as a possible waste disposal option but cost-prohibitive.	Prevalent in areas with high land costs and low availability of land (e.g., islands). Most incinerators have some form of environmental control and some type of energy recovery system. Governments regulate and monitor emissions.
Landfilling/ Dumping	Low-technology sites usually open dumping of wastes. High polluting to nearby aquifers, water bodies, settlements. Often receive medical waste. Waste is regularly burned—significant health impacts on local residents and workers.	Some controlled and sanitary landfills with some environmental controls. Open dumping is still common. CDM projects for landfill gas are more common.	Sanitary landfills with a combination of liners, leak detection, leachate collection systems, and gas collection and treatment systems. Often problematic to open new landfills due to concerns of neighbouring residents. Post-closure use of sites is increasingly important, e.g. golf courses and parks.
Costs	Collection costs represent 80 to 90% of the municipal solid waste management budget. Some local governments regulate waste fees, but the fee collection system is inefficient. Only a small proportion of the budget is allocated for disposal.	Collection costs represent 50% to 80% of the municipal solid waste management budget. Waste fees are regulated by some local and national governments, more innovation in fee collection e.g. included in electricity or water bills	Collection costs can represent less than 10% of the budget—large budget allocations to intermediate waste treatment facilities. Upfront community participation reduces costs and increases options available to waste planners (e.g., recycling and compost).

Source: Urban Development Series – Knowledge Papers, World Bank (*http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/Chap2.pdf*)

Table 1.2: Comparison of Solid Waste Management Practices in major cities of Pakistan

Activity	Lahore	Peshawar	Karachi
Source Reduction	No large scale and consistent programs are promoting source reduction, reuse and recycling. Lahore Waste Management Company carries out a cleanliness awareness drive occasionally. The activity aimed at briefing the public about the importance of cleanliness and plantation for a healthy life. [9]	No large scale and consistent programs are promoting source reduction, reuse and recycling. WSSP holds cleanliness drives, awareness drives and events such as Green Clean Peshawar. Community-based Mobilization sessions are planned in all 43 UC's of Peshawar for the awareness of the general public on the subject of WASH (Water and Sanitation, Hygiene)[10]	No large scale and consistent programs are promoting source reduction, reuse and recycling. Sindh Solid Waste Management Board holds cleanliness drives, awareness drives and events such as PSL cleaning activities.
Collection	Lahore Waste Management Company has outsourced collecting and lifting its solid waste to International Companies, namely Albaryak and Ozpak. [11]LWMC has an IT-based monitoring system of vehicles. The collection system of Lahore is considered the best in Pakistan.	WSSP is in charge of waste collection and transportation.	Sindh Solid, Waste Management Board, has outsourced four districts of Karachi Division for collection and lifting of its solid waste to International Companies.
Recycling/Treatment	There is no formal sorting of waste, and this activity is mainly in the hands of informal sector scavengers. Most of the recyclable materials consist of a variety of paper, cardboard, metal scrap, plastics, PETE bottles, dry bread, heals of shoes, bones etc. The price of an item depends on its quality or agreement among scavengers and contractors.[12] Lahore is one of the few cities where there are a compost plant and an RDF facility. However, both these facilities were not very successful.	There is no formal sorting of waste, and this activity is mainly in the hands of informal sector scavengers. The government has planned to build a Refuse Derived Fuel (RDF), Composting Plant and possibly a Waste to Energy Power Plant.[13]	Recyclable material collection services and high technology sorting and processing facilities are common and regulated. Overall, recycling rates are higher than low and middle income. Informal recycling still exists (e.g. an aluminium can collection.)
Landfilling/ Dumping	Lahore is the only place in Pakistan with an engineered sanitary landfill named Lakhodair Landfill.	The Water and Sanitation Services Peshawar (WSSP) is planning to build a sanitary landfill.	There are two landfill/ dumping sites in Karachi. However, Karachi still lacks an engineered sanitary landfill.

[9] http://albayrak.com.pk/clean-green-lahore-albayrak-team-distributes-saplings-among-citizens-to-promote-plantation/
[10] http://wssp.gkp.pk/en_US/#1461328919259-f69cd27c-5029
[11] https://www.lwmc.com.pk/index.php
[12] M Asim, S A Batool, M N Chaudhry, Scavengers and their role in the recycling of waste in Southwestern Lahore, Resources, Conservation and Recycling 2011
[13] https://www.bioenergyconsult.com/peshawar-swm/

2 WACS Methodology

2.1 Introduction

An open-ended exploratory methodology was adopted for conducting the Waste Amount Characterization Survey in the Central and Korangi districts of the Karachi Division.

2.1.1 Literature Review

The existing information and documents on Solid Waste Management in Pakistan have been reviewed and analysed, such as Solid Waste Management Strategy, Rules and Guidelines, Municipal Solid Waste Management Treatment and Disposal studies prepared by the Federal/Provincial Governments, International Donors, Public and Private Sector Organizations.

The literature review has provided a better understanding of solid waste management practices being adopted in Karachi and facilitated preparing data collection tools for the Waste Amount Characterization Survey.

Several previously conducted Waste Amount Characterization Surveys in Pakistan were reviewed, particularly their methodology and sample size, which helped in finalizing a sample size and methodology applicable in Pakistan's context.

2.1.2 Determination of WACS Methodology and Sample Size

There is currently no agreed international standard for waste stream analysis or Waste Amount Characterization Survey. However, many European countries have their national procedures. According to Dahlen and Lagervist, 200814, there are almost 20 methods available internationally, which are used in the Waste Amount Characterization Survey.

A comprehensive set of guidelines have been published by the Environmental Protection Agency, Ireland, "Municipal Waste characterization" 1996, where the whole methodology to conduct waste characterization study has been explained.15

To determine the sample size for the survey, the system boundary was first established. The area under this study is Central and Korangi districts of Karachi Division.

One of the requirements of SSWMB was that the samples should be spread in each zone of the respective district. To achieve this requirement, the sample size was adjusted to fulfil this requirement.

The EPA Ireland Method states that the number of household samples for a survey should be not more than 250 per day.

A sample size of 2,400 was selected from 11 sampling zones of Gulberg, North Nazimabad, Nazimabad II, Liaquatabad, North Karachi in Central district, and Model Colony, Shah Faisal, Qayyumabad, Allahwala Town, Landhi and Korangi in Korangi district as per EPA Ireland methodology for Municipal Waste Characterisation. The sampling areas were scattered to all zones in Central and Korangi districts.

The same areas included *residential* and *commercial* units. The stratified sampling procedure was adopted for the residential waste survey. The households were divided into three strata based on income level, such as a high, middle, and low-income level.

[14] Lisa &Anders, 2008, Methods for household waste composition studies, Waste Management 28 (2008) 1100–1112
[15] *https://www.epa.ie/pubs/reports/waste/wastecharacterisation/EPA_municipal_waste_characterisation.pdf*

Table 2.1: Sampling Program for District Central and District Korangi

Sr.#	District	Sampling Zone	Income Group	Number of Samples	Number of Days	Total Samples
1	Central	Gulberg	High	35	6	210
		North Nazimabad	Middle	35	6	210
		Nazimabad - II	Middle	85	4	340
		Liaquatabad	Low	35	6	210
		North Karachi	Commercia l	10	6	60
2	Korangi	Model Colony	High	35	6	210
		Shah Faisal	Middle	35	6	210
		Qayyumabad	Middle	85	4	340
		Allahwala Town	Low	85	4	340
		Landhi	Low	35	4	210
		Korangi	Commercia l	10	6	60
			Total	**485**		**2,400**

The details of the sampling areas along with GPS Coordinates have been provided as **Annexure-2**.

2.1.3 Relevance of selected methodology in the national/international context

The EPA Ireland methodology for Municipal Waste Characterisation is best applicable to the Waste Amount Characterisation Survey because the guidelines explain both the survey's sampling size and characterization method. Similarly, this selected methodology has been applied in 11 Cities / Towns of Pakistan.

The EPA Ireland methodology for Municipal Waste Characterisation has been prepared using the European Waste Catalogue and are reliable, has been practiced by the EPA Ireland since 1995 and have been updated with time.

In the national context, the methodology/sample size adopted for this survey is more comprehensive than the other solid waste surveys conducted in Pakistan. For example, a Waste Amount Characterization Survey conducted in Multan by a consulting firm took a total sample size of only 24 households for one week. Similarly, the Waste Amount Characterization Survey conducted in Sialkot took a sample size of 300 households from the whole city.

Similarly, a Baseline Study for Solid Waste Management in Karachi conducted by UNESCAP took a sample size of 1,440 households for the entire Karachi city. The Waste Amount Characterization Survey sample size in Central and Korangi districts has been kept higher than these studies for a better result.

2.2 WACS Methodology

The Waste Amount Characterization Survey started with an orientation meeting with SSWMB regarding selecting areas from all the zones in the Central and Korangi districts.

WACS Team: A total of 13 sanitary workers, laborers and supervisors were hired for the conduct of WACS in Central and Korangi districts. The consultant's team comprised of a Team Leader, two Environmental Engineers and two data collector supervisors. SSWMB nominated one focal person for coordination with the PPI team during the conduct of the survey.

HSE Plan for the Sanitary Workers: Personal Protective Equipment (PPEs) like gloves, masks, long boots, the Hi-Viz jacket were provided to the sanitary workers and laborers, as shown in **Figure 2.1**.

Training on the use and importance of PPEs was imparted to the whole team with specific reference to COVID-19.

Sampling points were selected in Central and Korangi District as shown in **Figure 2.2** and **Figure 2.3**. During the conduct of WACS, best management practices were adopted during collection, transportation to the segregation, identification, storage, and disposal was communicated. It included careful separation of different types of waste into distinct categories.

A first-aid box was kept at the waste segregation site in case of injuries. Sanitary workers were made aware of the first aid facility availability and an emergency number to contact the nearest health facility.[16]

Figure 2.1: PPEs and other tools used during conduct of WACS.

[16] https://www.who.int/water_sanitation_health/medicalwaste/140to144.pdf?ua=1

Establishment of a Temporary Waste Segregation Facility: A temporary waste segregation facility at Qayyumabad in Shah Faisal Town in an open ground. A tent was erected, and a first aid box, table, chairs, plastic sheets and weighing machines were placed for WACS.

Figure 2.2: Sampling areas from District Central for WACS

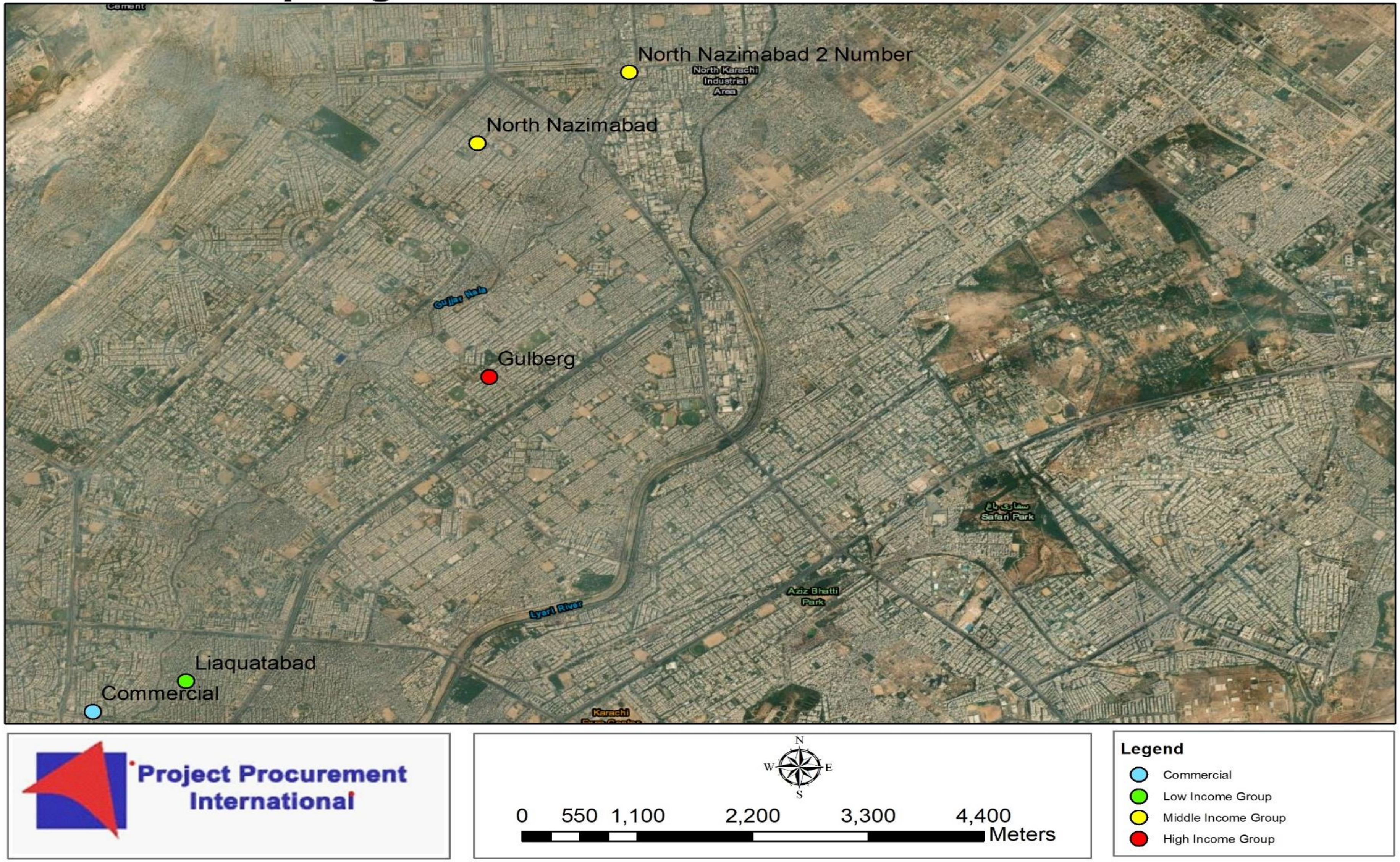
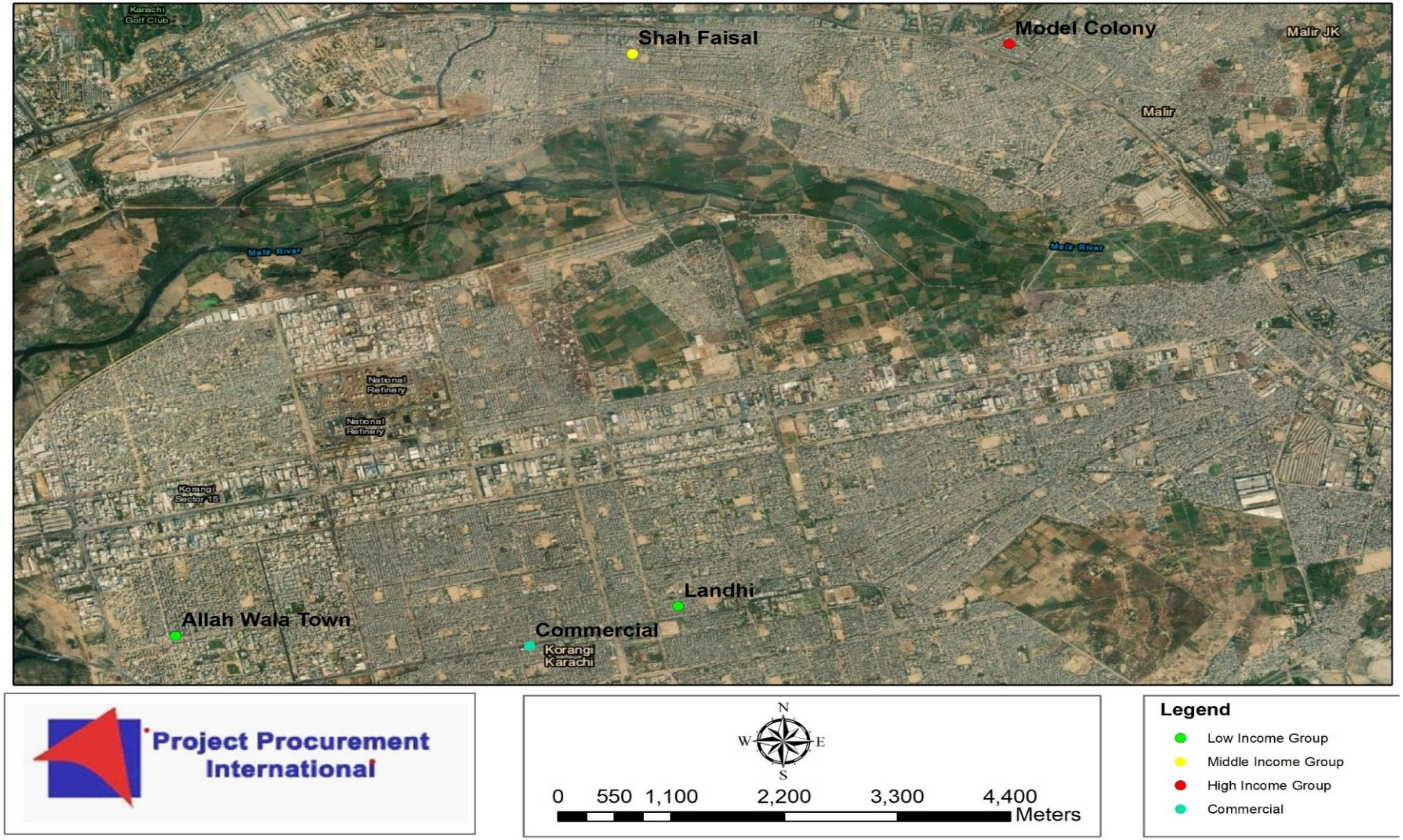


Figure 2.3: Sampling areas from District Korangi for WACS



Distribution of Waste Collection Bags: The waste collection bags of 10 kg were distributed to all households in all income groups and commercial units one day before the survey.

During the distribution of waste bags, the details about the number of persons in the household were noted. All the waste collection bags and the location of residential and commercial solid waste were tagged. The tagging number was placed on the premises and on waste collection bags, which assisted in identifying the waste generator.

Survey Day Plan: The solid waste bags were collected from each household and commercial area and brought to an open area in Suzuki pickups to the Waste Segregation Site.

Solid Waste Amount Survey: Each solid waste bag collected from households were weighed by using an electronic weighing machine at the Waste Segregation Site, and the amount of waste collected was noted.

Solid Waste Characterisation Survey: The Characterisation of solid waste generated from high, middle, and low-income areas as well as from commercial areas have been described hereunder.

The solid waste bags from all income groups were emptied into different piles based on the income group, i.e., three piles for the low, medium, and high-income group and one pile for the commercial areas. All the waste from each pile was mixed one by one, and bigger/bulky items were cut to make them into smaller pieces.

The density of waste was calculated by putting the waste into a 50-litre bucket. After that, the bucket was dropped from a height of 24-36 inches to allow the waste to settle naturally. As the solid waste settled, more waste was added to the bucket to fill it up. After this, the weight of the bucket was taken. The formula of the calculation of waste density is

Density (D) = $\mathrm{Mass}/\mathrm{Volume}$

The density was calculated by dividing the weight of waste by the volume of the bucket.

All solid waste was segregated into 11 categories for every income group and commercial area. A detailed description of each composition has been provided in **Annexure 4**.

Then the physical composition of waste was sorted into the following 15 items:

- Kitchen waste
- Paper and cardboard
- Textile
- Grass and wood
- Plastic – all types
- Leather and rubber
- Metal and tin beverages
- Bottle and glass
- Ceramic, stone, and soil etc.
- Domestic hazardous wastes
- Miscellaneous: Hairs, Bone, Tetra pack, Diapers, Dust/Sieve and E-Waste

The method for calculating the generation rate for the study was taken from the WHO Guidelines for solid waste management (1996). According to this guideline, the following formulas are used:

Mean daily solid waste generation rate = (Weight of total solid waste collected/Total family size/No. of sampling days) = Generation rate in kg/capita/day

Waste characterization = Weight of waste components/Total weight of waste X 100

2.3 Physical and Chemical Analysis of Solid Waste

2.3.1 Physical Parameters Analysis

Moisture Content

The moisture content was determined according to the ASTM D3173-03 standard. One gram of municipal solid waste was placed into an oven at 105℃ for two hours.

The sample is then cooled in a desiccator and reweighed. The difference in weight represented the moisture content of the sample expressed in percentage. The ratio of the weight of water present in waste to solid was expressed as a % of wet weight. The sample was taken to Société Générale de Surveillance (SGS) Karachi for moisture content testing.

M = (w – d) * 100 / w

Where m = moisture content, w = initial weight of sample (kg), d = dry wt. at 105˚ C

2.3.2 Chemical Parameters Analysis of Waste

A total of six samples were prepared for chemical analysis, i.e., from high, middle, low-income groups of Central and Korangi districts each.

The chemical analysis of solid waste was carried out by Société Générale de Surveillance (SGS) Karachi for proximate analysis, ultimate analysis, and calorific value.

i. Proximate analysis

The proximate analysis has been carried out to estimate the heating value of municipal solid waste fuel. This analysis is carried out to determine the characteristic of solid waste in terms of gross components of moisture, volatile matter, fixed carbon, and ash.

Volatile matter (additional loss of ignition at 950^{0}C): The applicable ASTM standard D7582 for the determination of volatile matter was used. The sample used for moisture determination was again heated in a covered crucible to avoid contact with air during devolatilization. The covered crucible was placed into a furnace at 950℃ for two hours. Then the crucible was taken out, cooled in a desiccator. The weight difference due to devolatilization was referred to as a volatile matter.

Ash (residue after burning): Ash is the inorganic solid residue left after the fuel is completely burned. The procedure used to determine ash is ASTM D3174. The remaining sample from the volatile matter is placed in the furnace at 575℃ for an hour for combustion. All carbon was burnt, and the sample was cooled and reweighted.

Fixed carbon (remainder): Fixed carbon in fuel is determined by the difference in the moisture, volatile matter, and ash contents.

FC= 100 - M - VM - ASH

Where: FC - Fixed carbon, M - Moisture, VM - Volatile matter and ASH – remaining ash

Fixed carbon represents the solid carbon in the MSW that remains in the char after the devolatilization process.

ii. Ultimate analysis: The ultimate analysis is the determination of the per cent of C (carbon), H (hydrogen), S (Sulphur) and ash.

The results are used to:

- Characterize the chemical composition of organic matter in municipal solid waste.
- Find the proper mix of waste material to obtain C/N ratios for biological conversion processes.

iii. Calorific value analysis

The calorific value of the sample is determined by using a standard bomb calorimeter.

The municipal solid waste samples are dried and grounded to small particles. The particles are sieved and compressed to form pellets. The bomb is assembled and filled with pressurized oxygen of about 30 bars. The firing circuit is tested, and the calorimeter is adjusted by weighing sufficient water into the calorimeter vessel to submerge the bomb completely. The bomb is fired, and after the temperature stabilization, the differences are noted and recorded. The calorific value of solid waste is calculated according to ASTM D5865.

2.3.3 Quality Control and Quality Assurance

A quality Control and Quality Assurance protocol for the WACS was implemented and checked by the Competitive and Livable City of Karachi (CLICK) Team.

The methodology for the conduct of WACS in the Central and Korangi districts of Karachi has been presented in **Figure 2.4**.

2.3.4 Challenges faced during the survey.

There was reluctance from the households to participate in WACS. The solid waste from the majority of households in Central and Korangi districts is collected by waste pickers.

During the WACS, they presumed that their business of collecting solid waste was in danger, so they did not cooperate. The waste pickers have themselves allotted their areas from where they collect household waste against a monthly payment.

Figure 2.4: Flow Diagram of Methodology of WACS of Central and Korangi Districts

Pictorial Presentation of Methodology

Identification of High, Middle and Low-Income Group

Exhibit 2.1: A view of the typical street from a High-income area (Gulberg, District Central)

Exhibit 2.2: View of a street from a middle-income area (North Nazimabad, District Central)

Exhibit 2.3 A view of typical passage from a low-income area (Liaquatabad, District Central)

Exhibit 2.4: A house with a middle-income area (Shah Faisal Colony, District Korangi)

Exhibit 2.5: A view of typical passage from a low-income area (Landhi, District Korangi)

Exhibit 2.6: A view of a street from a high-income area (Model Zone, District Korangi)

Creation and Training of Solid Waste Survey Teams

Conducting General Interview about the Household Size and Distribution of Plastic Bags

Solid Waste being Collected and Transferred to Segregation Site

Weighing Waste for Density

Classification of Waste and Weighing each Component

Quality Control / Quality Assurance of SSWMB / CLICK Staff

3 Findings of Waste Amount Characterization Survey

3.1 Introduction

The findings of the Waste Amount Characterisation Survey of Central and Korangi districts have been described in this chapter.

3.2 Summary of Conduct of Survey

The Waste Amount Characterization Survey for District Central and District Korangi was conducted for ten days from 20th – 24th February 2021 and 6th – 12th March 2021.

A total of 2,400 households were targeted. Solid waste was collected from 1,767 households (360 high income, 786 middle income and 621 from the low-income area).

The response rate to the survey was 74%. The Waste Amount Characterization Survey forms have been provided in **Annexure-5**.

Table 3.1: Summary of Conduct of WACS in District Central & District Korangi, Karachi

Districts	Survey Duration	No of Households				Average Household size	Household Samples Targeted
	No of Days	High Income	Middle Income	Low Income	Total Households		
Central & Korangi	10	360	786	621	1,767	6.00	2,400

3.3 Central District, Karachi

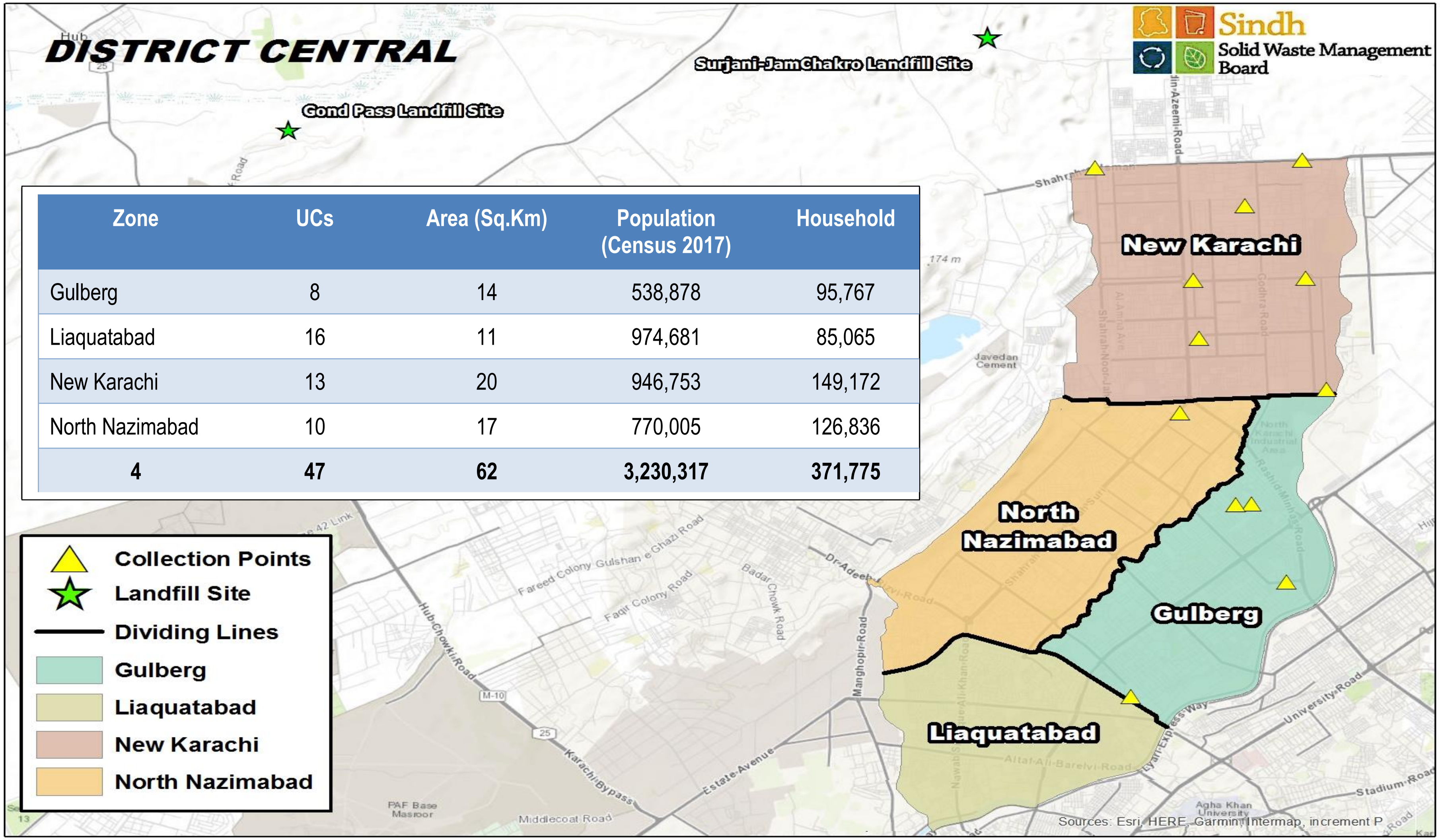
Central District is an administrative district of Karachi Division in Sindh, Pakistan. It is in the central part of Karachi. The district is comprised of four zones, i.e., Gulberg, Liaquatabad, North Nazimabad and New Karachi, with 371,775 households. There are 47 union councils in Central district with a total area of 62 square kilometers. There are 371,775 households.

The land use analysis of Central district shows that it is predominately a residential area with moderate commercial and industrial areas.

Table 3.2: Land use analysis of Central District

Zone	Residential Area	Commercial area	Industrial area
Gulberg	73	10	17
Liaquatabad	89	11	0
New Karachi	84	6	10
North Nazimabad	84	16	0

Figure 3.1: Map of Central District, Karachi



Zone	UCs	Area (Sq.Km)	Population (Census 2017)	Household
Gulberg	8	14	538,878	95,767
Liaquatabad	16	11	974,681	85,065
New Karachi	13	20	946,753	149,172
North Nazimabad	10	17	770,005	126,836
4	**47**	**62**	**3,230,317**	**371,775**

Figure 3.2: Map of Gulberg Zone, Central District, Karachi

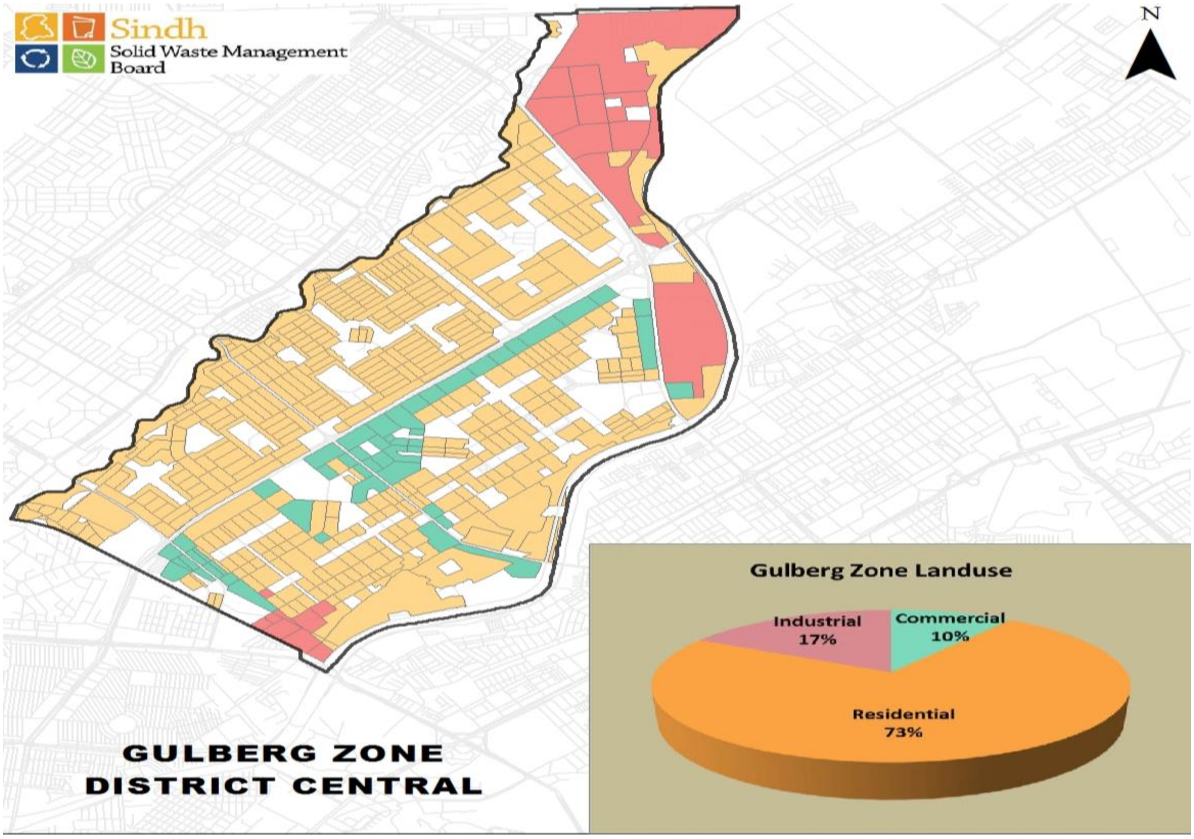


Figure 3.3: Map of Liaquatabad Zone, Central District, Karachi

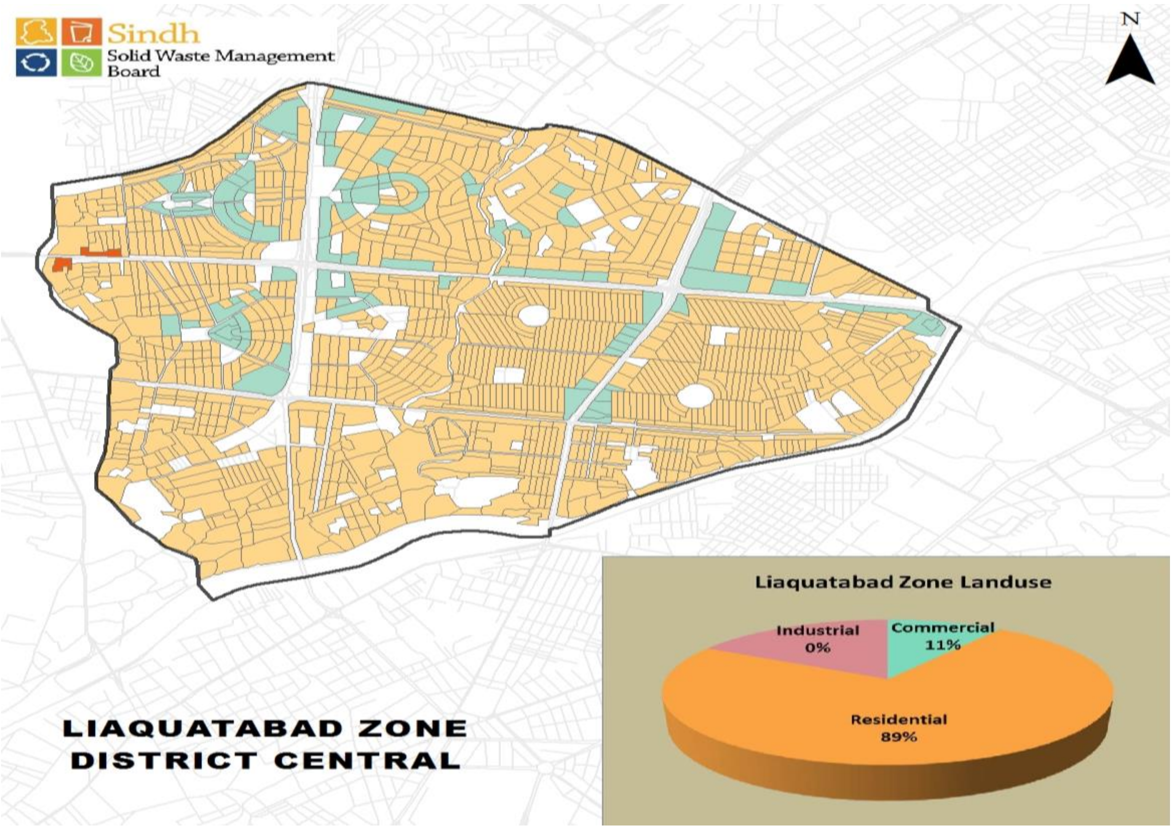


Figure 3.4: Map of New Karachi Zone, Central District, Karachi

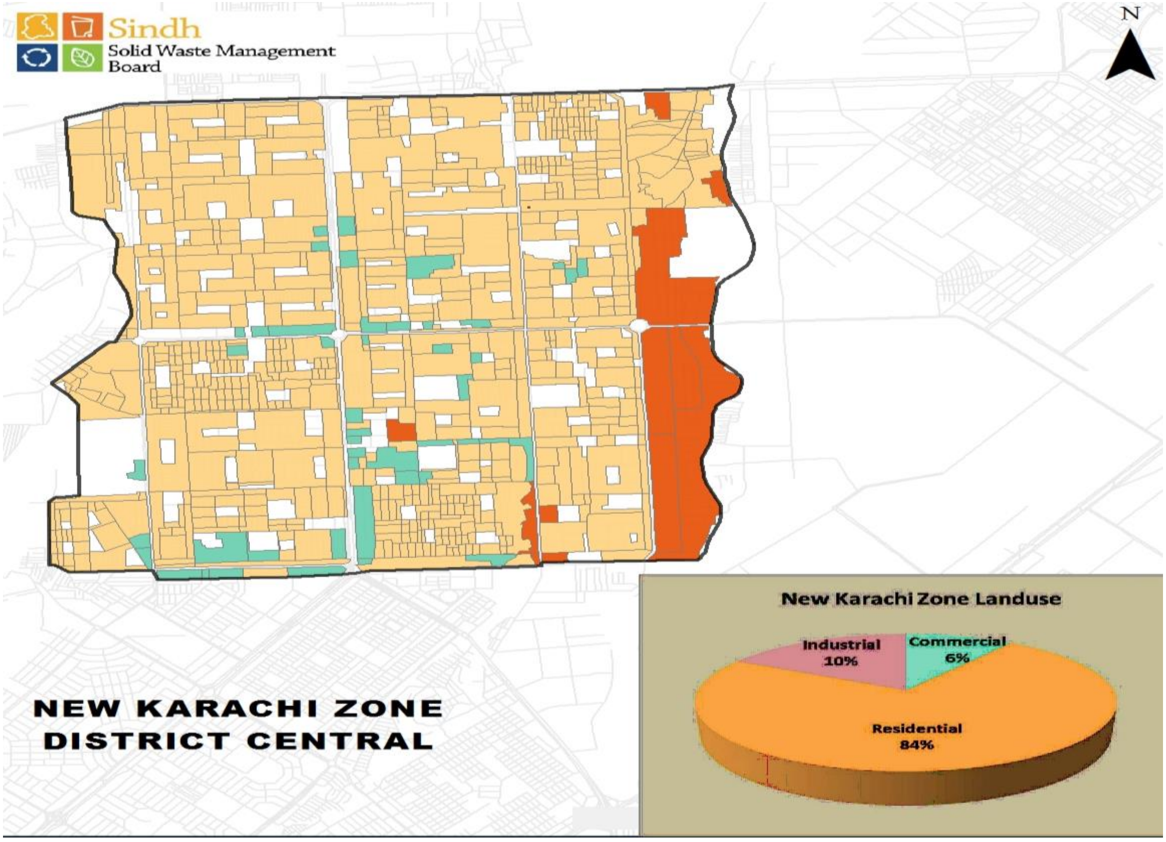
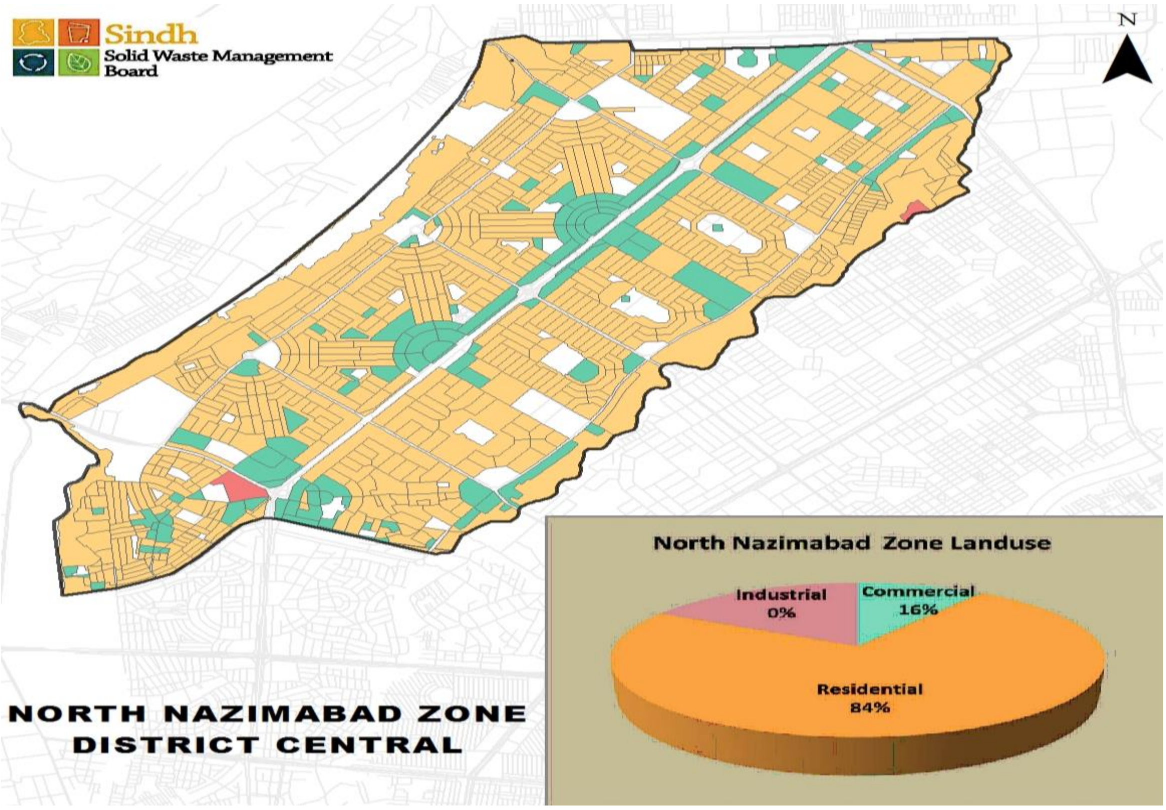


Figure 3.5: Map of North Naziabad Zone, Central District, Karachi



3.4 Residential Solid Waste Generation Rate of District Central, Karachi

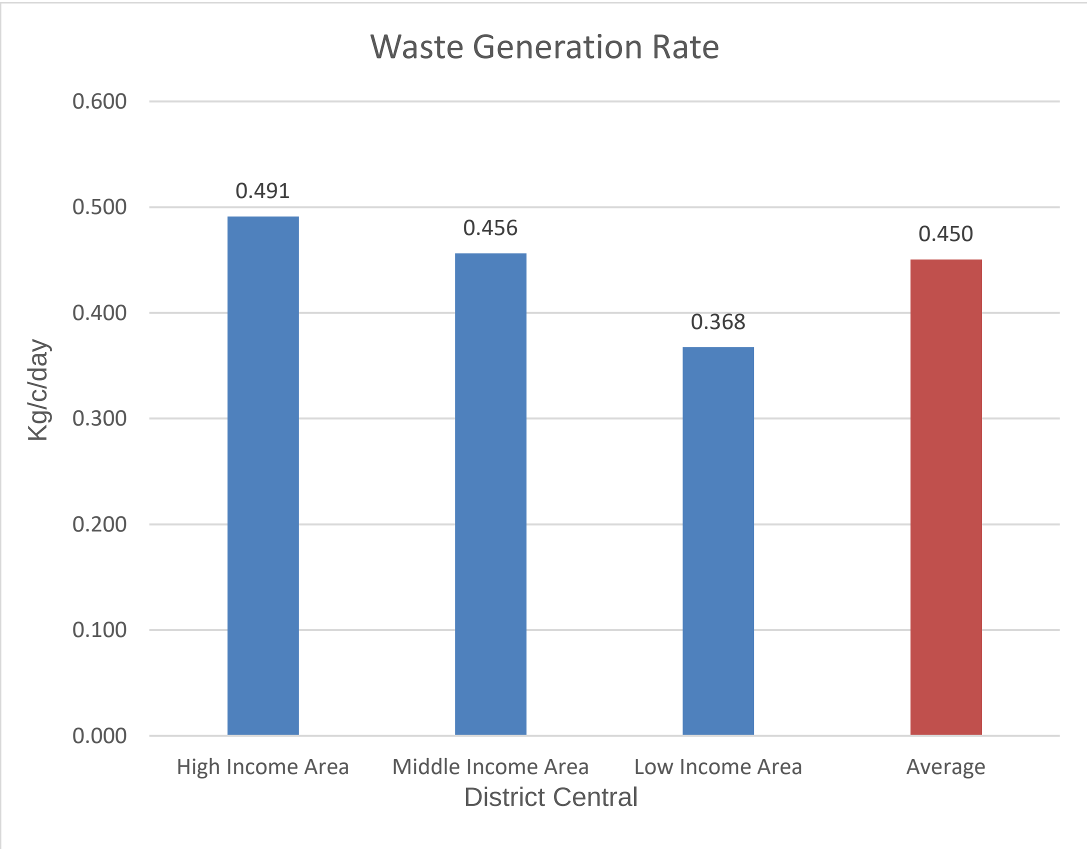
A total of 2,078.705 kg of solid waste was collected from 4,615 persons living in 756 households during the survey. The waste generation rate per household is 2.750 kg, and the average household size is 6.10. The residential solid waste generation rate is 0.450 kg/capita/day in Central district.

Table 3.3: Solid Waste Generation Rate in District Central

Area	Total Weight collected/analysed	Number of People	Samples Collected	Per Household WGR (kg/HH)	Per Capita WGR	Household Size
High-Income Area	486.663	991	174	2.797	0.491	5.70
Middle Income Area	1335.502	2926	431	3.099	0.456	6.79
Low Income Area	256.539	698	151	1.699	0.368	4.62
Total / Average	**2,078.705**	**4,615**	**756**	**2.750**	**0.450**	**6.10**

The residential solid waste generation rate ranges from 0.368 to 0.491 kg/capita/day. The highest solid waste generation is 0.491 kg/capita/day in the high-income area, 0.456 kg/capita/day in middle income and 0.368 kg/capita/day in the low-income group areas of Central district.

Figure 3.6: Waste Generation Rate in District Central, Karachi



The major factors that affect solid waste generation rate are the standard of living, cultural behaviour and attitude of the community towards solid waste management.

For example, in high-income areas, the solid waste characterization included higher percentages of kitchen waste, pampers and ceramic. This can be cited as one of the reasons for the higher waste generation rate in high-income areas.

3.5 Korangi District

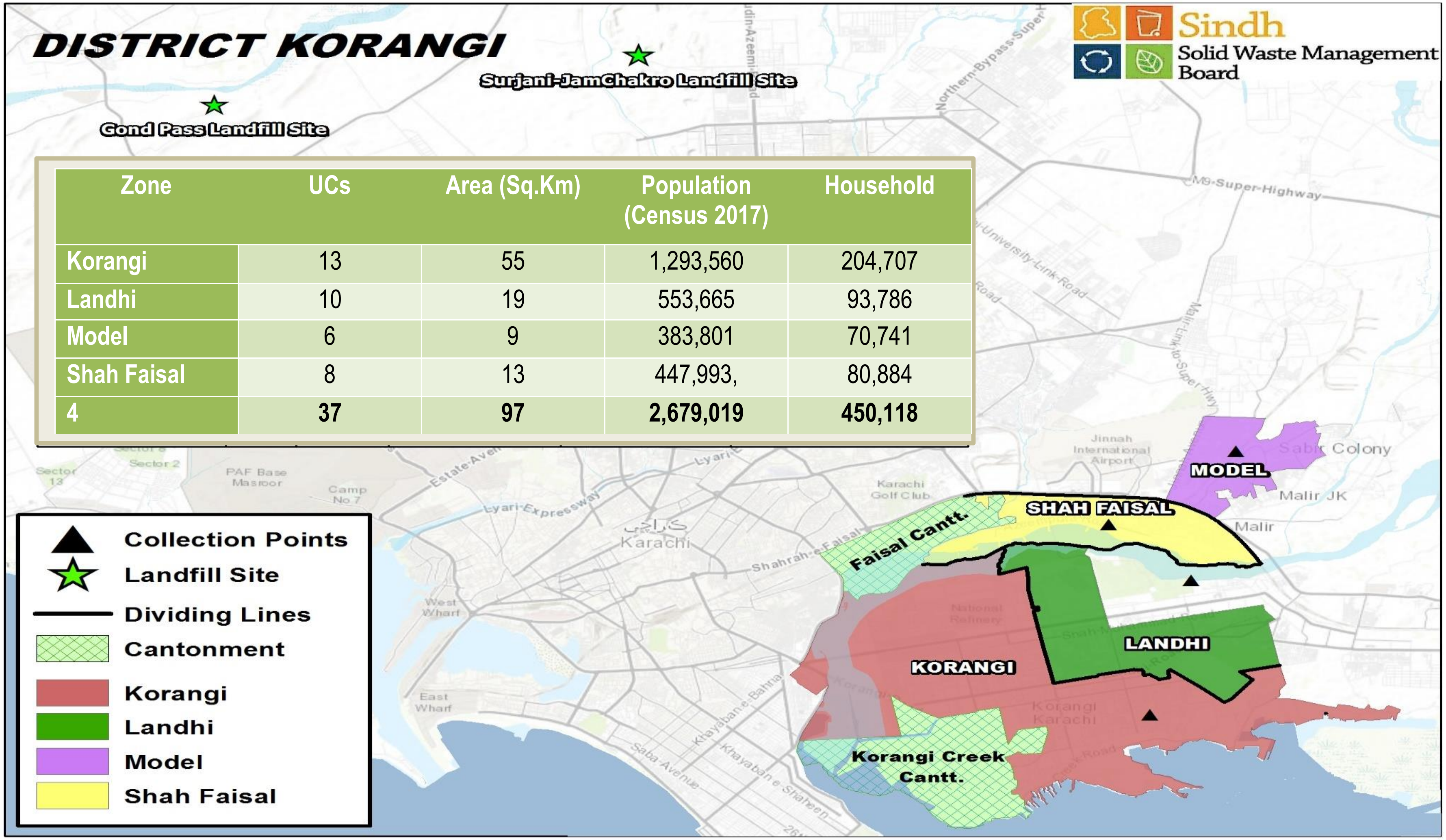
Korangi district is an administrative district of Karachi Division in Sindh, Pakistan. It is in the South-eastern part of Karachi. The district is comprised of four zones, i.e., Korangi, Model, Shah Faisal and Landhi, with 450,118 households. There are 37 union councils in Korangi district with a total area of 97 square kilometer.

The land use analysis of Central district shows that it is predominately a residential area with considerable industrial and commercial areas.

Table 3.4: Land use analysis of District Central

Zone	Residential Area	Commercial area	Industrial area
Korangi	60	30	10
Model	93	7	0
Shah Faisal	91	9	0
Landhi	75	7	8

Figure 3.7: Map of District Korangi, Karachi



Zone	UCs	Area (Sq.Km)	Population (Census 2017)	Household
Korangi	13	55	1,293,560	204,707
Landhi	10	19	553,665	93,786
Model	6	9	383,801	70,741
Shah Faisal	8	13	447,993,	80,884
4	**37**	**97**	**2,679,019**	**450,118**

Figure 3.8: Map of Korangi Zone, District Korangi, Karachi

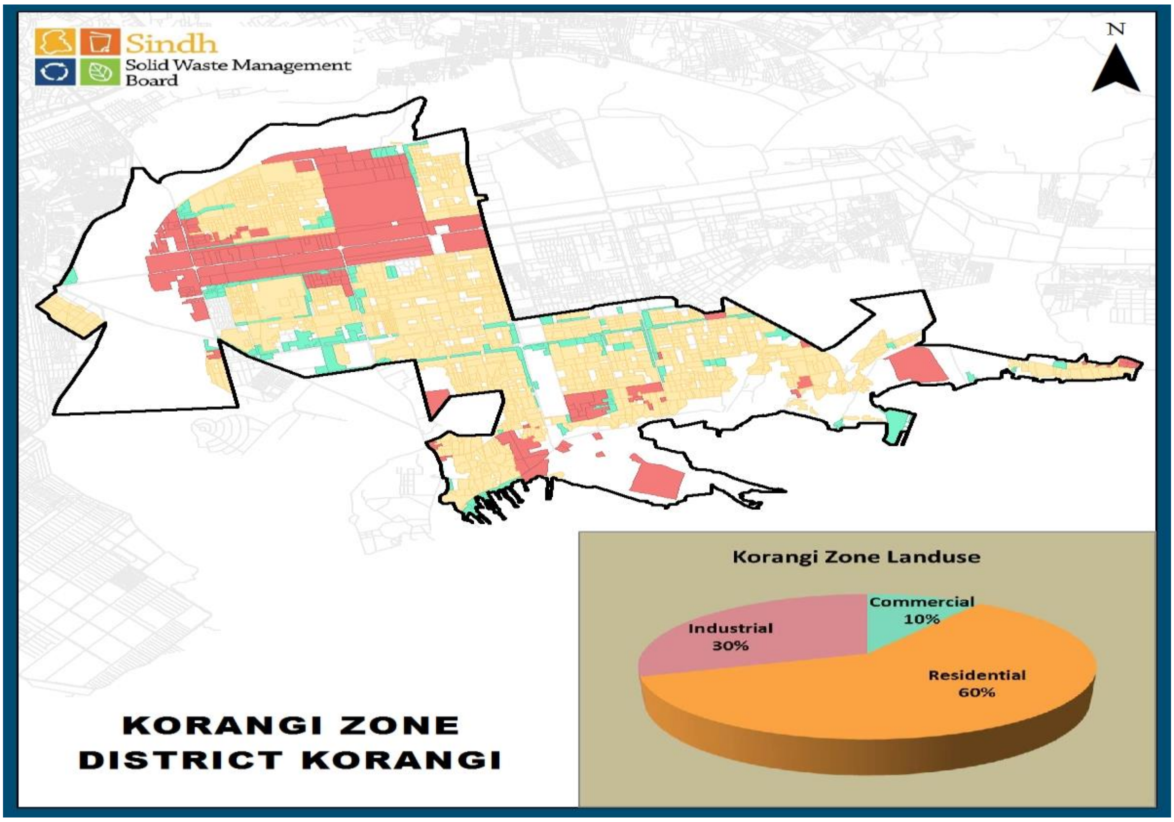


Figure 3.9: Map of Landhi Zone, District Korangi, Karachi

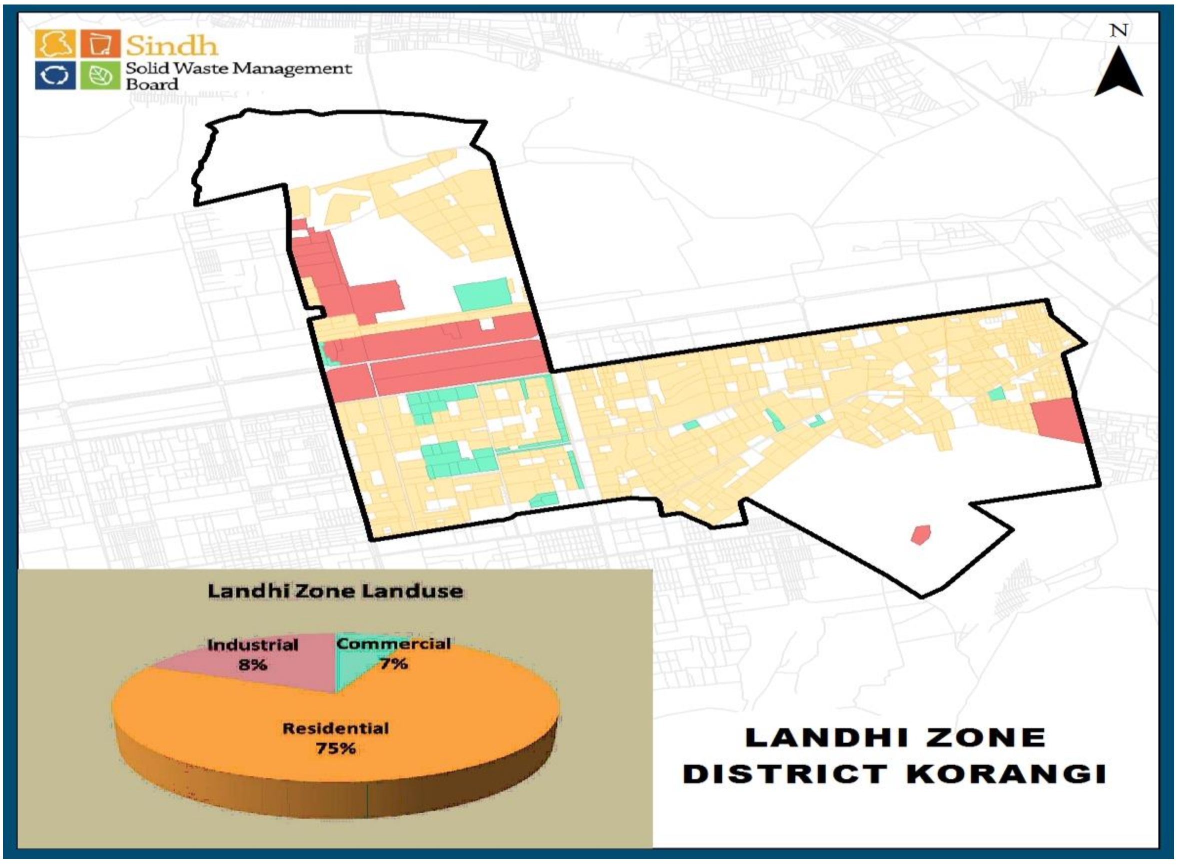


Figure 3.10: Map of Model Zone, District Korangi, Karachi

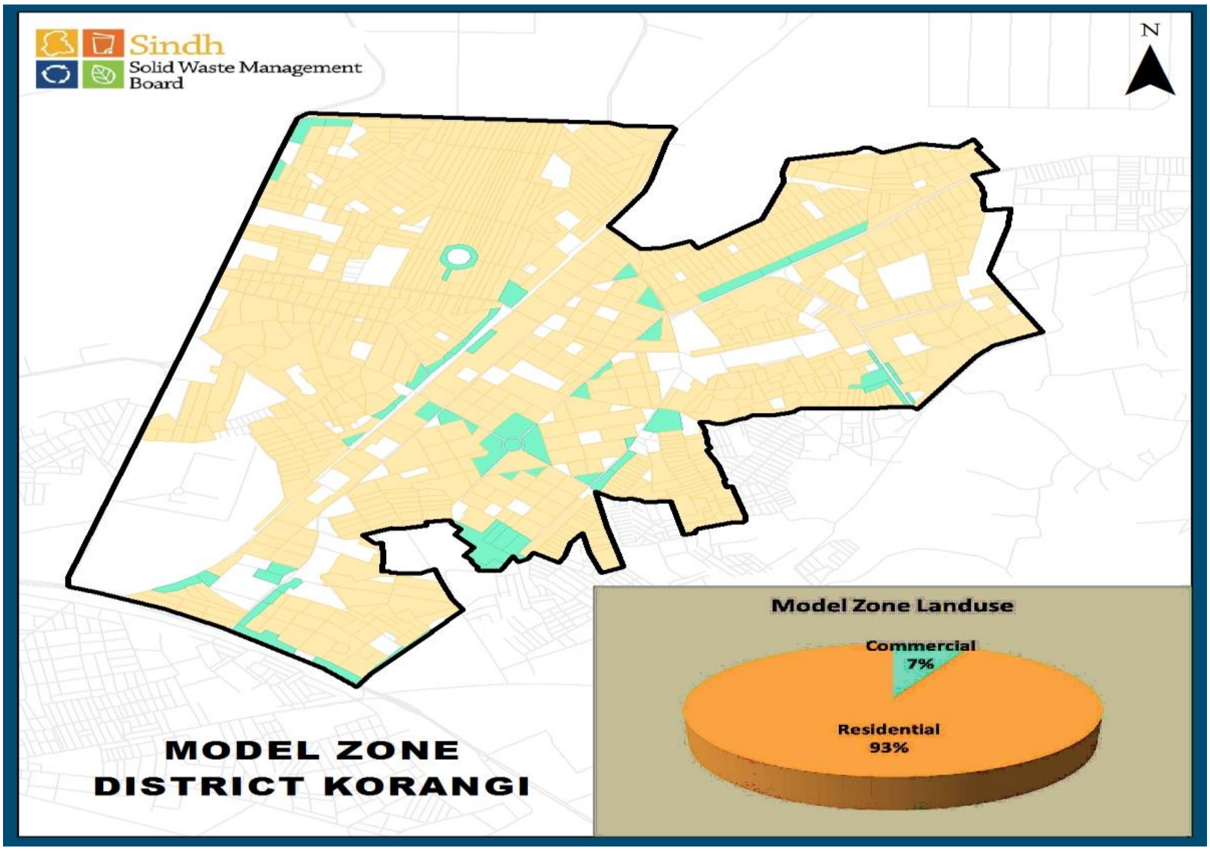
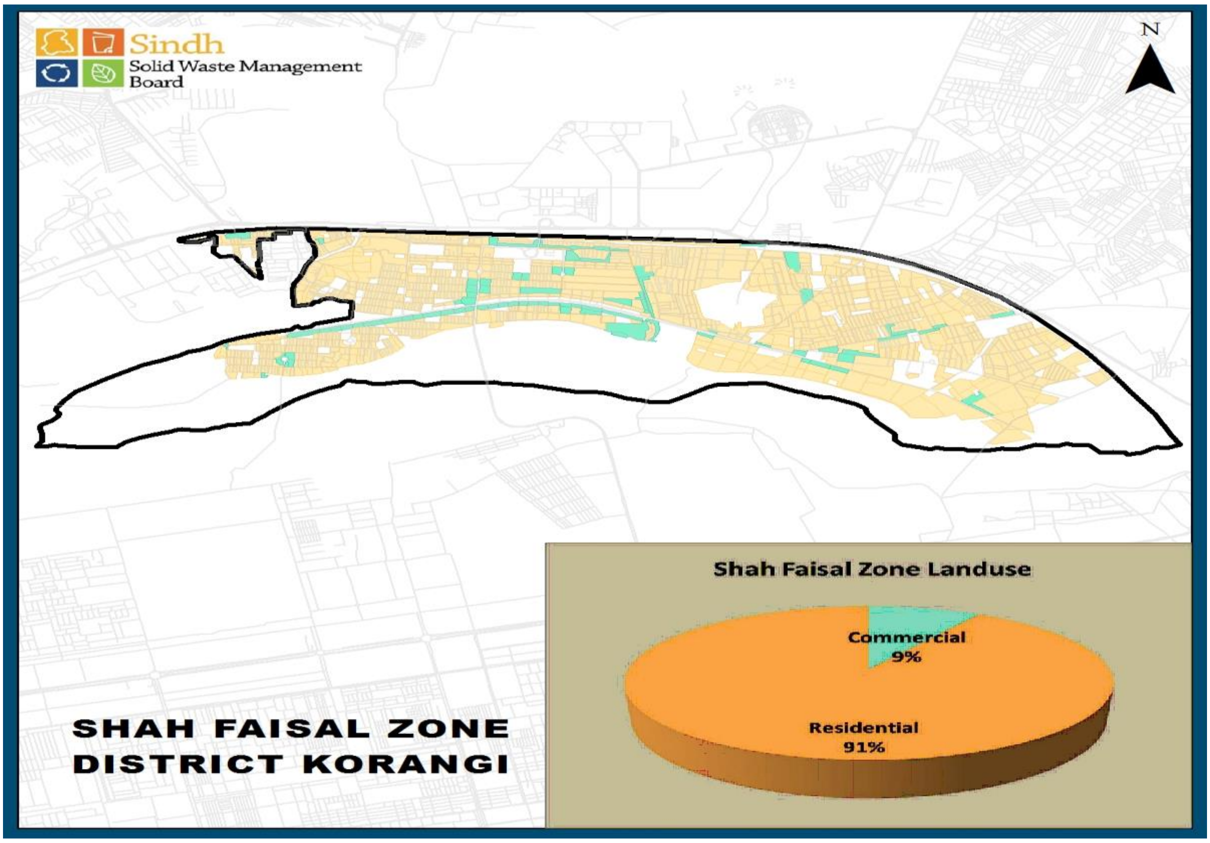


Figure 3.11: Map of Shah Faisal Zone, District Korangi, Karachi



3.5.1 Residential Solid Waste Generation Rate of District Korangi

A total of 2,672.356 kg of solid waste was collected from 5,984 persons living in 1,011 households during the survey.

The waste generation rate per household is 2.643 kg, and the average household size is 5.92. The residential solid waste generation rate is 0.447 kg/capita/day in the Korangi district.

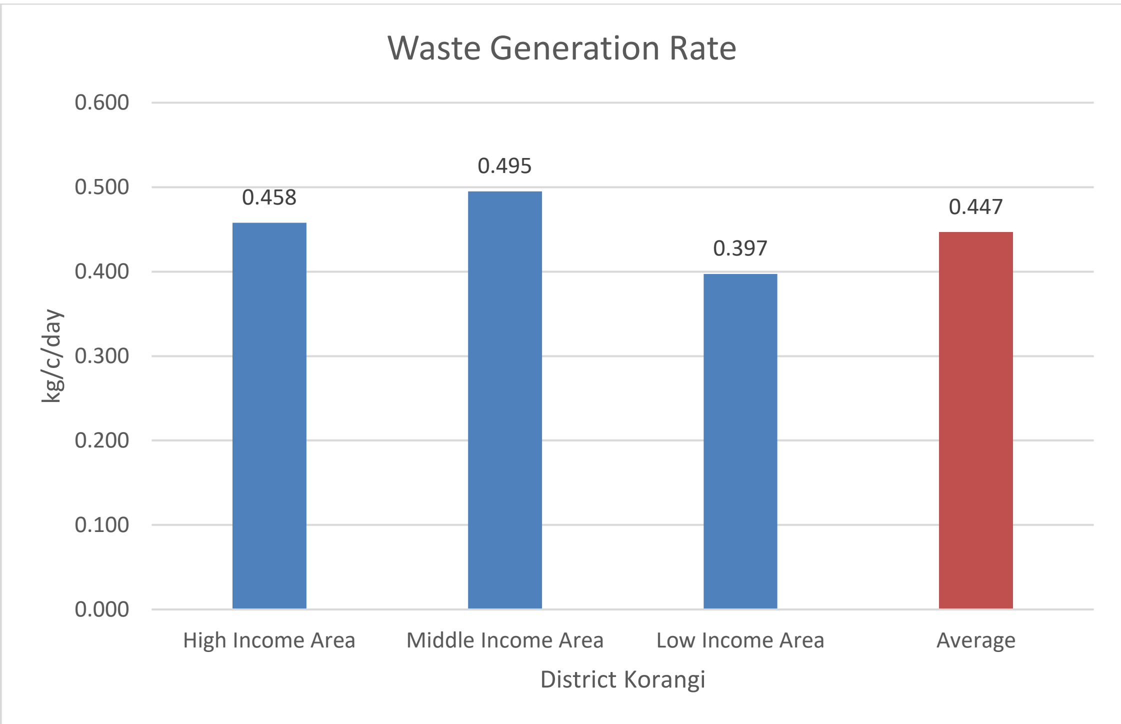
Table 3.5: Solid Waste Generation Rate in District Korangi, Karachi

Area	Total Weight collected/analysed	Number of People	Samples Collected	Per Household WGR (kg/HH)	Per Capita WGR	Household Size
High-Income Area	643.157	1405	186	3.458	0.458	7.55
Middle Income Area	1064.084	2149	355	2.997	0.495	6.05
Low Income Area	965.115	2430	470	2.053	0.397	5.17
Total / Average	**2,672.356**	**5,984**	**1,011**	**2.643**	**0.447**	**5.92**

The residential solid waste generation rate ranges from 0.397 to 0.495 kg/capita/day. The highest solid waste generation is 0.495 kg/capita/day in the middle-income area. In comparison, the lowest is 0.397 kg/capita/day in the low-income area.

One of the reasons that can be associated with a high waste generation rate in the middle-income area is because the percentages of food waste and ceramics in the waste were highest.

Figure 3.12: Waste Generation Rate in District Korangi, Karachi



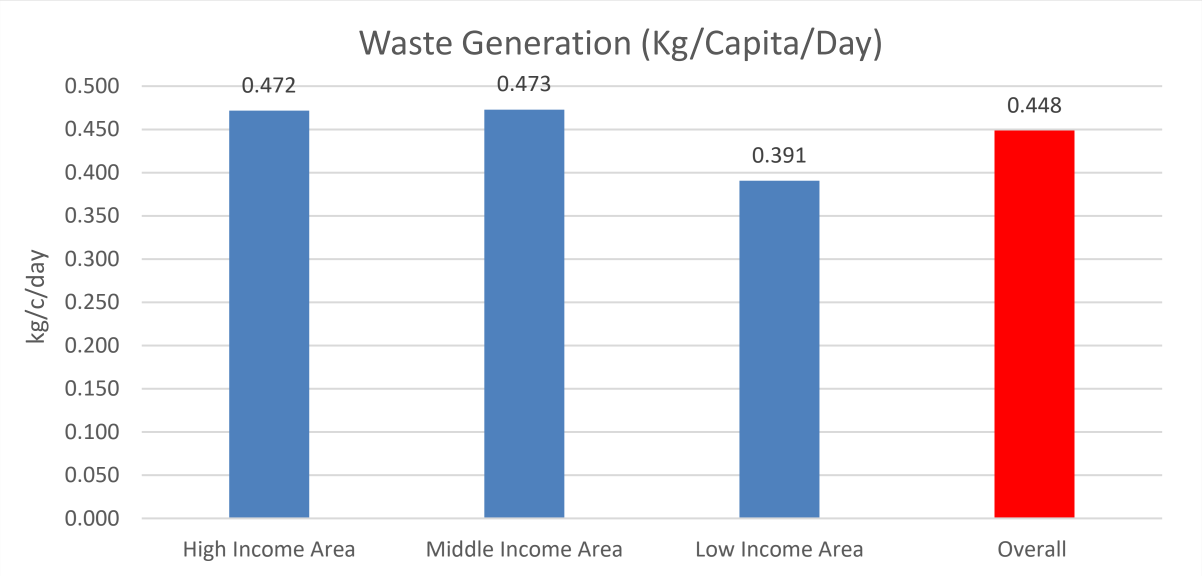
3.5.2 Overall Residential Solid Waste Generation Rate

The overall residential solid waste generation rate in District Central and District Korangi District is 0.448 kg/capita/day. **Table 3.5** provides details of the solid waste generation rate of District Central and District Korangi. The overall residential solid waste generation rate ranges from 0.391 to 0.473 kg/capita/day.

Table 3.6: Residential Solid Waste Generation Rate for all Income Groups for District Central and District Korangi

No.	District	High Income				Middle Income				Low Income				Total			
		No. of Household	Number of Persons	Waste Collected (kg)	Waste Generation Rate (kg/capita/day)	No. of Household	Number of Persons	Waste Collected (kg)	Waste Generation Rate (kg/capita/day)	No. of Household	Number of Persons	Waste Collected (kg)	Waste Generation Rate (kg/capita/day)	Total Household	Number of Persons	Total Waste Collected (kg)	Waste Generation Rate (kg/capita/day)
1	Central	174	991	486.663	0.491	431	2,926	1335.502	0.456	151	698	256.540	0.368	756	4615	2078.705	0.450
2	Korangi	186	1405	643.157	0.458	355	2,149	1064.084	0.495	470	2430	965.115	0.397	1011	5984	2672.356	0.447
	Total / Average	**360**	**2,396**	**1129.82**	**0.471**	**786**	**5,075**	**2,399.586**	**0.473**	**621**	**3128**	**1221.655**	**0.391**	**1767**	**10,599**	**4751.061**	**0.448**

Figure 3.13: Waste Generation Rate for Income Groups in Central and Korangi Districts (Combined), Karachi



3.5.3 Solid Waste Generation Rate - Commercial

The commercial solid waste was collected to estimate the amount of commercial waste generation and its characterization. For this purpose, the source of commercial waste, i.e., shops, were targeted.

Solid waste was collected from 10 shops in Central District - New Karachi and ten shops in Korangi District – Korangi for six days during the survey.

The Waste Amount Characterization Survey found that overall, a shop generates 1.771 kg/day in Central and Korangi District combined.

Table 3.7: Solid Waste Generation Rate in Commercial streams

Category		Unit	Waste Generated (Kg/unit/day)
Commercial	Central	per shop	1.608
	Korangi	per shop	1.956

3.6 Total Waste Generation of District Central and District Korangi, Karachi

The findings of WACS provides an idea to waste management companies on how much resources should be allocated to an area or zone. The resources include the number of sanitary workers employed, waste containers to provided, number of trips by vehicles to transport waste from household up to landfill site.

There is a need to calculate the total waste generated in Central and Korangi districts. However, to fully calculate the waste generation of a district or city, waste from the commercial, institutional, and industrial areas have to be estimated.

In a Waste Amount Characterization Survey carried out in Gujranwala by JICA[17], the solid waste generated from commercial areas is assumed to be 14%. Similarly, several studies indicate that much of the municipal solid waste from developing countries is generated from households (55–80%), followed by commercial or market areas (10–30%) with varying quantities from streets, industries, and institutions[18].

3.6.1 Total Waste Generation of District Central

The Waste Amount Characterization Survey has revealed that the Residential Waste Generation Rate of District Central is 0.450 kg/c/day.

For quantifying commercial waste in District Central, the commercial waste has been assumed to be 15% of the residential waste generation and 15% of the residential waste is assumed to be taken as Bulk Waste.

The total Waste Generation Rate of the Central District is **0.585 kg/c/day**.

Table 3.8: Estimated total Waste Generation Rate in Central District

Type of Waste	WGR (kg/c/day)
Municipal Solid Waste (MSW) Rate	0.450
Commercial Waste @ 15% of MSW Rate (Fruit & Vegetable Market, Street sweeping, Parks)	0.068
Bulk Waste @ 15% of MSW Rate (Bulk Waste)	0.068
Overall Waste Generation Rate including Commercial & Bulk Waste	**0.585**

After considering all these factors, District Central has a total waste generation of **1839 tons per day** in 2021. **Table 3.10** shows the waste quantities to be generated by the Year 2030 in Central district.

3.6.2 Total Waste Generation of Korangi District

The commercial waste has been assumed to be 10% of the residential waste generation, and 25% of the residential waste is assumed to be taken as Bulk Waste for Korangi district. According to the WACS analysis, the residential waste generation rate per capita in the District Korangi is 0.447 kg/c/day.

Table 3.9: Estimated Overall Waste Generation Rate in Korangi District

Type of Waste	WGR (kg/c/day)
Municipal Solid Waste (MSW) Rate	0.447
Commercial Waste @ 10% of MSW Rate (Fruit & Vegetable Market, Street sweeping, Parks)	0.045
Bulk Waste @ 25% of MSW Rate (Bulk Waste)	0.112
Overall Waste Generation Rate including Commercial & Bulk Waste	**0.603**

The total Waste Generation Rate of Korangi District is 0.603 kg/c/day. After considering all these factors, District Korangi has a total waste generation of 1,631 tons per day in 2021. **Table 3.11** shows the waste quantities to be generated until the Year 2030 in Korangi district.

[17] Integrated Solid Waste Management Master Plan, Gujranwala (http://gwmc.com.pk/media/downloads/iswm-master-plan-in-gujranwala-volume-01.pdf) Page 131, 132

[18] Miezah et al Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana, Waste Management Volume 46, December 2015, Pages 15-27 https://www.sciencedirect.com/science/article/pii/S0956053X15301185#b0180

Table 3.10: Total Waste Generation in Central District, Karachi

District	Parameters	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Central	Population as per 2017 Census	3,143,875	3,219,328	3,296,592	3,375,710	3,593,700	3,456,727	3,539,688	3,624,641	3,711,632	3,800,711
	Population Growth Rate in %	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%
	Overall Waste Generation Rate	0.585	0.594	0.6032	0.612	0.621	0.630	0.640	0.65	0.668	0.668
	Annual Increment	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%
	Waste Generation	**1,839**	**1,912**	**1,987**	**2,065**	**2,231**	**2,178**	**2,264**	**2,353**	**2,446**	**2,542**

Table 3.11: Total Waste Generation in Korangi District, Karachi

District	Parameters	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Korangi	Population as per 2017 Census	2,702,576	2,767,438	2,833,856	2,901,869	2,971,514	3,042,830	3,115,858	3,190,639	3,267,214	3,345,627
	Population Growth Rate in %	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%
	Residential Waste Generation Rate	0.603	0.612	0.621	0.631	0.640	0.650	0.659	0.669	0.679	0.689
	Annual Increment	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%
	Waste Generation	1,631	1,694	1,760	1,830	1,902	1,977	2,054	2,135	2,219	2,307

3.7 Solid Waste Characterisation Survey in District Central and District Korangi, Division Karachi

The solid waste collected was segregated into 11 categories, as described in the methodology.

3.7.1 Solid Waste Composition in Residential Areas – District Central

Overall, in residential areas, the highest percentage was found out to be of the kitchen or food waste at 56% followed by plastic at 16.30%, Pamper / Diapers / Sanitary Pads at 12.42%, Paper at 4.62%, textile at 3.65 % and residue material remaining on the sheet at 1.59%. All the rest of the items were below 1%.

The study shows a very low quantity of tetra packs, metals, bottles, and glass. These values are expected to increase substantially in the summer season when the intake of soft drinks and juices increases.

The socio-economic conditions and influences can be observed in the waste characterization of the three income areas. Kitchen waste is found the highest in high-income areas when compared to middle and low-income areas. This increase in kitchen waste can be associated with the fact that people living in the high-income area can afford larger quantities of food. In high-income areas, the food waste was in higher percentages consisting of vegetables, fruit peels and leftover food.

Plastic waste, including plastic tableware, Styrofoam containers, and LDPE (Polythene Bags), was found highest in Low-Income Areas, followed by high- and Middle-Income areas. The high percentages of plastics in low-income areas are that plastics utensils are cheaper than glass or ceramic ones. This trend has also been observed in Islamabad in a study conducted in 2017[19].

There is an increase in the percentages of textiles in the low-income class. This can infer the probability of women working in the small-scale garment industry. The percentage of pampers is highest in the high-income area at 13.92%, 13.75% in middle-income areas and 8.91% in low-income areas. This shows the usage of diapers is less in low-income areas, which shows lower hygienic conditions and awareness than in high-income areas.

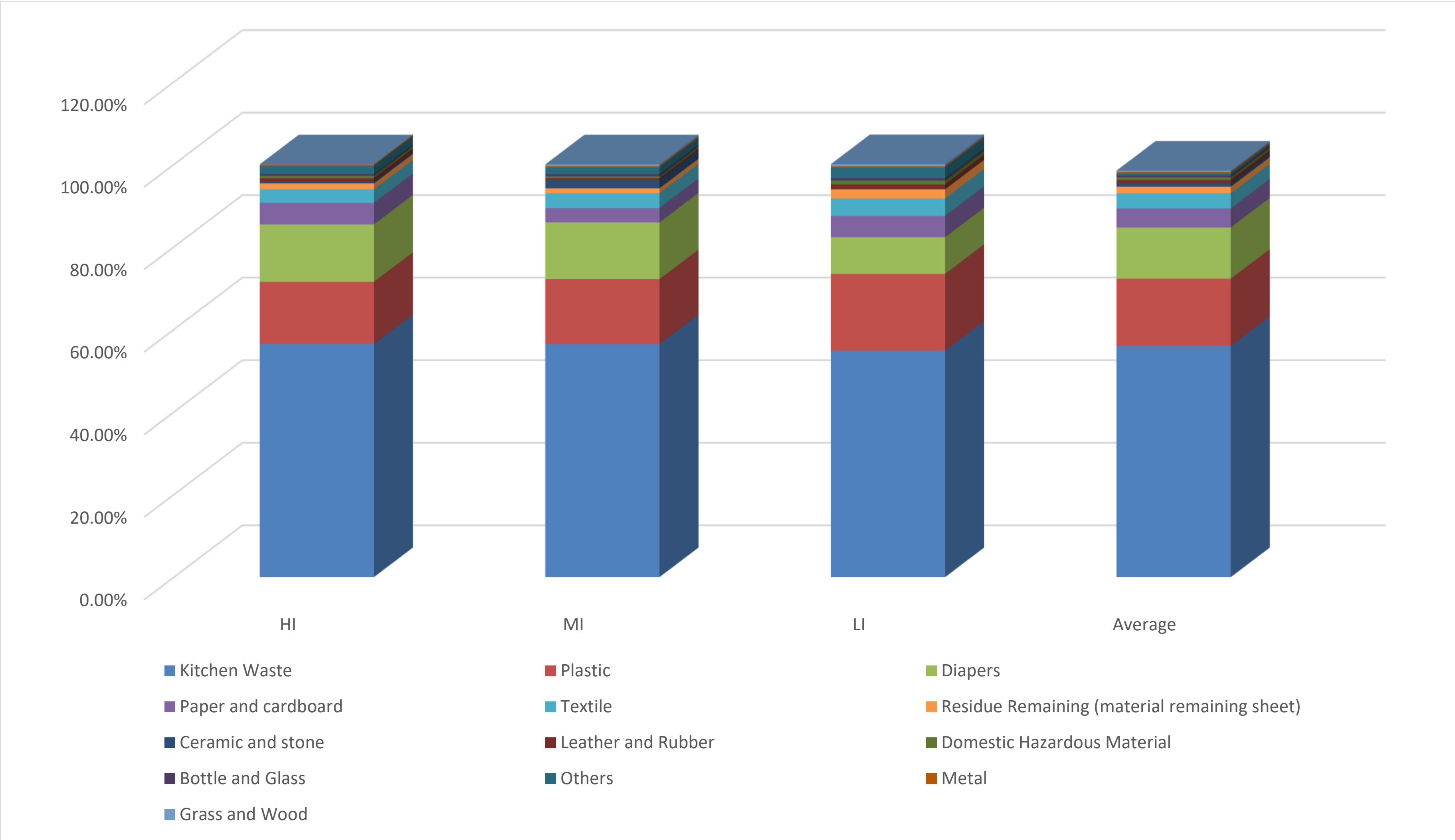
The characterization of the waste varied with different socio-economic groups, as shown in **Table 3.12**. The graphical presentation of this variation is shown in **Figure 3.14.**

[19] Amina Zia, Syeda Adila Batool, Nawaz Chaduary, Soniya Munir, Influence of Income Level and Seasons on Quantity and Composition of Municipal Solid Waste: A Case Study of the Capital City of Pakistan. MDPI, doi:10.3390/su9091568

Table 3.12: Composition of Residential Waste in Central District

Sr No.	Item	Percentage			Average
		High Class	Middle Class	Low Class	
1	Kitchen Waste	56.48	56.45	54.86	56.00
2	Paper and cardboard	5.22	3.49	5.14	4.62
3	Textile	3.28	3.56	4.25	3.65
4	Grass and Wood	0.07	0.39	0.49	0.30
5	Plastic	15.05	15.74	18.58	16.30
6	Leather and Rubber	0.78	0.41	1.16	0.77
7	Metal	0.34	0.35	0.33	0.34
8	Bottle and Glass	0.44	0.54	0.58	0.51
9	Ceramic, stone	0.48	2.04	0.02	0.87
10	Domestic Hazardous Material	0.58	0.42	0.96	0.63
11	Residue Remaining (material remaining sheet)	1.44	1.22	2.21	1.59
12	Miscellanoeus				
A	Tetrapack	0.51	0.39	0.57	0.48
B	Hairs	0.03	0.00	0.00	0.01
C	Pampers	13.92	13.75	8.91	12.42
D	Bones	0.60	0.32	0.20	0.39
E	Dust	0.75	0.85	1.45	0.98
F	E-Waste	0.04	0.08	0.29	0.12
	Total	**100.00**	**100.00**	**100.00**	**100.00**

Figure 3.14: Waste Composition Variations in Residential Area – Central District, Karachi



3.7.2 Solid Waste Composition in Residential Areas – District Korangi

Overall, in residential areas, the highest percentage was found out to be of the kitchen or food waste at 52.56% followed by Pampers at 14.30%, Plastic at 13.86%, Textile at 4.01%, Paper at 3.72%, Dust at 2.89%, Residue material at 1.84%, Domestic Hazardous Waste at 1.32% and Leather and Rubber at 1.25%. All the rest of the items were below 1%.

The socio-economic conditions and influences can be observed in the waste characterizations of the three income areas. Kitchen Waste is found in a higher percentage in high- and middle-income areas than the low-income area.

Metal, Bottles and Glass items also indicate the socio-economic conditions of each area. Metal is highest in High Income at 0.58% and whereas in middle and low-income areas, it was 0.27% and 0.14% respectively.

Plastics is the lowest in high-income areas and the highest in middle-income areas, followed by low-income areas. Textile is seen in an increased percentage in Korangi district as compared to Central district. Similarly, textile is highest in Low Income followed by Middle- and High-Income area. This trend also indicates the probability of small-scale garment industry in low-income areas.

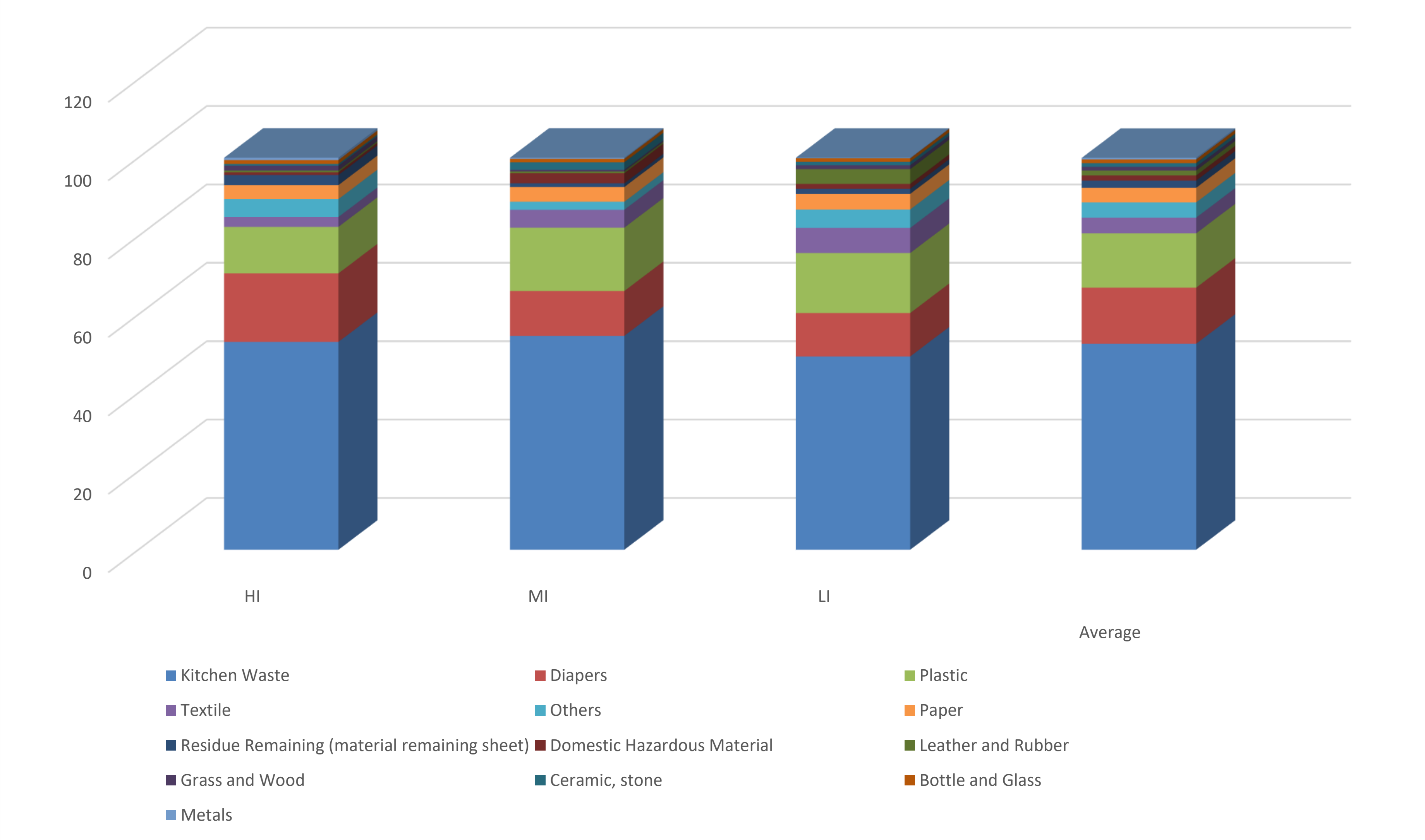
The percentage of pampers is highest in the high-income area at 17.48%, 11.44% in middle-income areas and 11.08% in low-income areas. This shows that the usage of diapers is less in low-income areas, indicating less purchasing power and less awareness towards hygiene.

The characterization of the waste varied with different socio-economic groups, as shown in **Table 3.13**. The graphical presentation of this variation is shown in **Figure 3.15.**

Table 3.13: Composition of Residential Waste in District Korangi

Sr No.	Item	Percentage			Average
		High Class	Middle Class	Low Class	
1	Kitchen Waste	53.03	54.57	49.31	52.56
2	Paper	3.58	3.76	3.97	3.72
3	Textile	2.52	4.57	6.40	4.01
4	Grass and Wood	1.24	0.38	1.00	0.95
5	Plastic	11.87	16.16	15.31	13.86
6	Leather and Rubber	0.45	0.49	3.76	1.25
7	Metals	0.58	0.27	0.14	0.39
8	Bottle and Glass	1.00	0.89	0.88	0.94
9	Ceramic, stone	0.44	1.93	0.88	0.95
10	Domestic Hazardous Material	0.68	2.56	1.24	1.32
11	Residue Remaining (material remaining sheet)	2.59	0.95	1.32	1.84
12	Miscellaneous				
A	Tetrapack	0.61	0.95	0.54	0.68
B	Hairs	0.00	0.01	0.00	0.00
C	Pampers	17.48	11.44	11.08	14.30
D	Bones	0.11	0.15	0.33	0.17
E	Dust	3.66	0.91	3.57	2.89
F	E-Waste	0.17	0.02	0.27	0.15
	Total	**100.00**	**100.00**	**100.00**	**100.00**

Figure 3.15: Waste Composition Variations in Residential Area – Korangi district, Karachi



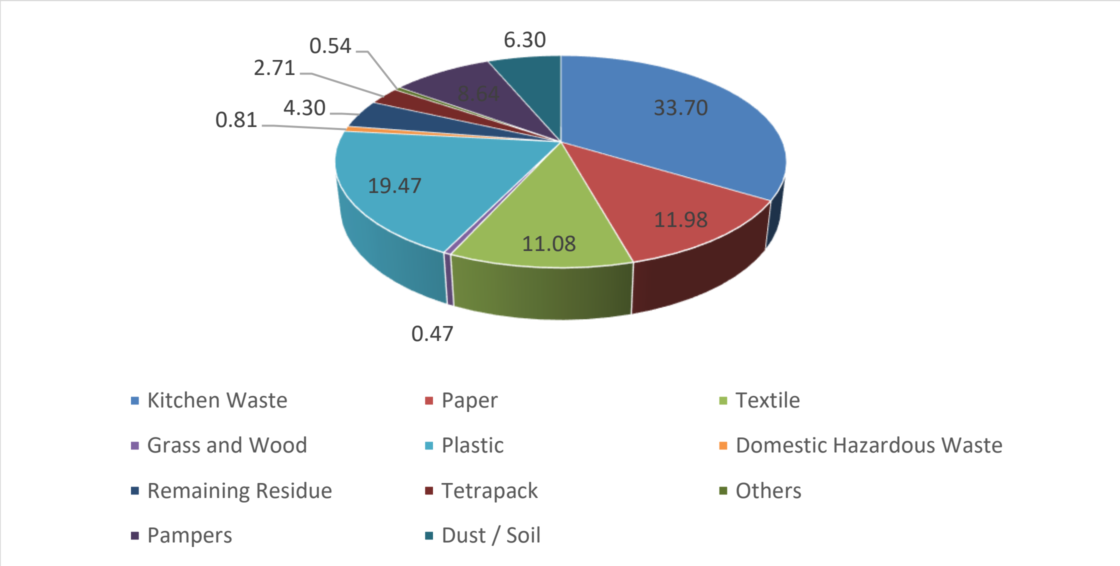
3.7.3 Solid Waste Composition – Commercial waste streams District Central

The characterization of commercial solid waste was collected from 10 shops. The major components of waste from commercial and other waste were food waste, paper waste, and pampers waste from the overall waste characterization. **Table 3.14** and **Figure 3.16** provides the details of the waste characterization variation.

Table 3.14: Percentage-wise waste components from commercial sources

Sr No.	Item	%
1	Kitchen waste	33.70
2	Paper	11.98
3	Textile	11.08
4	Grass and wood	0.47
5	Plastic	19.47
6	Leather and rubber	-
7	Metal	-
8	Bottle and glass	-
9	Ceramic, stone and soil etc.	-
10	Domestic hazardous wastes	0.81
11	Residue Material (Material Remaining on Sheet)	4.30
12	Miscellaneous	
A	Tetra Pack	2.71
B	Hairs	0.03
C	Pampers	8.64
D	Bones	0.48
E	Dust/ Sieve	6.30
F	E-Waste	0.03
	Total	**100.00**

Figure 3.16: Waste Composition of Commercial Waste – District Central



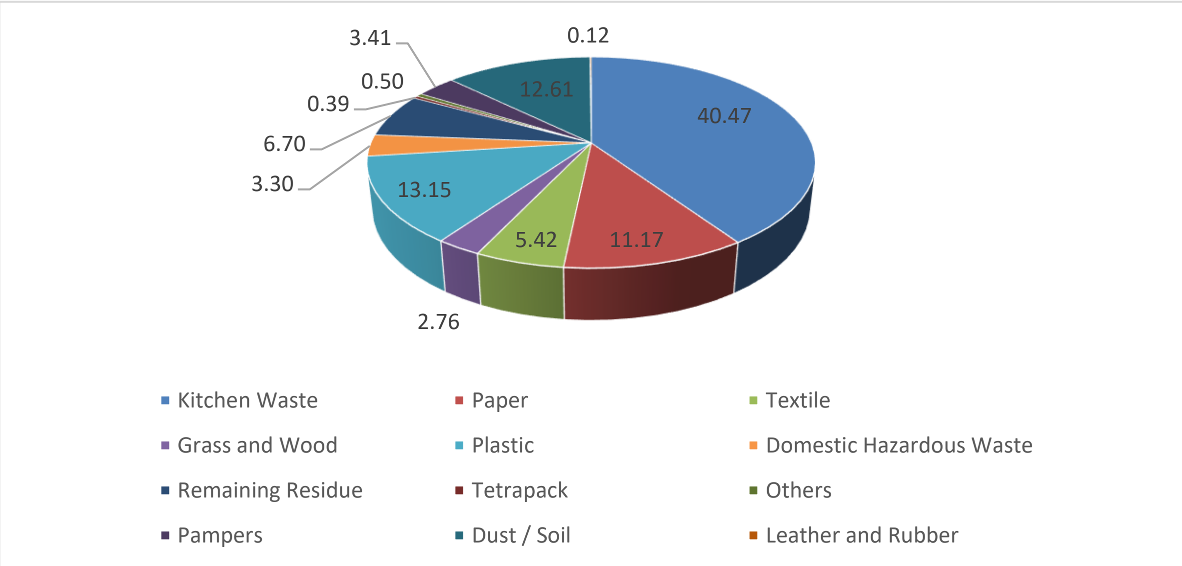
3.7.4 Solid Waste Composition – Commercial waste streams District Korangi

The characterization of commercial solid waste was collected from 10 shops. The major components of waste from commercial and other waste were food waste, paper waste, and plastic from the overall waste characterization. **Table 3.15** and **Figure 3.17** provides the details of the waste characterization variation.

Table 3.15: Percentage-wise waste components from commercial sources

Sr No.	Item	%
1	Kitchen waste	40.47
2	Paper	11.17
3	Textile	5.42
4	Grass and wood	2.76
5	Plastic	13.15
6	Leather and rubber	0.12
7	Metal	0.00
8	Bottle and glass	0.00
9	Ceramic, stone and soil etc.	0.00
10	Domestic hazardous wastes	3.30
11	Residue Material (Material Remaining on Sheet)	6.70
12	Miscellaneous	
A	Tetra Pack	0.39
B	Pampers	3.41
C	Bones	0.00
D	Dust/ Sieve	12.61
E	E-Waste	0.50
	Total	**100.00**

Figure 3.17: Waste Composition of Commercial Waste – District Korangi



3.8 Physical and Chemical Analysis of Solid Waste

3.8.1 Density/Specific Gravity of Solid Waste – Central and Korangi districts

The average density of residential solid waste for Central district is 272.15 kg/m^3. The highest solid waste density (specific gravity) is in the high-income area, 281.92 kg/m^3. The lowest is in the low-income group being 266.97 kg/m^3

The density of waste is usually required to determine how much space it will take for collection, transportation, and disposal. Solid waste density is also an important factor for planning and designing a solid waste management system, including waste storage, transportation, and disposal at landfill sites.

The density helps in determining the area required for the sanitary landfill or disposal site. It also helps determine the number of dust bins required for an area and the number of loading and transporting trucks. The density of solid waste for all the income groups is shown in **Table 3.16**.

Table 3.16: Solid waste Density (Kg/m^3)

Area		Density (Kg/m^3)
Central	High	281.92
	Middle	267.56
	Low	266.97
	Average	272.15
Korangi	High	248.83
	Middle	257.05
	Low	251.57
	Average	252.48

Figure 3.18: Density of Residential Waste – Central district

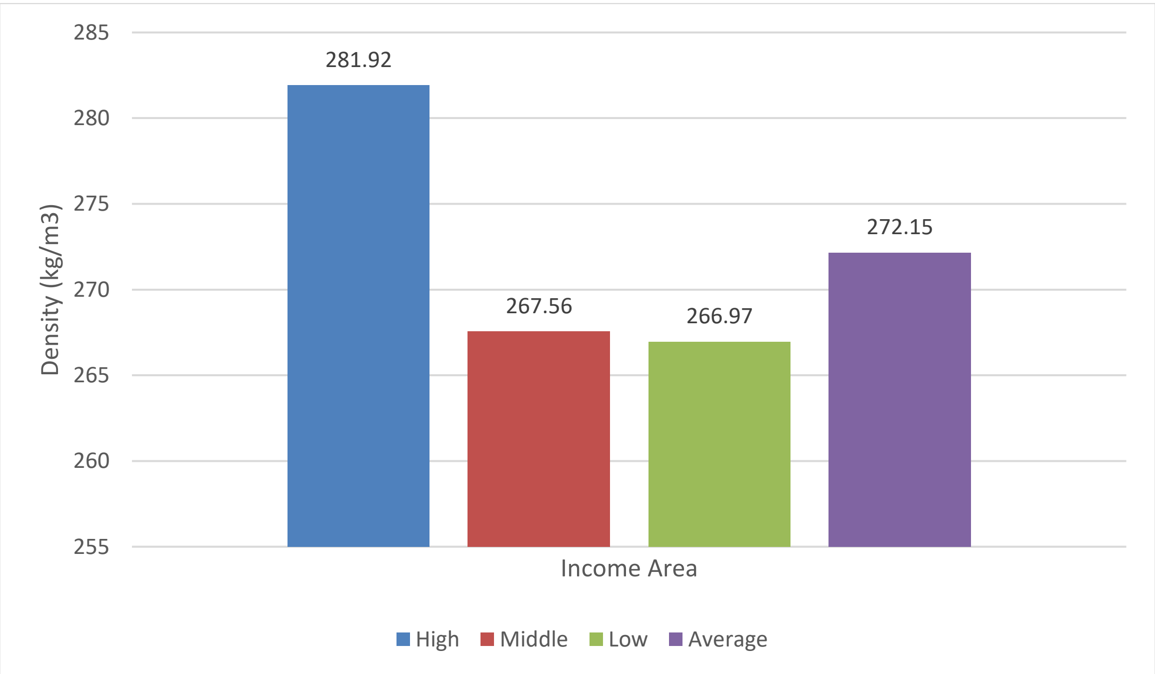
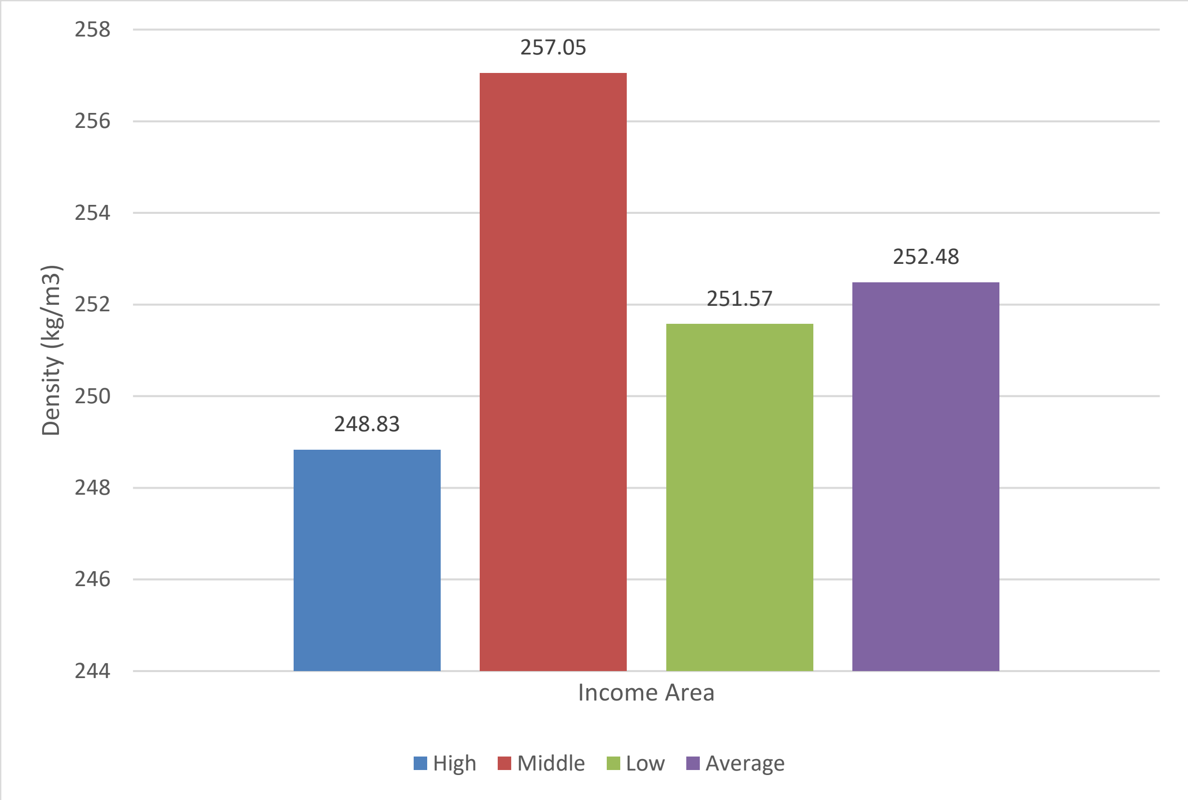


Figure 3.19: Density of Residential Waste – Korangi district



The trend can be seen in **Figure 3.18** and **Figure 3.19** is that the characterization of waste affects the density of waste. The high-income area had the highest density of waste, i.e., 281.92 kg/m^3 and the lowest in the low-income area is 266.97 kg/m^3. The components that usually increase the density of solid waste are kitchen waste, diapers, ceramic, and stone. All these items are in greater percentage where the density of solid waste is higher.

In a study conducted in Gujranwala (Illyas et al., 2017), the density (specific gravity) of solid waste for high income was 275 kg/m^3 and 285 kg/m^3 for the low-income group.[20]

A similar study conducted in Azad Jammu & Kashmir showed that the average density of solid waste in Azad Jammu and Kashmir is 250.165 kg/m^3. The highest solid waste density (specific gravity) was in Mirpur, 328.26 kg/m^3, while the lowest is in Athmuqam, 132 kg/m^3.

3.8.2 Chemical Analysis of Solid Waste

The chemical analysis was performed on six composite samples from 6 different waste sources. The scan copy of the detailed chemical analysis report, including the values of As Received (AR) basis, Air Dried (AD) basis and Dry basis, are provided as **Annexure-6**.

Proximate Analysis

The proximate analysis was carried out to estimate the heating value of municipal solid waste fuel. It is used to determine the characterization of solid waste in terms of gross components

[20] Illyas H, Illyas S, Ahmad SR, Nawaz MCH, 2017, Waste Generation Rate and Composition Analysis of Solid Waste in Gujranwala City Pakistan. International Journal Waste Resource.

of moisture, volatile matter, fixed carbon, and ash. In proximate analysis, moisture content, volatile matter and ash are analyzed.

Table 3.17: Proximate Analysis of Solid Waste

Waste Source	Parameters	High-Income Area	Middle Income Area	Low-Income Area
District Central	Total Moisture	48.99	47.89	41.08
	Volatile Matter (As Received (AR))	44.53	33.51	45.37
	Fixed Carbon	3.06	0.21	4.64
	Ash (AR)	3.42	18.39	8.91
District Korangi	Moisture	73.16	61.27	58.97
	Volatile Matter	20.74	23.00	29.68
	Fixed Carbon	2.66	2.62	3.37
	Ash	3.44	13.11	7.98

Moisture Content: Moisture content is an important quality to test the maturity of compost produced by different kinds of organic waste. In compost, moisture is also essential for microbe activity as it increases its metabolism.[21]

The typical range of moisture varies from country to country, as in a survey conducted in the cities of Greece; this value ranges from 30-40%.[22]

In another survey in Ghana, this value ranged between 36-58% in different months of the year.[23] Chattopadhyay[24] reported that the percentage by mass of moisture of MSW should be approximately 25%.

According to a survey in Pakistan, the average value of the moisture range is 36%. At the same time, for compost, this could increase within the range of 40-50%.[25]

During this survey, the moisture content of the waste streams was found to be in the range of 40 – 75 % in District Central and District Korangi.

If these samples are considered for compost, this could prove feasible because the waste characterization reveals a high amount of organic waste (50 – 60%). Typically, Moisture Content is in the range of 50~70% for successful production of compost.

Volatile Matter: Volatile content and fixed carbon contents are good indicators of the combustion properties of waste. The volatility in this study was obtained. The Volatile Matter for the high-income area was at 44.53%, 33.51% for middle and 45.37% for low-income areas

[21] Ameen, A, Ahmad. J and Raza, S., Effect of pH and moisture content on composting of Municipal solid waste. International Journal of Scientific and Research Publications, Volume 6, Issue 5, May 2016. ISSN 2250-3153
[22] E. Gidarakos *, G. Havas, P. Ntzamilis Municipal solid waste composition determination supporting the integrated solid waste management system in the island of Crete. Waste Management xxx (2005)
[23] R. Kuleape, S.J Cobbina., S.B, Dampare., A.B, Duwiejuah, E.E, Amoako, W, Asare. Assessment of the energy recovery potential of solid waste generated in Akosombo, Ghana, Vol. 8(5), pp.297-305, May 2014. DOI: 10.5897/AJEST2014.1663, ISSN 1996-0794.
[24] Chattopadhyay,P. (2006).Boiler Operation Engineering .Tata McGraw-Hill New Delhi.
[25] J, Seema, Municipal solid Waste Composting and its Assessment for reuse in plant production. Pak. J. Bot., 39(1): 271-277, 2007.

of Central district. At the same time, fixed carbon percentages ranged from 0.21 – 4.64 for high, middle, and low-income areas.

Similarly, the Volatile Matter for the high-income area was at 20.74%, 23.00% for the middle-income area and 29.68% for the low-income area. While Fixed Carbon percentages were in the range of 2.62 – 3.37 for Korangi district.

The high amount of loss on ignition represents that a significant fraction of wastes can be removed via incineration. The presence of a high percentage of fixed carbon in a waste shows its suitability for incineration, as it requires a longer retention time in the incinerator to attain complete burning. The present results agree with the reported data for volatile content ranging from 20.2% to 54.7%. Fixed carbon ranged from 0.9% to 5.8% by Sadef et al. in Lahore (2017).[26]

According to Shukla et al. (2000), typical values for a volatile matter of solid waste sample should be more than that of 40%. The high value of ash content in solid waste makes it suitable as a fuel.[27]

Ash: Ash (A) is the inorganic residue that is left over after fixed carbon burning. Ash content is influential in transport, handling, and overall process costs. The high ash content of the solid fuel tends to create slag deposits, causing higher thermal resistance to heat transfer and necessitating more expensive equipment maintenance.

During the survey, ash content is found to be 3.42 to 18.39% in Central district and 3.44 to 13.11% in Korangi district on an as-received basis. Similarly, ash content (dry basis) is 6.71% to 35.30% for Central district and 12.81% to 33.86% for Korangi district, which indicates the high content of paper and plastics, which increased ash content value.

A study conducted in Malang City, Indonesia, indicated average ash content of 5.51% (Dry Basis) specified that it is preferable for solid fuel with low operating cost.[28]

Ultimate Analysis

This refers to an analysis of waste to determine the proportion of carbon and sulphur. The analysis is carried out to make mass balance calculations for a chemical or thermal process.

Table 3.18: Ultimate Analysis of Solid Waste

Waste Source	Parameters	District Central (%)	District Korangi (%)	Average (%)
High Income	Carbon	26.72	13.01	19.87
	Sulphur	0.17	0.06	0.12
	Oxygen	16.03	7.81	11.92
	Hydrogen	4.23	2.13	3.18
	Nitrogen	0.437	0.391	0.41

[26] Sadef, Y., Nizami, A. S., Batool, S. A., Chaudary, M. N., Ouda, O. K. M., Asam, Z. Z., ... & Demirbas, A. (2016). Waste-to-energy and recycling value for developing integrated solid waste management plan in Lahore. *Energy Sources, Part B: Economics, Planning, and Policy*, *11*(7), 569-579.

[27] Shukla SR., Akola, AB., Bhide AD., Dhussa AK., Varshney AK., Acharya DB., Dalta MM., Dultam., Mozumdar NB., Asnani PU., Ramanathan R., Ramaprasad VB., Uppal BB. (2000) Energy recovery from municipal solid waste India. Ministry of urban environment, Government of India pp 262-310

[28] Sukarni. (2016) Exploring the potential of municipal solid waste (MSW) as solid fuel for energy generation: Case study in the Malang City, Indonesia, AIP Publishing. https://doi.org/10.1063/1.4965733

Waste Source	Parameters	District Central (%)	District Korangi (%)	Average (%)
	Carbon / Nitrogen Ratio	61.14	33.27	47.21
Middle Income	Carbon	21.33	12.38	16.86
	Sulphur	0.10	0.09	0.10
	Oxygen	7.98	10.45	9.22
	Hydrogen	3.41	2.05	2.73
	Nitrogen	0.903	0.649	0.78
	Carbon / Nitrogen Ratio	23.62	19.07	21.35
Low Income	Carbon	28.94	17.70	23.32
	Sulphur	0.09	0.07	0.08
	Oxygen	14.00	11.95	12.98
	Hydrogen	4.38	2.73	3.56
	Nitrogen	2.602	0.603	1.60
	Carbon / Nitrogen Ratio	11.12	29.35	20.24

Carbon: The ultimate analysis determines the total carbon content, which includes the carbon present in volatile matter. There is no particular value for carbon, but it is accepted that the carbon content of a compost sample should be at least 40%.

Carbon and Nitrogen are of utmost importance for compost values. Their correct ratio favours waste to be used as a fertilizer. In the present study, the calculated C/N values of household waste were 61.1, 23.62, and 11.1 for High, Middle and Low-income areas, respectively, in Central district. The calculated C/N values of household waste were 33.27, 19.07 and 29.35 for High, Middle and Low-Income areas of Korangi district.

Ideally, the C/N ratio for composting should be in the range of 25 to 40.[29] In the areas where the C/N ratio is less than the recommended range, additional food waste or yard trimmings can be added to bolster the C/N ratio.

Sulphur: The sulphur content in solid waste is calculated to see if the waste can be used as fuel. In the literature review, sulphur is reported to be near 0.1% of the solid waste.

The sulphur content in Central district is in the range of 0.09 – 0.17%, whereas in Korangi district, sulphur content is 0.08 – 0.12%. The Sulphur value range for both Central and Korangi districts is 0.08 – 0.17%, near the typical value. The value suggests that solid waste can be a good source of combustion.

Oxygen: Oxygen is a parameter that affects the performance of the microbial activity. Inadequate oxygen levels lead to the growth of anaerobic micro-organisms, which can produce odorous compounds. While adequate oxygen can minimize these odours, it is important to note that anaerobic pockets will exist in a heterogeneous material like a municipal

[29] Tom L. Richard. Municipal Solid Waste Composting: Biological Processing. 1996. http://compost.css.cornell.edu/MSWFactSheets/msw.fs2.html Accessed on 16th April 2021.

solid waste. Some odours, including ammonia and some organic compounds, can be generated even under generally aerobic conditions.

Oxygen concentrations in the large pores must normally be at least 12-14 per cent (ideally 16-17 per cent) to allow adequate diffusion into large particles and water-filled pores.[30]

The oxygen content is 7.98 – 16.03 % in Central district and 7.81 – 11.95% in Korangi district. The results indicate that municipal solid waste will need to be mechanically aerated during the initial stage.

3.8.3 Calorific Value

Calorific value is the basic tool to describe the energy content of the waste and propose the suitability of the waste and an energy source. For incineration or mass burning, solid waste's average lower calorific value must be at least 1434 kcal/kg (6 MJ/kg) during all seasons. The annual average lower calorific value must not be less than 1673 kcal/kg (7 MJ/kg).

Table 3.19: Gross Calorific Value of Solid Waste

Waste Source	High Income Area (kcal/kg)	Middle Income Area (kcal/kg)	Low Income Area(kcal/kg)	Average (kcal/kg)
District Central	2745	2348	3343	2812
District Korangi	1346	1261	1938	1515
Average	**2045.5**	**1804.5**	**2640.5**	**2,163.5**

3.9 Comparison of Waste Amount Characterisation Survey's Results

The comparison of the Waste Amount Characterization Survey in Central and Korangi districts results with national/international studies was carried out, which is a great way to survey the differences caused by the topography, climatic conditions, urbanization, and socio-economic conditions.

3.9.1 Solid Waste Generation Rate – Residential

The solid waste generation patterns in the low-income countries vary within the range of 0.3 to 0.9 kg/cap/day, whereas, in high-income countries, this reaches up to 1.4 to 2 kg/cap/day.[31]

The solid waste produced in at least developed and developing countries contains higher fractions of organic materials than industrialized countries where more processed and tinned food is used.[32]

According to the World Bank survey on solid waste management, approximately 70 million tons of solid waste is generated per year, with per capita values ranging from 0.12 to 5.1 kg/capita/day and an average of 0.45 kg/capita/day.[33]

[30] Tom L. Richard. Municipal Solid Waste Composting: Biological Processing. 1996. http://compost.css.cornell.edu/MSWFactSheets/msw.fs2.html . Accessed on 18th April 2021.
[31] Khatib A (2011) Municipal Solid Waste Management in Developing Countries: Future Challenges and Possible Opportunities. INTECH Open Access Publisher.
[32] Oyelola, Babatunde (2004) Characterization of domestic and market solid wastes at source in Lagos metropolis, Lagos, Nigeria, African Journal of Environmental and Waste Management 1:085-091.
[33] Hoornweg, Daniel; Bhada-Tata, Perinaz. (2012). What a Waste: A Global Review of Solid Waste Management. Urban development series; knowledge papers no. 15. World Bank, Washington, DC. © World Bank

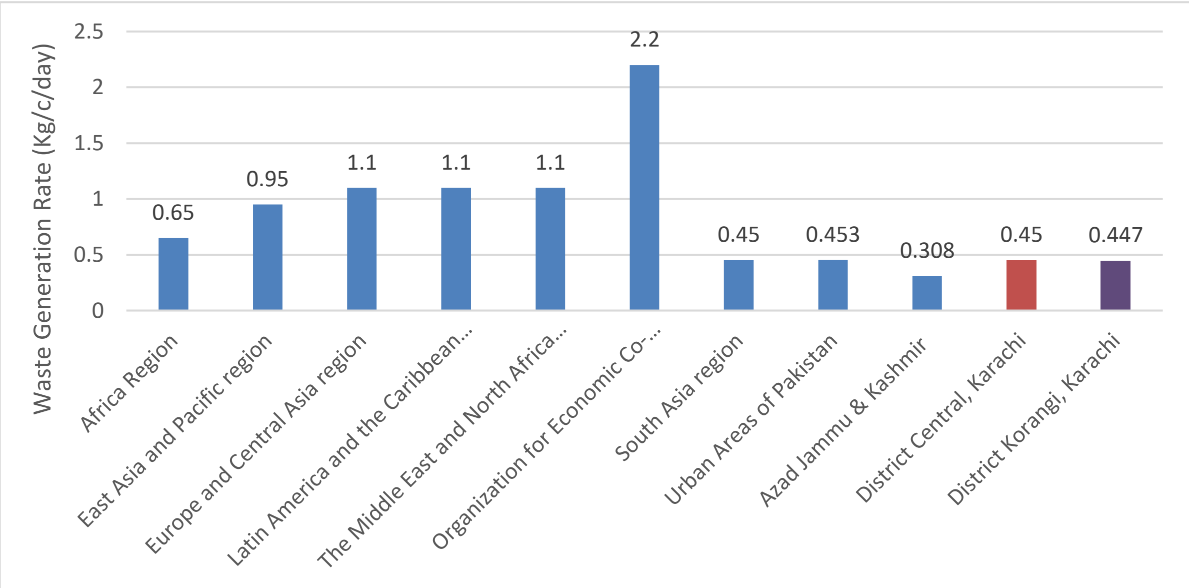
The waste generation in the Central district is 0.450 kg/capita/day. Waste generation in Korangi district is 0.447 kg/capita/day, which is in the range of waste generation by the South Asia Region and slightly above the region's average, as shown in **Table 3.20**.

In a similar study conducted in Karachi in 2013, the waste generation rate for residential waste was 0.44 kg/capita/day, indicating that the present waste generation rate agrees with the previously conducted study in Karachi.[34]

Table 3.20: Solid Waste Generation Per Capita for Different Regions of the World

Region	Lower Boundary	Upper Boundary	Average Waste Generation Per Capita (kg/capita/day)
Africa Region	0.09	3	0.65
East Asia and Pacific region	0.44	4.3	0.95
Europe and Central Asia region	0.29	2.1	1.1
Latin America and the Caribbean region	0.11	5.5	1.1
The Middle East and North Africa region	0.16	5.7	1.1
Organization for Economic Co-operation and Development	1.1	3.7	2.2
South Asia region	0.12	5.1	0.45
Urban Areas of Pakistan	0.283	0.613	0.453
Azad Jammu & Kashmir	0.193	0.382	0.308
District Central, Karachi	0.368	0.491	0.450
District Korangi, Karachi	0.391	0.495	0.447

Figure 3.20: Solid Waste Generation Per Capita for Different Regions of the World



[34] UNESCAP, 2013, Baseline Study for Solid Waste Management – Karachi. https://www.unescap.org/sites/default/d8files/SWM-COMPLETE%20REPORT%20KARACHI%20%20%2012-Mar-13.pdf

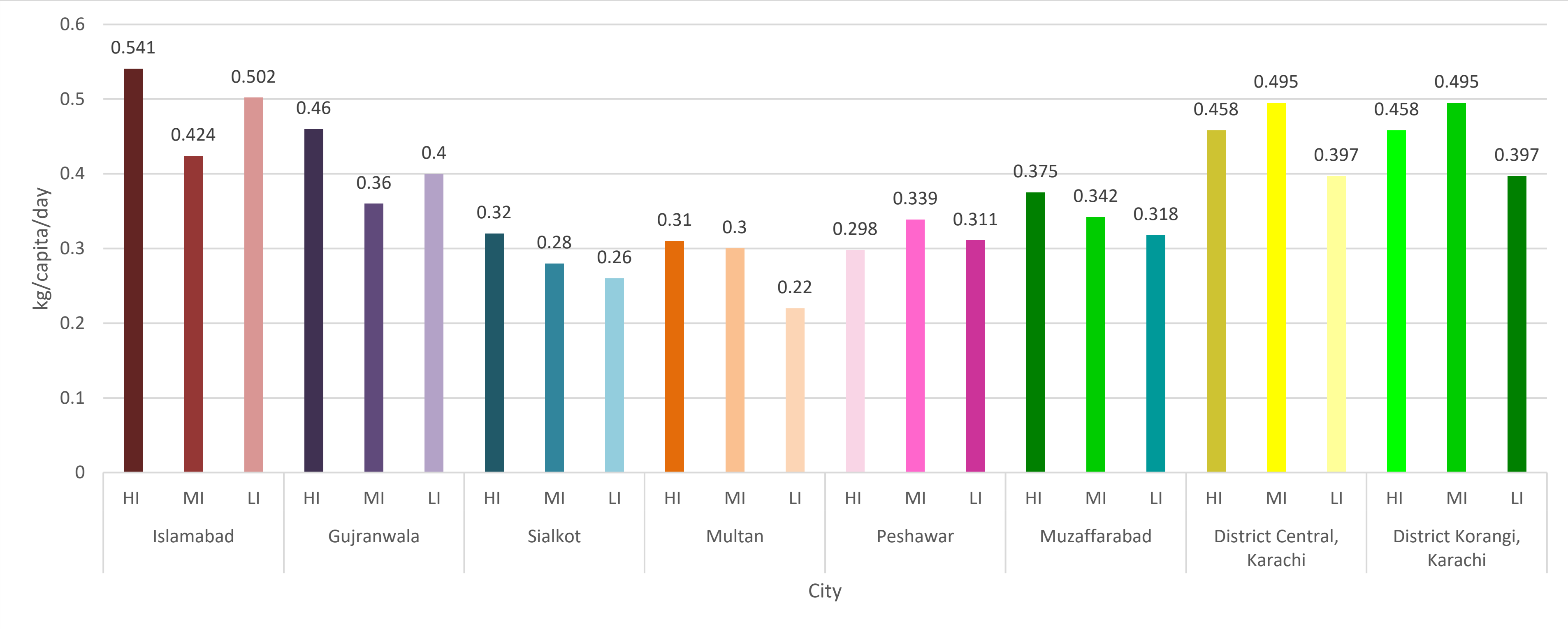
Table 3.21: Solid Waste Generation Per Capita for Different Cities of Pakistan

City		Average Waste Generation Per Capita (kg/capita/day)	Reference
Islamabad, Capital Territory	High Income Group	0.541	Baseline Survey Solid Waste Management in Islamabad, 2013, UNESCAP https://www.unescap.org/sites/default/files/baseline%20survey_islamabad_finalised.pdf
	Middle Income Group	0.424	
	Low Income Group	0.502	
Gujranwala, Punjab	High Income Group	0.46	Waste Amount Survey and Physio-Chemical Analysis of Municipal Solid Waste Generated in Gujranwala-Pakistan, Urban Unit, Lahore. https://www.omicsonline.org/open-access/waste-amount-survey-and-physiochemical-analysis-of-municipal-solidwaste-generated-in-gujranwalapakistan-2252-5211-1000196.php?aid=68914
	Middle Income Group	0.36	
	Low Income Group	0.40	
Sialkot, Punjab	High Income Group	0.320	Sialkot Waste Assessment and Characterization Survey, 2010, GHK Consulting. http://uu.urbanunit.gov.pk/Documents/Publications/0/124.pdf
	Middle Income Group	0.280	
	Low Income Group	0.260	
Multan, Punjab	High Income Group	0.310	Establishing Integrated Solid Waste Management in the Large Cities of Pakistan, Multan, 2010, GHK Consulting. http://documents.worldbank.org/curated/en/958641468144569940/Establishing-integrated-solid-waste-management-in-the-large-cities-of-Pakistan-Multan-comprehensive-scope-evaluation-report
	Middle Income Group	0.300	
	Low Income Group	0.220	
Peshawar, Khyber Pakhtunkhwa	High Income Group	0.298	Study on Municipal Solid Waste Generation Rate; Composition; Analysis; Characterisation, Peshawar City, 2009, ICEPAK. https://www.academia.edu/29820983/STUDY_ON_MUNICIPAL_SOLID_WASTE_GENERATION_RATE_COMPOSITION_ANALYSIS_CHARACTERISATION_PESHAWAR_CITY_PAKISTAN
	Middle Income Group	0.339	
	Low Income Group	0.311	
Muzaffarabad, Azad Jammu & Kashmir	High Income Group	0.375	Hospital/Solid Waste (Generation & Classification) Survey in Azad Jammu & Kashmir, 2017, Project Procurement International. Abdullah, A., Abbasi, M.S., Ali, A. *et al.* Residential solid waste generation and classification study of ten headquarter cities of Azad Jammu & Kashmir, Pakistan. *J Material Cycles Waste*
	Middle Income Group	0.342	
	Low Income Group	0.318	

City		Average Waste Generation Per Capita (kg/capita/day)	Reference
			Management (2021). https://doi.org/10.1007/s10163-021-01265-w
Mardan, Khyber Pakhtunkhwa	High Income Group	0.309	Study of Waste Generation and Composition Survey in Mardan, 2019, Project Procurement International
	Middle Income Group	0.233	
	Low Income Group	0.322	
Karachi, Sindh	High Income Group	0.84	UNESCAP, 2013, Baseline Study for Solid Waste Management – Karachi. https://www.unescap.org/sites/default/d8files/SWM-COMPLETE%20REPORT%20KARACHI%20%20%2012-Mar-13.pdf
	Middle Income Group	0.29	
	Low Income Group	0.19	
District Central, Karachi	High-Income Area	0.491	**Present Study**
	Middle Income Area	0.456	
	Low-Income Area	0.368	
District Korangi	High-Income Area	0.458	
	Middle Income Area	0.495	
	Low-Income Area	0.397	

One observable aspect that can be seen in **Figure 3.21** is that socio-economic conditions do not have a definite correlation with the waste generation rate of a city, meaning the WGR varies between income groups.

Figure 3.21: Waste Generation Rate for High, Middle and Low-Income Groups in Different Cities of Pakistan



3.9.2 Solid Waste Composition – Residential

The characterization of solid waste is almost the same in the cities of Pakistan. However, fractions of each component vary due to change in income level, climatic conditions, and cultural norms.[35]

Table 3.22: Characterisation of Solid Waste in various cities of Pakistan

Items	Mirpur	Mardan	District Central	District Korangi	Karachi[36]	Lahore[37]	Gujranwala	Azad Jammu & Kashmir (Overall)[38]	Peshawar	Islamabad[39]
Kitchen waste	62.33	62.96	56.00	52.56	53	57.00	62.50	60.71	53.74	59.95
Paper	4.46	3.91	4.62	3.72	12	3.37	15.3	5.47	7.32	7.26
Textile	3.05	3.71	3.65	4.01	4	9.93	3.87	3.28	2.35	1.81
Grass and wood	1.43	1.05	0.30	0.95	0	-	1.63	1.33	10.29	-
Plastic	10.51	7.36	16.30	13.86	14	14.23	7.70	13.69	9.34	7.49
Leather and rubber	0.84	0.61	0.77	1.25	0	3.41	0.77	1.35	0.63	-
Metal	0.31	0.20	0.34	0.39	9	0.04	0.23	0.39	0.72	0.68
Bottle and glass	1.03	0.87	0.51	0.94	2	0.97	1.16	1.5	2.32	2.79
Ceramic, stone and soil etc.	0.59	3.09	0.87	0.95	0	1.54	1.10	0.73	12.32	-
Domestic hazardous wastes	0.37	0.45	0.63	1.32	0	0.65	0.60	0.51	-	-
Sieve remaining / Residue Material Remaining on Sheet	1.61	-	1.59	1.84	0	-	3.23	0.86	-	19.2
Miscellaneous										
Hairs	0.09	0.09	0.01	0.00	-	-	1.90	0.19	0.65	
Bones	0.25	0.21	0.39	0.17	3	-		0.07		
Tetra-pack	2.30	0.33	0..48	0.68	3	3.13		2.08		
Diapers	9.45	10.22	12.42	14.30		5.73		7.25	0.22	

[35] *Khajuria A (2010) Estimation of municipal solid waste generation and landfill area in Asian developing countries. Journal of Environmental Biology31: 649-654*

[36] UNESCAP, 2013, Baseline Study for Solid Waste Management – Karachi. https://www.unescap.org/sites/default/d8files/SWM-COMPLETE%20REPORT%20KARACHI%20%20%2012-Mar-13.pdf

[37] Y. Sadef, A. S. Nizami, S. A. Batool, M. N. Chaudary, O. K. M. Ouda, Z. Z. Asam, K. Habib, M. Rehan & A. Demirbas (2016) Waste-to-energy and recycling value for developing integrated solid waste management plan in Lahore, Energy Sources, Part B: Economics, Planning, and Policy, 11:7, 569-579, DOI: 10.1080/15567249.2015.1052595

[38] Abdullah, A., Abbasi, M.S., Ali, A. *et al.* Residential solid waste generation and classification study of ten headquarter cities of Azad Jammu & Kashmir, Pakistan. *J Material Cycles Waste Management* (2021).

[39] *Zia, A., Batool,S.A., Chaudhry M, N.,Munir., S Influence of Income Level and Seasons on Quantity and Composition of Municipal Solid Waste: A Case Study of the Capital City of Pakistan, Sustainability 2017, 9(9), 1568; doi:10.3390/su9091568.*

Items	Mirpur	Mardan	District Central	District Korangi	Karachi[36]	Lahore[37]	Gujranwala	Azad Jammu & Kashmir (Overall)[38]	Peshawar	Islamabad[39]
Sieve Remaining/Dust	1.30	1.61	0.98	2.89		-		0.51	-	
E- Waste	0.09	0.15	0.04	0.15		-		0.06	0.10	
Hay / Animal Dung	-	3.19	-	-		-		-	-	
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Although the waste generation rates vary from city to city, as seen in **Table 3.22.** However, in comparison to characterisation, the percentage of organics is comparatively close.

The percentage of kitchen waste in 10 different Cities / Districts ranges from 52.56% – 62.96 %. The fraction of kitchen waste in Central and Korangi district is 53.11% and 52.56%, which is within range.

The percentage of plastics in Islamabad, Mardan and Gujranwala, is under 8%. The percentage of plastic in Azad Kashmir (Overall), Mirpur and Peshawar, is above 9%. In megacities, i.e., Lahore, Central and Korangi districts of Karachi, the percentage of plastics is 16.30%, 13.86%, and 14%.

Seasonal variation does play a role in waste characterization. In Mardan and Gujranwala, the WACS studies were carried out in early spring. In this season, there is very little consumption of soft drinks, juices, and other canned food items. All these food items are mostly packaged in plastics/metals. This can be further consolidated by the fact that in Mirpur, Muzaffarabad, and the overall AJK study, the percentage of plastics was above 10 %. The studies were conducted in Kashmir during the summer season. Therefore, seasonal variations do affect the characterization of solid waste.

3.9.3 Solid Waste Generation Rate – Commercial

The solid waste generation rate for commercial units varies significantly depending upon the nature of business being practised at each unit. A fruit juice stall will have an entirely different waste generation rate compared to bookselling the store.

Table 3.23: Composition of Solid Waste in various cities of Pakistan

Category	Unit	Mardan	Gujranwala	AJK	District Central	District Korangi	Karachi
Shops	per establishment (kg/day)	2.01	2.17	1.087	1.608	1.956	1.795

4 Potential Use of Waste Stream as a Resource

Based on the findings of the study, the potential uses of the waste stream as a resource have been explored in this chapter. The different options of waste treatment can be observed in **Figure 4.1**.

It can be observed that for mixed municipal waste stream, i.e., without any waste segregation either at the source or at the transfer station, the main waste utilization and treatment options are to:

i) dispose of the MSW at a sanitary landfill, and

ii) incineration or mass burning.

If the waste is segregated either at the source or at a transfer station, the primary waste treatment options are to:

a) segregate the combustible materials to make Refuse Derived Fuel which can be further incinerated/burned or used as a co-processing material in a factory; for example, waste is used as a fuel in cement or fertilizer manufacturing.

b) Establish a material recovery facility (MRF) where recyclable materials such as paper, plastic and metals are segregated and sold.

c) Establish a compost plant where organic waste can further be decomposed into compost or fertilizers.

There are other methods to dispose of segregated waste, such as pyrolysis, where plastics can be converted into fuels, organic material such as animal dung can be converted into biogas. However, in this chapter, we are primarily interested in incineration, which includes mass burning and RDF, MRF facility, and Composting. Further, the effect of scavengers on the waste composition at the transfer station must be noted in detail, as indicated in **Figure 4.2**.

Figure 4.1: Overview of Municipal Solid Waste (MSW) material flow and its different utilization and treatment options

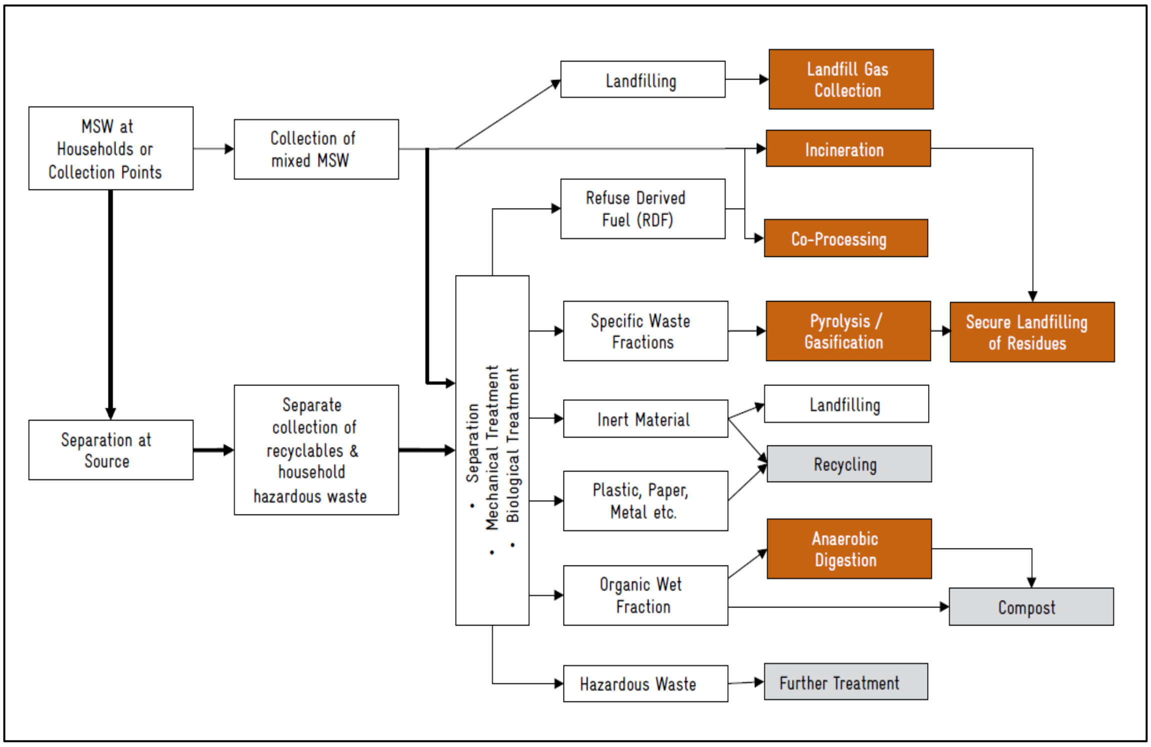
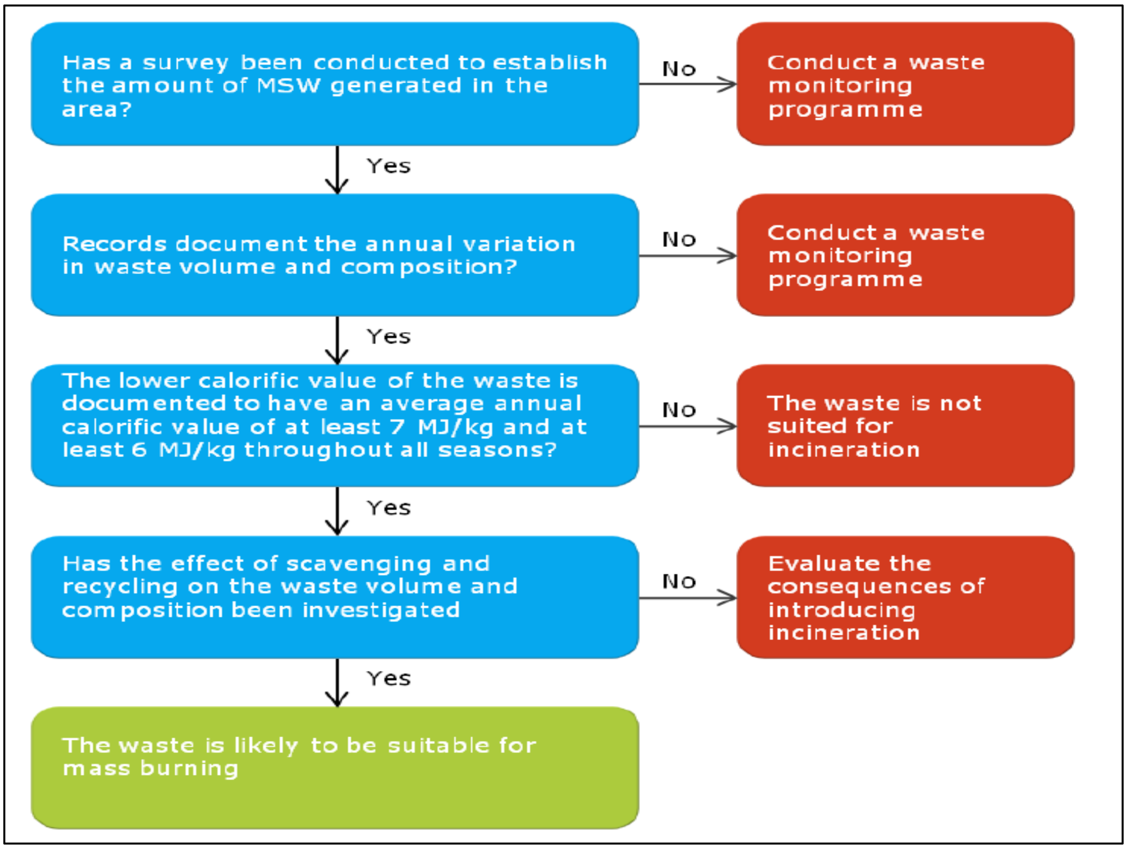


Figure 4.2: Flowchart Assessment of waste as fuel indicated the need for further seasonal studies on waste characterization



4.1 Waste Composition of District Central and District Korangi

To ease the discussion on the potential use of waste for District Central and District Korangi, the overall waste characterization of District Central and District Korangi has been combined and is shown in **Table 4.1**.

Table 4.1: Percentages of residential waste characterization - Combined

Sr No.	Item	District Central	District Korangi	Percentage Overall
1	Kitchen waste	56.00	52.56	54.00
2	Paper	4.62	3.72	4.10
3	Textile	3.65	4.01	3.86
4	Grass and wood	0.30	0.95	0.67
5	Plastic	16.30	13.86	14.88
6	Leather and rubber	0.77	1.25	1.05
7	Metal	0.34	0.39	0.37
8	Bottle and glass	0.51	0.94	0.76
9	Ceramic, stone.	0.87	0.95	0.92
10	Domestic hazardous wastes	0.63	1.32	1.03
11	Residue Remaining (Material Remaining on sheet	1.59	1.84	1.73
12	Miscellaneous			
A	Tetra Pack	0.48	0.54	0.60
B	Hairs	0.01	0.00	0.01
C	Pampers	12.42	11.08	13.51
D	Bones	0.39	0.33	0.27
E	Dust/ Seive	0.98	3.57	2.09
F	E-Waste	0.12	0.27	0.14
	Total	**100**	**100**	**100**

Table 4.2: 3R (Reduce, Reuse, Recycle) and Intermediate Potential by Solid Waste Composition – Combined

Material Recycling Potential		Composting Potential		RDF Potential	
Component	(%)	Component	(%)	Component	(%)
Paper	4.10	Kitchen waste	54.00	Paper	4.10
Plastic	14.88	Grass and wood	0.67	Plastic	14.88
Leather and rubber	1.05	Bones	0.27	Textile	3.86
Metal	0.37	Hairs	0.01	Grass and wood	0.67
Bottle and glass	0.76	**Total**	**54.95**	Leather and rubber	1.05
Tetra pack	0.60			Tetra Pack	0.60
Total Recyclable Wastes	**21.76**			**Total**	**25.16**

Proposed Value for Planning	**22**	**55**	**26**

Table 4.3: 3R (Reduce, Reuse, Recycle) and Intermediate Potential by Solid Waste Composition – District Central

Material Recycling Potential		Composting Potential		RDF Potential	
Component	**(%)**	**Component**	**(%)**	**Component**	**(%)**
Paper	4.62	Kitchen waste	56.00	Paper	4.62
Plastic	16.30	Grass and wood	0.30	Plastic	16.30
Leather and rubber	0.77	Bones	0.39	Textile	4.01
Metal	0.34	Hairs	0.01	Grass and wood	0.30
Bottle and glass	0.51	**Total**	**56.7**	Leather and rubber	0.77
Tetra pack	0.48			Tetra Pack	0.48
Total Recyclable Wastes	**23.02**			**Total**	**26.12**
Proposed Value for Planning	**24**		**57**		**27**

Table 4.4: 3R (Reduce, Reuse, Recycle) and Intermediate Potential by Solid Waste Composition – District Korangi

Material Recycling Potential		Composting Potential		RDF Potential	
Component	**(%)**	**Component**	**(%)**	**Component**	**(%)**
Paper	3.72	Kitchen waste	52.56	Paper	3.72
Plastic	13.86	Grass and wood	0.95	Plastic	13.86
Leather and rubber	1.25	Bones	0.33	Textile	3.65
Metal	0.37	Hairs	0.00	Grass and wood	0.95
Bottle and glass	0.94	**Total**	**53.84**	Leather and rubber	1.25
Tetra pack	0.54			Tetra Pack	0.54
Total Recyclable Wastes	**20.68**			**Total**	**23.97**
Proposed Value for Planning	**21**		**54**		**24**

4.2 Waste Utilization and Intermediate Treatment Options for District Central and Korangi

There are many technical methods for the intermediate treatment of municipal waste. However, some of them are effective only for small-scale systems, and some other options are technically sophisticated. Considering the waste characteristics, the waste amount for treatment and the technologies that are practical for developing countries[40], the following technical options, including composting, MRF and waste to energy (incineration, RDF, landfill

[40] http://gwmc.com.pk/media/downloads/iswm-master-plan-in-gujranwala-volume-02.pdf

gas capture and pyrolysis), were selected to further study as possible intermediate treatment facilities for District Central and District Korangi, Karachi.

4.2.1 Waste as a fuel option for District Central and District Korangi

Waste collection usually constitutes the major solid waste management cost in cities and Municipalities. Therefore, Waste to Energy (WtE) options are of great interest within the municipal leadership to possibly (and partially) cover the waste collection cost. Utilities tend to consider their solid waste as a resource that, within appropriate institutional and financial arrangements, can be used to bring in private sector investment for waste to energy projects. However, care should be taken in applying off-the-shelf solutions to particular projects—each project should be evaluated on a stand-alone basis. These solutions should be sized to cater for the non-recyclable, non-recoverable, and non-up cyclable materials and any landfill mining over the life cycle of the project. One should not presume that all the municipal waste can be used for waste to energy projects[41].

The viability of any MSW incineration facility depends highly, and most importantly, on the quantity and calorific value of the waste. The economic state of the country/area is highly correlated to the calorific value of the waste. Countries with a high degree of consumerism tend to have higher calorific waste characterization due to plastics and cardboard for packaging consumer goods.[42]MSW of District Central and Korangi is distinct when compared with the MSW around the world as its paper quantity is significantly less. Other than that, the characterization of the MSW is quite similar.

The large incinerator burning Municipal Solid Waste is the process that comes to mind when WtE is mentioned. However, a similar public utility need can be met by making biogas from the organic fraction of municipal solid waste, which is mostly food; refuse-derived fuels (RDF) from combustible materials; and repurposing inert materials as fuel. The further utility can be provided by converting biogas to compressed biomethane fuel (BioCNG). BioCNG can be bottled to provide a solution to cooking, light industry, or even transport. Asian Development Bank itself is considering the usage of biogas for transportation for a mass transit project in Karachi[43].

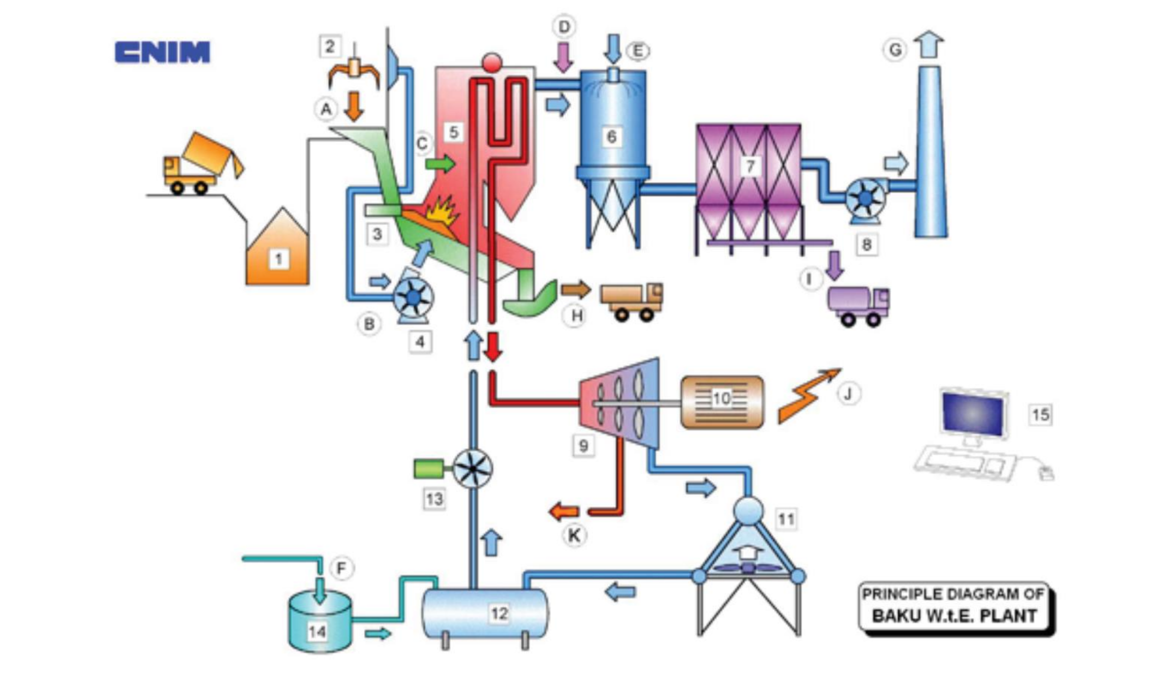
Table 4.5: WtE conversion techniques applicable to the waste available in Karachi:

Item	Technology	Output
Thermal	Combustion	Heat, Electricity, Bottom Ash and Fly Ash
Mechanical-thermal	Mechanical Biological Treatment	Biogas, Electricity, RDF, compost like material
	Landfill gas capture	Biogas, heat, electricity,
Thermo-chemical	Gasification	Syn Gas, Bottom Ash
	Pyrolysis	Syngas, char, oil

[41] Waste to Energy in the age of circular economy, Asian Development Bank, November 2020
[42] https://www.iswa.org/index.php?eID=tx_iswaknowledgebase_download
[43] https://www.thenews.com.pk/print/575719-red-line-brt-to-be-based-on-ecofriendly-biogas-says-adb-official-at-moot

Municipal Solid Waste Incineration/ Mass Burning Option: Direct combustion is the oldest technology for biomass conversion, especially for generating heat and steam. The combustion technologies to convert MSW to heat and electricity use similar processes if using fossil fuels. The MSW is burned in a boiler to produce high-pressure steam that flows through a series of turbine blades, causing the turbine to rotate. The turbine is connected to an electric generator that produces electricity. Dumping grate type boilers are the preferred choice for MSW.

Figure 4.3: Mass Burning Process



Legend: EQUIPMENT: 1- Waste bunker, 2- Traveling crane and grab, 3- CNIM/MARTIN GmbH combustion grate, 4- Combustion air supply, 5- CNIM recovery boiler, 6- LAB Semi-dry type reactor, 7- Fabric filter, 8- Induced draft fan, 9- Steam turbine, 10-Alternator, 11-Air cooled condenser, 12-Deaerator and feed water tank, 13- Feed water pumps, 14- Feed water treatment and demineralized water tank, 15-Operation and control unit in control room.

INPUT: A- Waste; B- Air, C- Urea solution, D- Activated carbon, E- Lime slurry, F- Raw water.

OUTPUT: G-Clean flue gas, H- Coarse ash (clinker) to storage and maturation area, I- Fly ash and flue gas treatment by-products, J- Electricity, K- Steam to district heating network (future possibility).

Source: Constructions Industrielles de la Méditerranée (CNIM) Group.

Mass burning aims to reduce MSW volume and mass and make it chemically inert in a combustion process without the need for additional fuel (autothermic combustion). There are always about 25% residues from incineration in slag (bottom ash) and fly ash. Bottom ash is made up of fine particulates that fall to the bottom of the incinerator during combustion, whilst fly ash refers to fine particulates in exhaust gases that must be removed in flue gas treatment. These residues need further attention and, in the case of hazardous fly ash, a secure place for final disposal. Incinerate the waste and convert the heat derived from the process to generate electricity. The energy recovered from incineration produces power and/or steam, depending on local infrastructure and needs. For combined heat and power plants, one ton of waste can be converted to approximately 2 MWh heat and 2/3 MWh electricity.

In general, the average(year-wide) and recommended lower calorific value of waste should be at least 7 MJ/kg –(1671 kcal/kg) and must never fall below 6 MJ/kg –(1433 kcal/kg). Without this value, there would be a need to constantly supply auxiliary fuel, which would decrease the viability of an MSW incineration facility. It can be observed that the average or the recommended lower calorific value is only met for District Central, Karachi. In District Korangi, only Landhi meets the minimum calorific value requirement. The calorific value varies in the different zones of the districts due to the moisture content and composition of waste.

The energy content of District Central and District Korangi is 1680 kcal/kg, as calculated in **Table 4.5**.

Table 4.6: Gross and Net Calorific Value in District Central and District Korangi, Karachi

	District Central			District Korangi			
	Gulberg (High Income)	**North Nazimabad (Middle Income)**	**Liaquatabad (Low Income)**	**Model Colony (High Income)**	**Shah Faisal Colony (Middle Income)**	**Landhi (Low Income)**	**Average (kcal/kg)**
Gross Calorific Value (kcal/kg)	2745	2348	3343	1346	1261	1938	2164
Lower (Net) Calorific Value(kcal/kg)	2242	1895	2879	810	798	1453	1680
Calorific Content	**Meet requirements**			**Does not meet minimum requirement**		**Meets minimum requirement**	**Meet Requirements**

Seasonal factors also play an important role in the determination of constant high calorific value evaluation throughout the year. Therefore, for District Central and District Korangi, the waste to energy option will be evaluated completely after the seasonal survey on waste amount characterization is conducted in District Central and District Korangi. The Waste Amount Characterization Survey needs to be carried out at least twice a year or preferably quarterly to obtain year-round results.[44]

Another aspect is the economic viability of proposing such a facility. The specific investment and operation costs per ton of waste decrease as the capacity of the plant and the utilization rate increase.

Therefore, the plant capacity should be preferably higher than 100,000 tons per year to achieve optimal economies of scale together with average collection distances (GIZ, 2017). Both the districts do have enough waste generated to make incineration economically viable. Furthermore, GIZ Guidelines on Waste to Energy calculate the net cost of using incineration to treat waste in developing countries as 40-80 Euro per ton.

Based on the proximate and ultimate analysis of the MSW of District Central and Korangi, the following is the electricity generation potential of the W_tE plant.

[44] Hla, S.S., Roberts, D. Characterisation of chemical composition and energy content of green waste and municipal solid waste from Greater Brisbane, Australia. Waste Management (2015), http://dx.doi.org/10.1016/j.wasman.2015.03.039

Table 4.7: Waste to Energy Potential in District Central and District Korangi

Area	MSW tons per day	LHV Kcal/kg	Energy in MSW MWh	Electrical Power Potential MW	Power to grid MW
Central	1909	2339	3633	45.4	30.7
Korangi	1629	1020	1352	16.9	11.4
Combined	3,538	1680	4509	60.5	40.8

In 2018, NEPRA announced a competitive upfront tariff of US Cents 10.007/kWh for waste to energy projects based on 25 years operational period, with an overall capacity cap of 250 MW wherein the share of each province and Federal Territory have been kept at 50 MW each[45]. In 2018, In line with the new tariff structure, NEPRA granted a generation license to a Chinese company registered in Pakistan as "Lahore Xingzhong Renewable Energy Company (Private) Limited to construct and operate the waste to the energy power plant of 40MW at Lakhodair in Lahore and accepting 20,000 tons/day of the municipal waste. NEPRA has announced the tariff of MSW based power plants to be 9.87 cent/kWH[46] for one project under this regime. It ought to be noted that this tariff is the highest among all the renewable tariffs announced by NEPRA on the date of compiling this report.

It ought to be noted that electrical energy accounts for 25% of the total revenues in waste-to-energy plants in the European Union. The remainder is for the environmental treatment fee (gate fee) and the sale of ancillary products, including heat, bottom ash, and slag. Therefore, the careful examination needs to be undertaken before going for waste to energy options generating electrical energy.

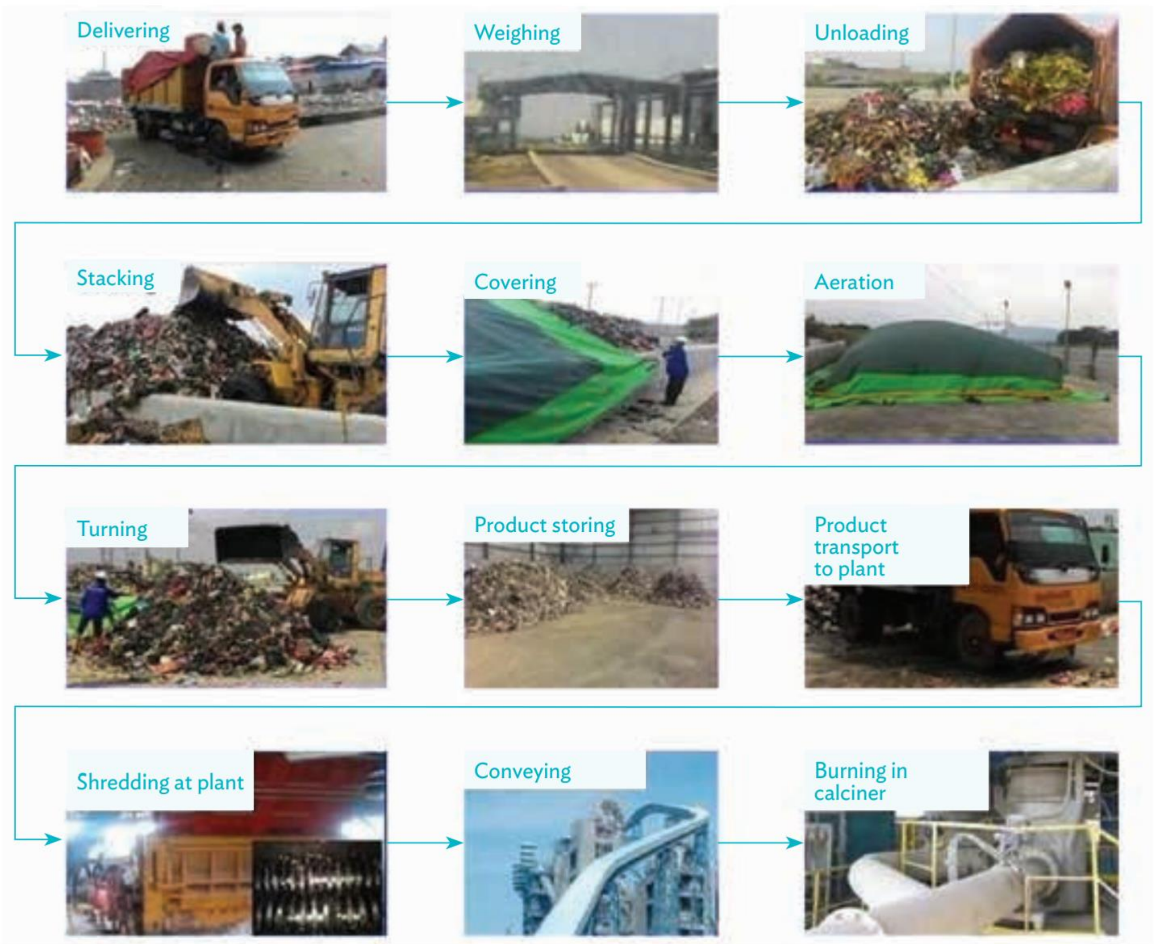
Refuse Derived Fuel Via Mechanical Biological Treatment (MBT): RDF consists largely of combustible components of municipal waste such as plastics and biodegradable waste. Refuse-derived fuel (RDF) or solid recovered fuel/specified recovered fuel (SRF) is a fuel produced by shredding and dehydrating solid waste with waste technology. Co-processing of RDF in cement plants has also become a widespread waste management system in several developing and emerging countries.

Mechanical biological treatment (MBT)[47] involves the combination of various processes such as mechanical (e.g., sorting, shredding, milling, separating, or screening) and biological components (drying, composting, or anaerobic digestion) to create solid recovered fuel or RDF and divert organic materials for fertilizer and energy. This fuel can be further processed as pellets or briquettes and can be used as feedstock in energy facilities as a replacement for fossil fuels. MBT consists of different treatment processes and has four types of outputs:

[45] https://nepra.org.pk/tariff/Tariff/Upfront/2018/UGTMSWPP-18%20Determination%2015-01-2018%20539-41.PDF
[46] https://nepra.org.pk/tariff/Generation%20IPPs%20Waste%20to%20Energy.php
[47] F. Fe, Z. Wen, and S. Huang. 2018. Mechanical Biological Treatment of Municipal Solid Waste: Energy Efficiency, Environmental Impact and Economic Feasibility Analysis. https://doi.org/10.1016/j.jclepro.2018.01.060

1. RDF – has a high calorific value due to high paper and plastic content.
2. Stabilized organic waste – produced from the biological treatment of the organic portion of the waste.
3. Ferrous and non-ferrous metals – for potential recycling; and
4. inert wastes – scraps/residues that are disposed of in landfills.

Figure 4.4: Pictorial Presentation of RDF Process



For RDF to be successful, a high percentage of the waste streams needs to have a high calorific value. The RDF potential in District Central and District Korangi, Karachi, is 27%. Another aspect is the economic viability of proposing such a facility. According to GIZ Waste-to-Energy Options in Municipal Solid Waste Management, the minimum pre-sorted waste required is 50,000 tons per year. Furthermore, GIZ calculates the net operating cost of using RDF to treat waste in developing countries as 19-40 Euro per ton.

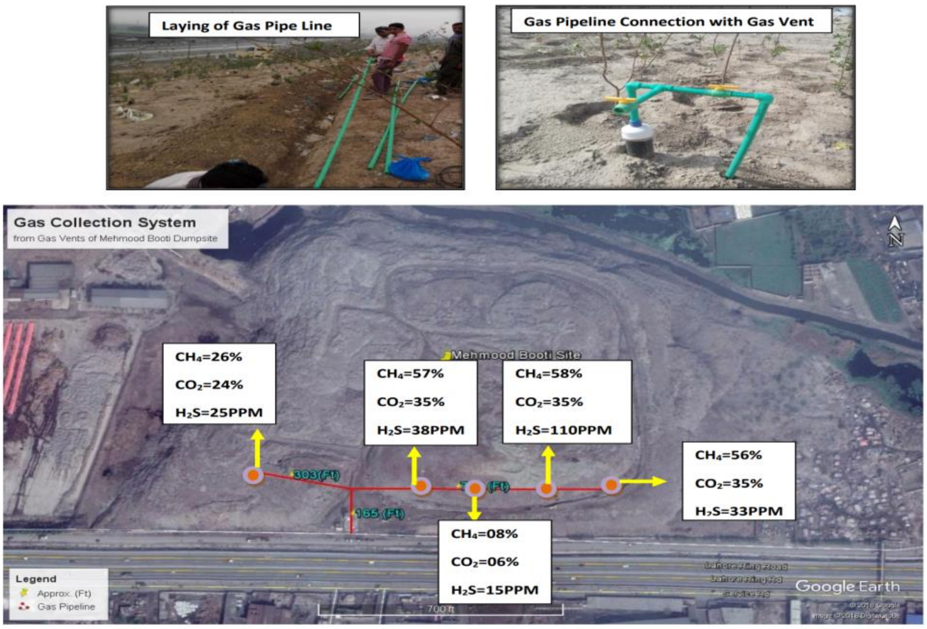
Refuse Derived Fuel is suitable for District Central and District Korangi due to high waste quantity and suitable calorific value. MSW of Korangi has 24.47% material that can be used for RDF production. It is estimated that with the solid waste production of 3,538 TPD, the potential of RDF stands at 895 TPD. RDF price in the market stands at PKR 3,000 per ton. However, it fluctuates as per demand. Long term agreements can be sought with the cement plants near Karachi for the sale of RDF. There have been instances in Pakistan where cement plants have opted to establish RDF plants with their own investment while buying MSW at a price of PKR 52/ton from Lahore Waste Management Company.[48]

A similar quantity of compost can be expected out of the plant, i.e.,716 TPD. The price of compost is Rs 6000 per ton. However, its market demand is uncertain.

Landfill Gas Capture: While operating an engineered or a sanitary landfill, landfill gas, which consists of 35%–55% methane, is generated by the anaerobic digestion of organic matter in the landfill body. To capture the methane generated, a landfill gas recovery plant is installed consisting of an extraction system and flaring system[49]

An example of one such pilot system was installed by LWMC at Mehmood Booti Dumpsite. Gas has been monitored initially from installed gas vents. During the trial project, Gas from four (04) identified Gas Vents already installed at the dumpsite was collected and transported through 900 feet long gas pipeline to one point for testing and flaring. After completion of work and gas has been tested during different intervals, and as proposed, Methane gas has been identified, which is a combustible gas that can be utilized to generate heat and power. More than 50% concentration of methane was noted at most of the vents.

Figure 4.5: Pictorial presentation of Landfill Gas Capturing Process

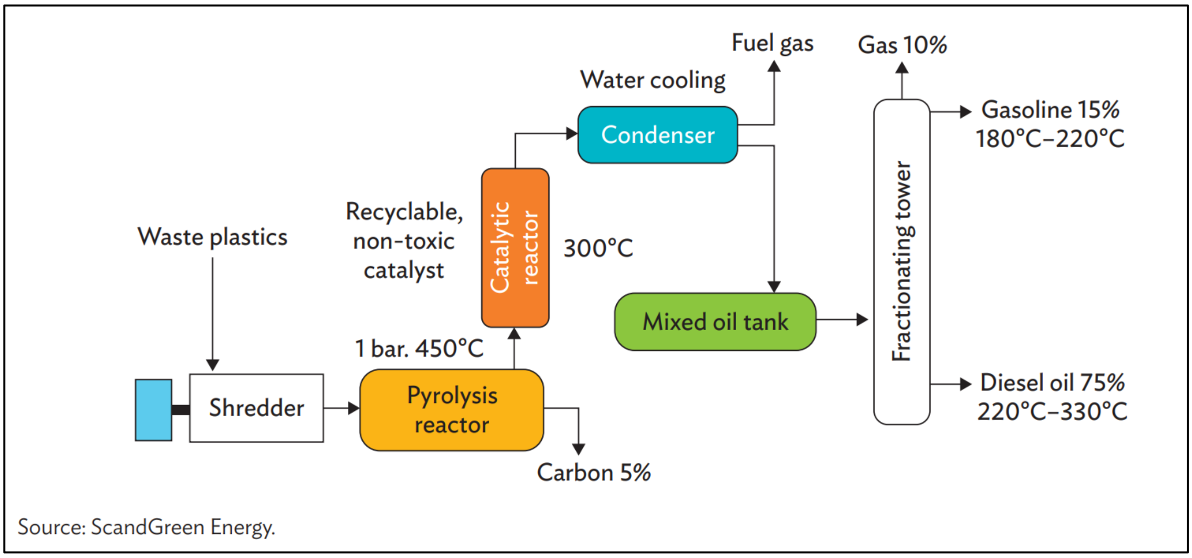


Pyrolysis: Pyrolysis is a thermochemical process conducted at a temperature between 400˚C–600˚C in the absence of air. As there is no oxygen present, the organic material cannot be combusted, but chemical compounds such as cellulose, hemicellulose, and lignin decompose into combustible gases and charcoal. Depending on factors such as temperature, pressure, and heating rate, pyrolysis produces three products—solid, liquid, and gas in the form of biochar, bio-oil, and syngas.

48 https://tribune.com.pk/story/1966466/lahore-stands-tall-generating-green-fuel-waste

49 H. Terraza and H. Willumsen. 2009. Guidance Note on Landfill Gas Capture and Utilization. Technical Notes 108. InterAmerican Development Bank. http://www.resol.com.br/textos/guidance_note_on_landfill_gas_capture-idb.pd.

Figure 4.6: Pyrolysis Process



Given the fact that around 15% of the MSW at Korangi and Central is plastic. It has the potential of generating diesel, petrol, and carbon black under the right pyrolysis conditions. It is estimated that the MSW has the potential of generating 160.4 tons of diesel, 108 tons of petrol and 38 tons of carbon black per day.

Table 4.8: Potentials of waste to energy options for MSW at Korangi and Central Districts

Technology	Output per day
Combustion	730,000 kWh
Mechanical Biological Treatment	895 TPD RDF 716 TPD Compost
Landfill gas capture	2,065 MMBTU
Pyrolysis	160.4 tons of diesel, 108 tons of petrol and 38 tons of carbon black

However, it ought to be noted that the presented indicative waste to energy potential is based on industrial practices and consultant estimates based on similar projects. The selection of a single or mix of technologies will require detailed feasibility studies. Therefore, it is recommended that separate detailed technical, environmental, and financial feasibility studies for using waste to energy should be carried out by SSWMB.

4.2.2 Composting Option for District Central and District Korangi

High moisture content suggests the applicability of wet treatment options, including composting, anaerobic digestion is more feasible options for the segregated organic stream of the municipal waste; this could prove to be a feasible option because, during waste generation, a high amount of organic waste (more than 50%) with high moisture content (50~70%) was obtained that could be incorporated into compost successfully. With the high percentage of biodegradable waste, at 54% of municipal waste in District Central and District Korangi, composting will be the most practical means for intermediate treatment.

Carbon and Nitrogen are of utmost importance for compost values as their correct ratio favours waste to be used as a fertilizer. In the present study, the average calculated C/N rato values of household waste for both districts combined is 21.5, i.e., near the recommended range. The optimal C/N ratio value of the composting material is 25-40.[50]

Table 4.9: Chemical characterization based composting potential of waste in District Central and District Korangi

Area		Moisture (%)	Carbon (%)	Carbon/ Nitrogen Ratio
District Central	Gulberg (High Income)	48.99	26.7	61.14
	North Nazimabad (Middle Income)	47.89	21.33	23.62
	Liaquatabad (Low Income)	41.08	28.94	11.12
District Korangi	Model Colony (High Income)	73.16	13.01	32.77
	Shah Faisal Colony (Middle Income)	61.27	12.38	19.37
	Landhi (Low Income)	58.97	17.70	29.35
District Central and District Korangi		**55.23**	**20.01**	**21.5**

In our study, if this sample is considered for compost, this could prove to be a feasible option. During waste generation, a high amount of organic waste (up to 50%) was obtained to be incorporated into compost successfully. Added moisture content could be obtained by inoculating agents like cow dung, poultry manure, yard waste etc., in the solid waste. Similarly, the C/N ratio can be improved by adding wood chips to the waste.

Some examples of composting in low-income countries include composting plants in Lahore (Pakistan), Indonesia, and Bangladesh. In Punjab, Pakistan, a composting plant is being operated in Lahore Compost (Pvt.) Ltd. (LCL). The LCL has been operating since 2006, and they produce compost and RDF. The plant could not sell the compost. Also, more than half of the compost products remained unsold. One reason is no trust of the users (farmers and inhabitants) on organic fertilizers, i.e., compost.

In one of the largest parks in Gujranwala City, named Gulshan Iqbal Park, composting has been practised for more than 23 years. After establishing the Parks and Horticulture Authority

[50] Tom L. Richard. Municipal Solid Waste Composting: Biological Processing. 1996. http://compost.css.cornell.edu/MSWFactSheets/msw.fs2.html . Accessed on 16th April 2021

(PHA) on 11 April 2014, the administration of all parks was handed over by the Tehsil Municipal Administrations (TMA) to PHA.

The pit and open heap/pile method of composting is being practised. In the open heap/pile method, cow dung, dry crushed leaves and earth are mixed at the ratio of 3:2:14. A periodic sprinkling of 5% DAP (Di-Ammonium Phosphate) solution is done on the pile. In the pit method of composting, 2 feet high layers of leaves of a eucalyptus tree in the park are placed in the pit, and a periodic sprinkling of 5% DAP is also done.

The process is completed in 3 pits. After every three months, the material is transferred to the next pit. This type of compost is prepared in 9 months. Compost prepared in this park is used only for horticulture and floriculture within the park. As many as 100,000 plants of 23 different varieties grew using this compost in 2014. PHA has a plan to expand composting into the other parks in Gujranwala City.[51]

In Surabaya (Indonesia), the breathing or ventilation type container compost plant such as the plastic basket lined with geotextile is used for the home method composting to put in raw wastes discharged from kitchens, etc., together with seeding material for composting.

In Dhaka, the capital of Bangladesh, Waste Concerns, the registered NGO, constructed a middle-scale compost plant with the capacity of 130 tons per day and started operations at the beginning of 2009 to produce compost from biodegradable wastes collected from markets upon approval by the Government of Bangladesh and by the project Executive Board of UN for the Project. This example is a good case to develop the central compost project through linkage with the activities of the private sector regardless of the financial weakness of the local government.

4.2.3 MRF (Material Recovery Facility) Option for District Central and District Korangi

Suitable waste input for MRF includes sorted waste for recycling metal, glass, paper, plastics, and other valuables. The recyclables are stored in the open space or small-scaled houses. Recyclables are sold to junkshops, recyclable shops, etc.

The survey results on characterization (**Table 4.2)** indicated a total of 21.76 % of items that can be recycled from the waste stream. The potential of recycling in District Central and District Korangi is 22%. Therefore, it is recommended that the Material Recovery Facility can be installed at the Garbage Transfer Station.

Table 4.10: MRF Potential in District Central and District Korangi, Karachi

	Zone	MRF (%)
District Central	Gulberg (High Income)	22.34
	North Nazimabad (Middle Income)	20.92
	Liaquatabad (Low Income)	26.36
District Korangi	Model Colony (High Income)	18.09
	Shah Faisal Colony (Middle Income)	22.52
	Landhi (Low Income)	24.6
	Overall	**21.76**

[51] Project For Integrated Solid Waste Management Master Plan In Gujranwala Final Report Volume 3 (http://open_jicareport.jica.go.jp/pdf/12246336_02.pdf page 18)

An example of the Philippines includes establishing a materials recovery facility (MRF), which is mandated to the local barangays (villages) under the Ecological Solid Waste Management Act of 2000 as the centre for recovery of recyclable waste. Accordingly, the MRF shall have the role as a core facility of 3R activities operated by the villages with the participation of community residents. However, in most cases, the MRF facilities in the Philippines are operated mainly for the community level composting of organic wastes since the recovery of valuable wastes by private junkshops is very active. The valuable wastes brought to the MRFs are very few.

Another example of MRF is in Thailand, which includes waste banks establishing segregated recyclable wastes such as paper, glass, plastics and metal recovered directly from the waste generation sources by the residents and/or community activities. The recovered recyclables are sold at the bank. The junk shops or the recyclers purchase the recovered waste from the bank. According to the report "Waste Minimization in Thailand: Experience and Trend" by Mr Rangsan Pinthong, Pollution Control Department, MONRE, Thailand, nowadays, more than 500 waste recyclable bank systems have been established in 30 provinces.

4.2.4 Biogas

Biogas means gas produced by the anaerobic digestion or fermentation of organic matter. The organic matter can be manure, sewage sludge, municipal solid waste, biodegradable waste, or any other biodegradable feedstock. Biogas is mainly methane and carbon dioxide. Depending on where it is produced, biogas is also called: swamp gas, marsh gas, landfill gas, digester gas. Biogas can be used as vehicle fuel or for generating electricity. It can also be burned directly for cooking, heating, lighting, process heat and absorption refrigeration[52].

In Pakistan, biomass is readily available in most areas of the country, particularly in rural areas. Biomass energy uses natural materials such as trees, plants, and wastes to make electricity and biofuel. It is also environmentally friendly. Since 1974, more than 1,700 biogas plants have been installed under a nationwide programme funded by the Government of Pakistan.

NRSP provides the research to access the design, maintenance, usage, and sustainability of biogas plants as an energy source at the household level. "Evaluation of Biogas Initiative in Punjab", National Rural Support Programme (NRSP), August 2011.

The full cost of biogas plants in Punjab, Pakistan, is in ranges from Rs. 40,000 to Rs. 80,000 and above, depending on the size.[53] Based on the economic analysis conducted in the US, the total cost for a biogas plant, including all essential installations but not including land, is between 50-75 US Dollars per m^3 capacity. 35 - 40% of the total costs are for the digester.[54]

Table 4.11: Daily requirements of biogas plant by size[55]

[53] http://www.nrsp.org.pk/publications/Evaluation-Assessment-Studies/Renewable-Energy-Evaluation-of-Biogas-Initiative-in-Punjab.pdf
[54] https://energypedia.info/wiki/Costs_of_a_Biogas_Plant#Production_Costs
[55] (Source: RSPN information brochure on biogas http://www.rspn.org/our_projects/projects_pdfs/Brochure.pdf)

Plant Size(m^3)	Daily dung requirements (kgs)	Livestock requirements (cow/bullocks)	Daily water requirements (liters)	Gas Production (M^3/day)
4	30	2-3	30	4
6	45	4-5	45	5-6
8	60	5-6	60	6-8
10	75	7+	75	8-10

4.3 Proposed Solution:

Based on the Qualitative Evaluation Matrix of Intermediate Waste Treatment Options for District Central and Korangi, Karachi given under **Table 4.11** & **4.12**, the most suitable technological option for handling the municipal waste generated in Central and Korangi Districts is a combination of mechanical and biological treatment options enabling around 80% of the organics, recyclables and combustibles from the landfill and saving landfill space for a longer time, recovering the economic potential of the waste and improving the environment through reducing the methane emission from the landfill. A centralized waste management facility will be handling MSW in the following steps:

1. A sorting line consists of a bags opener, trommel screens/vibratory, magnets, ballistic separator, and baling units. The possibility of establishing a pyrolysis plant may be considered after ascertaining the plastic quantity that can be salvaged from scavengers.
2. After sorting and segregation, organic waste will be subjected to Anaerobic Digestion and subsequent composting using aerated piles.
3. Biogas produced will either be used to generate energy for the MSW plant and gas filling after necessary treatment or will be used as transportation fuel after necessary compression
4. RDF will be produced, which may be sold to the cement industries or brick kilns.
5. Recyclables will be sorted, which may be sold to the recycling industry.
6. The remaining inert waste will be landfilled

Table 4.12: Qualitative Evaluation Matrix of Intermediate Waste Treatment Options for District Central, Karachi

Evaluation Items	Option 1: No Treatment (Current condition)	Option 2: Composting	Option 3: MRF	Option 4: Mass Incineration	Option 5: RDF	Option 6: Bio-gas
Waste Type	Mixed waste	Biodegradable waste	Sorted waste for recycling	Combustible	Combustible (plastic, paper)	Biodegradable
Cost of Facility	No cost due to no facility	Cheaper	Cheaper	Very expensive	Expensive	Moderate
	-	A	A	B	A	A
Environmental Aspect	Need to acquire 100% collection efficiency	Odour if mishandled	Odour if mishandled	Need removal of pollutants from combustion gas emission. However, Incineration has additional environmental benefits as well.	Need removal of pollutants from combustion gas emission	Odour if mishandled
	B	A	A	A	A	A
Applicability	-	Small towns to large cities	Small communities to middle cities	Best for Large Cities such as District Central and Korangi	Small towns to large cities	Villages /small towns in rural areas
	A	A	A	A	A	A
Actual Practical Experiences in Pakistan	Present	There is the Lahore Compost Company.	Not present (Few projects are underprocessed)[56]	Not present	RDF as fuel in D.G. Khan Cement Company, and Lafarge/Fauji Cement companies.	Present (Installed by NRSP)
	B	A	A	B	A	A
Recommendations for application to District Central solid waste	-	Highly Applicable	High potential/ proportion (22%), but if the compost plant is established, MRF is	Calorific Value meets the minimum requirement	Applicable as sufficient amount of combustibles are present	Organic matter was comparatively less as compared to other Cities

[56] https://www.dawn.com/news/1613131/segregation-treatment-and-disposal-plant-to-be-functional-in-april

Evaluation Items	Option 1: No Treatment (Current condition)	Option 2: Composting	Option 3: MRF	Option 4: Mass Incineration	Option 5: RDF	Option 6: Bio-gas
intermediate treatment facilities			viable as both activities are interdependent.			
	-	A	A	A	A	B
Recommendation as per solid waste policies applicable to District Central	Recommended options for waste utilization and recovery are Option 2: Composting, Option 3: Material Recovery Facility, Option 4: Mass Incineration, Option 5: RDF as the most practical/reliable intermediate treatment facilities in District Central.					
	-	A	A	A	A	A
Evaluation Results		A	A	A	A	A

Legend: A- Suitable; B- Not suitable

Source: JICA Project Team, GWMC

Note:* NRSP stands for National Rural Support Programme (NGO).

** NRSP, Monitoring, Evaluation & Research Section, "Renewable Energy: Evaluation of Biogas Initiative in Punjab" August 2011

Table 4.13: Qualitative Evaluation Matrix of Intermediate Waste Treatment Options for District Korangi, Karachi

Evaluation Items	Option 1: No Treatment (Current condition)	Option 2: Composting	Option 3: MRF	Option 4: Mass Incineration	Option 5: RDF	Option 6: Bio-gas
Waste Type	Mixed waste	Biodegradable waste	Sorted waste for recycling	Combustible	Combustible (plastic, paper)	Biodegradable
Cost of Facility	No cost due to no facility	Cheaper	Cheaper	Very expensive	Expensive	Moderate
	-	A	A	B	A	A
Environmental Aspect	Need to acquire 100% collection efficiency	Odour if mishandled	Odour if mishandled	Need removal of pollutants from combustion gas emission. However, Incineration has additional environmental benefits as well.	Need removal of pollutants from combustion gas emission	Odour if mishandled
	B	A	A	A	A	A
Applicability	-	Small towns to large cities	Small communities to middle cities	Best for Large Cities	Small towns to large cities	Villages /small towns in rural areas
	A	A	A	A	A	A
Actual Practical Experiences in Pakistan	Present	There is the Lahore Compost Company.	Not present (Few projects are underprocessed)[57]	Not present	RDF as fuel in D.G. Khan Cement Company, and Lafarge/Fauji Cement companies.	Present (Installed by NRSP)
	B	A	A	B	A	A

[57] https://www.dawn.com/news/1613131/segregation-treatment-and-disposal-plant-to-be-functional-in-april

Evaluation Items	Option 1: No Treatment (Current condition)	Option 2: Composting	Option 3: MRF	Option 4: Mass Incineration	Option 5: RDF	Option 6: Bio-gas
Recommendations for application to District Korangi solid waste intermediate treatment facilities	-	Highly Applicable	High potential/ proportion (22%), but if the compost plant is established, MRF is viable as both activities are interdependent.	Low potential (Low energy value) needs additional data to decide	Applicable as sufficient amount of combustibles are present	Organic matter was comparatively less as compared to other Cities
	-	A	A	B	A	B
Recommendation as per solid waste policies applicable to District Korangi	Recommended options for waste utilization and recovery are Option 2: Composting, Option 3: Material Recovery Facility and Option 5: RDF as the most practical/reliable intermediate treatment facilities in District Korangi.					
	-	A	A	B	A	A
Evaluation Results		A	A	B	A	A

Legend: A- Suitable; B- Not suitable

Source: JICA Project Team, GWMC

Note:* NRSP stands for National Rural Support Programme (NGO).

** NRSP, Monitoring, Evaluation & Research Section, "Renewable Energy: Evaluation of Biogas Initiative in Punjab" August 2011

5 Conclusion & Recommendations

This chapter describes the conclusion and recommendation of the Waste Amount Characterization Survey in District Central and District Korangi, Karachi.

5.1 Conclusion

Following conclusions can be drawn from the Waste Amount Characterization Survey:

- The residential solid waste generation rate ranges from 0.368 to 0.491 kg/capita/day. The average residential solid waste generation rate is 0.450 kg/capita/day in Central District, Karachi.
- The residential solid waste generation rate ranges from 0.397 to 0.495 kg/capita/day. The average residential solid waste generation rate is 0.447 kg/capita/day in Korangi District, Karachi.
- Overall, in residential areas of Central District, the highest percentage was found out to be of the kitchen or food waste at 56.00%, followed by Plastic at 16.30%, Pamper / Diapers / Sanitary Pads at 12.42%, Paper at 4.62%, textile at 3.65% and residue material remaining on the sheet at 1.59%. All the rest of the items were below 1%.
- Overall, in residential areas of Korangi District, the highest percentage was found out to be of the kitchen or food waste at 52.56% followed by Pampers at 14.30%, Plastic at 13.86%, Textile at 4.01%, Paper at 3.72%, Dust at 2.89%, Residue material at 1.84%, Domestic Hazardous Waste at 1.32% and Leather and Rubber at 1.25%. All the rest of the items were below 1%.
- The commercial waste generation rate of shops is 1.608 and 1.956 kg/day in Central and Korangi Districts, respectively. Major components included plastic and papers indicating the recycling potential of commercial waste.
- The density of residential solid waste (Central district) at high, middle & low incomes were 281.92 kg/m^3, 267.56 kg/m^3 and 266.97 $kg/m^{3,}$ while the average density was 272.15 kg/m^3.
- The density of residential solid waste (Korangi district) at high, middle & low incomes were 248.83 kg/m^3, 257.05 kg/m^3 and 251.57 $kg/m^{3,}$ while the average density was 252.48 kg/m^3.
- There is 21.76% recyclable components in the total waste collected. The organic components constituted 53.91% of the waste, and 26.05% of waste had RDF potential. Therefore the proposed values for planning waste utilization and recovery options are 22%, 54% and 27% for recycling, composting, and incineration/RDF, respectively.
- Presently, the best method to treat the waste is establishing a Material Recovery Facility and Compost Plant. Composting is also favourable due to optimum moisture content and C/N ratio.
- The energy content of District Central is 2,339 kcal/kg, and for District Korangi, it is 1020 kcal/kg. Whereas the energy content (average LCV_{wb}) of Central and Korangi districts is 1680 kcal/kg. In general, the average lower calorific value of waste should be at least 1671 kcal/kg (7 MJ/kg) and must never fall below 1433 kcal/kg (6 MJ/kg). Without this value, there would be a need to constantly supply auxiliary fuel, which would increase the viability of an MSW incineration facility at risk.

5.2 Recommendations

After reviewing the concluded results and data acquired, the following are the recommendations which are proposed for the betterment of the waste management system of Central and Korangi Districts of Karachi:

- For future Waste Amount Characterization Survey, the EPA Ireland method should be adopted by SSWMB to avoid differences in methodologies for WACS.
- The strategies of SSWMB should be an equal or higher emphasis on “upstream” waste reduction efforts compared to “downstream” waste management options such as treatment and disposal.
- SSWMB jurisdiction in Central and Korangi districts produces 14.88% plastic waste. With the growing concern on **plastic waste** pollution globally, SSWMB should ban non-biodegradable plastic bags and promote other alternatives such as textile bags.
- Based upon the waste characterization data, a Compost Plant and a Material Recovery Facility is feasible. This will help divert a major portion of the solid waste generated close to the source of generation, thereby significantly reducing transportation costs and prolonging the lifespan of sanitary landfills. Furthermore, an awareness campaign to start segregation at the source can have a dramatic positive impact on the success of MRF.
- The energy content of Central and Korangi districts are 1680 kcal/kg. Seasonal factors play an important role in the determination of constant high calorific value evaluation throughout the year. Therefore, for Central and Korangi Districts, the waste to energy option will be completely evaluated after a seasonal survey on waste generation and Characterisation is conducted for the remaining three seasons. The Waste Amount Characterization Survey needs to be carried out at least twice a year or preferably quarterly to obtain year-round results.
- 3R (Reduce, Reuse, Recycle) should be incorporated in SSWMB Plans for waste minimization. The community’s participation in implementing 3R (Reduce-Reuse-Recycle) should be incorporated for efficient MSW management.
- Mass awareness campaigns by the SSWMB needs to be planned, designed and implemented to make the community aware of the consequences of improper solid waste handling and disposal.

Annexure-1: The Consultant – Project Procurement International

Project Procurement International has offered consultancy services in the field of environmental engineering and socio-economic development since 2004.

Over the years, PPI has experience of hundreds of consultancy assignments in Pakistan, ranging in scale and scope for International Non-Governmental Organizations (INGOs), multinational donor Organizations, public and private enterprises.

PPI will conduct the following types of consultancy studies for its clients:

- Environmental and Social Impact Assessment Studies,
- Hospital/Solid Waste Management, Treatment and Disposal,
- Environmental, Occupational Health & Safety Management System (EHSMS) Assessments and Audits,
- Socio-economic Development Studies, and
- Third-Party Validation /Mid Term/End of Project Evaluations

Solid Waste Management Treatment and Disposal

- Solid Waste Characterization and Quantification Studies
- Time and Motion Studies for Solid Waste Transportation System
- Need Assessment for Solid Waste Management System
- Integrated Solid Waste Management System
- Investigation and selection of a site for construction of Sanitary Landfill
- Preliminary Engineering Design of Sanitary Landfill
- Manual for the operation of Sanitary Landfill
- Guideline for Solid Waste Management Strategy
- Feasibility Study for Material Recovery Facility
- Feasibility Study for Recycling of Plastic Waste

PPI is proud to have several INGOs and multinational donor organizations on its client list. PPI website: www.projectpi.pk.

PPI Team for Waste Amount Characterization Survey in District Central and Korangi

Name of Staff and Designation	Educational Qualification	Professional Experience
Mr. Saadat Ali, Environmental Engineer/Team Leader	Postgraduate Diploma in Sanitary Engineering 1984, Institute of Hydraulic and Environmental Engineering, Delft, Netherland. B. Sc. Civil Engineering 1978, University of Peshawar, Peshawar	Mr Ali has 40 years of experience in project management, environmental impact assessment, solid waste management, treatment and disposal and third-party validation. More than 15 years of experience in the design and implementation of Solid Waste Management, Treatment and Disposal Facilities, Prepared on ***Present Status of Solid Waste Management in Pakistan and strategy for its improvement, Guidelines on Solid Waste Management, establishment of sanitary landfills and Incineration*** **for Environmental Protection Agency**. Conducted **Waste Amount Compositional Survey (WACS) for 22 Municipal Corporations/Private sector Housing Societies/Cities throughout Pakistan** to prepare Solid Waste Management strategy, Solid Waste Management Plans, and establishment of Material Recovery Facilities, including a feasibility study for plastic.
Mr Ali Abdullah, Environmental Engineer	M. Sc. Environmental Engineering, 2016 Newcastle Upon Tyne University, United Kingdom. B. Sc., Civil Engineering, 2014, University of Lahore, Lahore	More than six years of experience in baseline data collection, Hospital / Solid Waste Management, Treatment and Disposal and Environmental & Social Impact Assessment. He was the overall field research coordinator for the Hospital / Solid Waste (Generation and Classification) Survey in Azad Jammu & Kashmir (AJK). In the same assignment, he assisted in preparing a *strategy and action plan for the improvement of Solid Waste Management in AJK*. He has **conducted Waste Amount Characterization Survey (WACS) in 11 cities/towns and two private housing schemes** for Solid Waste Management strategy, Solid Waste Management Plans, and establishment of Material Recovery Facilities
Mr Ammar Yasser	MSc Engineering Management, University of Engineering Technology, Taxila, 2009 BSc Mechanical Engineering, University of Engineering Technology, Lahore, 2005	Mr Yasser has been a Licensed Professional Engineer working in the energy sector in various roles since 2007. Mr Yasser has worked on more than 23 projects (including five mega projects having more than 25 beneficiaries) with accumulative power generation/saving, demand release impact of 435 MW.
Ms Fehmida Rafi, Environmental Scientist	MS in Water Resources and Management, MUET, Jamshoro BSc in Environmental Science, Fatima Jinnah Women University Rawalpindi,	Ms Fehmida has experience in baseline data collection on the physical, biological and socio-economic environment and solid waste management plans.
Mr Asadullah, Junior Engineer/ Research Assistant	BSc Environmental Scientist, Bahria University, Islamabad	Experience in Data Collection and Analysis

Annexure-2: Sampling Areas and GPS Coordinates

Sr. No	Income Area	Address and detail of GPS coordinates	Pictorial Presentation	
1	High-Income Area (North Nazimabad Block Number 2)	24.902, 67.033 Address: Plot A 1/29, Block 2 Nazimabad, Karachi, Karachi City, Sindh 74600, Pakistan		
2	Middle Income Area (Qayyumabad)	24.824, 67.086 Address: Plot 212 D Area Qayyumabad, Karachi, Karachi City, Sindh 75640, Pakistan		
3	Low-Income Area (Allah Wala Town)	24.824, 67.108 Address: Plot L 928, Allah Wala Town-Sector 31 B Allah Wala Town Sector 31 B Korangi, Karachi, Karachi City, Sindh, Pakistan		

Sr. No	Income Area	Address and detail of GPS coordinates	Pictorial Presentation	
1	High Income Area (Model Colony)	24.884, 67.181 Address: Ali Rd, Darakhshan Society Darakhshan Cooperative Housing Society Kala Board, Karachi, Pakistan		
2	Middle Income Area (Shah Faisal)	24.883, 67.148 Address: Plot 131 C, Block 2 Shah Faisal Colony, Karachi, Karachi City, Sindh 75230, Pakistan		

Sr. No	Income Area	Address and detail of GPS coordinates	Pictorial Presentation	
3	Low-Income Area (Landhi)	24.827, 67.152 Address: 190 Sector 35 C Korangi, Karachi, Karachi City, Sindh, Pakistan		
4	Commercial	24.823, 67.139 Address: 2 Main Korangi Rd, Sector 23 Sector 41 A Korangi Industrial Area, Karachi, Karachi City, Sindh, Pakistan		

Sr. No	Income Area	Address and detail of GPS coordinates	Pictorial Presentation	
1	High-Income Area (Gulberg)	24.935, 67.067 Address: Plot B 250, Federal B Area Block 10 Gulberg Town, Karachi, Karachi City, Sindh, Pakistan		
2	Middle Income Area (North Nazimabad)	24.957, 67.065 Address: Plot R 451, Sector 15-A Sector 15 A 2 Buffer Zone, Karachi, Karachi City, Sindh, Pakistan		

Sr. No	Income Area	Address and detail of GPS coordinates	Pictorial Presentation	
3	Low-Income Area (Liaquatabad)	24.905, 67.041 Address: Lane No 2, Block 2 Liaquatabad Town, Karachi, Karachi City, Sindh, Pakistan		
4	Commercial (New Karachi)	24.965 67.078 Address: Unnamed Road, Sector-11 E Sector 11 E Godhra, Karachi, Karachi City, Sindh, Pakistan		

Annexure-3: Waste Composition Key

Categories	Components
Kitchen Waste	Food, bread, vegetable, fruit etc. **except bones**
Paper and cardboard	All office paper, cardboard, white paper, coloured paper, newspaper (bags and strings removed), magazines (all types), catalogues (all types), phonebooks (all types), junk mail, paperboard, tissue boxes, heavyweight folders, paper towel and toilet paper rolls, food packaging, shredded paper, books: all softcover, hardcovers should be ripped off, empty paper coffee cups (plastic lids removed). Napkins, tissue paper, paper towels, wax paper, wrapping paper, any paper product which has the potential to be contaminated with bodily fluids
Textile	Thread, Yarn, Fabric, Rugs, Cotton etc
Grass and Wood	Plant parts, Grass, Wooden pieces etc
Plastic	All plastic types: PET, food and beverage containers, screw-top jars, deli-style containers, clam-shell take-out containers, plastic cups (lids and straws removed), milk jugs, soap bottles, clean grocery and retail plastic bags (no other type accepted), plastic jugs/bottles: soda bottles, laundry detergent jugs. Plastic tableware, Styrofoam containers, Polythene Bags, Crisps bag.
Leather and Rubber	Leather, Rubber, nylon items, tyre, shoes etc.
Metal	Metal and tin beverages containers, metal and tin food containers, Aluminium Foil, Aluminium take out containers, aluminium pie plates and containers, cutlery, kitchen cookware: metal pots, pans, tins and utensils, metal wires, metallic spare parts etc. Motor Oil Cans, paint cans, metal, and cardboard mixed containers
Bottles and Glass	Colour/ transparent glass bottle and Jars, Juice bottles (unbroken), Light Bulbs, Mirror glass, Window glass (vehicles and home window), Crystal etc.
Ceramic and Stones	Stone and ceramic
Domestic Hazardous Waste	Battery cells, paint boxes, medicine bottles, chlorine bottles, Auto batteries, Antifreeze, Oils/Filters, Tires, Fertilizers, Lighter Fluid, Pesticides, Pool chemicals, Aerosol cans, Batteries (non-alkaline), Cleaners, Fluorescent bulbs, Furniture polish, Needles/syringes/lancets, propane/compressed gas cylinders
Residue Remaining	Particles larger than 6 mm (Basically the remaining material on the sheet)
Miscellaneous	
a. Hairs	Human / Animal hairs
b. Bones	Bones
c. Tetra pack	Milk box, fruit juice box, tetra pack
d. Diapers	Nappies /pampers / Sanitary pads
e. Dust/Sieve	Only Dust particles
f. E-Waste	TV appliances, computers, laptops, tablets, mobile phones, wires, headphones, white goods

Figure 1: Paper Recyclable include All office paper, white paper, coloured paper, newspaper (bags and strings removed), magazines (all types) etc.

Figure 2: Paper Recyclable include Cardboard.

Figure 3: Ceramics include Marbles.

Figure 4: Ceramics Include Pots.

Figure 5: Plastic Non-Recyclable include Plastic tableware, Styrofoam containers.

Figure 6: Plastic Non-Recyclable include Plastic tableware, Styrofoam containers.

Figure 7: Kitchen Waste include all Food, bread, vegetable, fruit etc., **except bones.**

Figure 8: Kitchen Waste include all Food, bread, vegetable, fruit etc., **except bones.**

Figure 9: Plastic Recyclable include all plastics types. PET bottles, food and beverage containers etc.

Figure 10: Plastic Recyclable include all plastics types. PET bottles, food and beverage containers etc.

Figure 11: Tetra Pack.

Figure 12: Tetra Pack.

Figure 13: Polythene Bags

Figure 14: Polythene Bags.

Figure 15: Leather & Rubber.

Figure 16: Leather & Rubber including shoes

Figure 17: Metal Non-Recyclable includes Paint Cans.

Figure 18: Metal Non-Recyclable includes Motor Oil Cans, paint cans, metal, and cardboard mixed containers

Figure 19: Pampers.

Figure 20: Pampers.

Figure 21: Grass & Wood.

Figure 22: Grass & Wood.

Figure 23: E-Waste includes Charger.

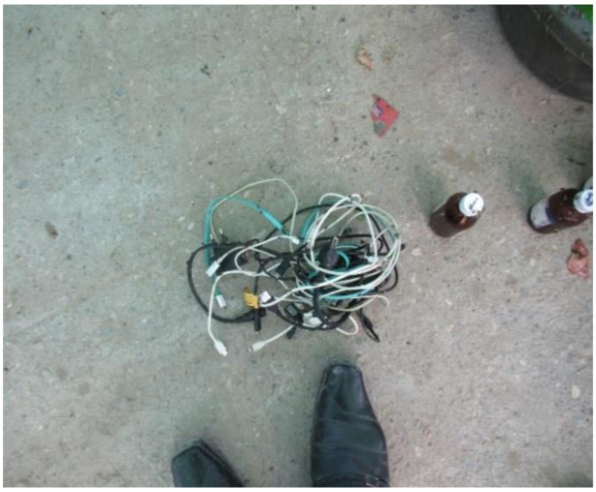


Figure 24: E-Waste includes headphone wires.

Figure 25: Textile Waste

Figure 26: Textile Waste

Figure 27: Domestic Hazardous Waste

Figure 28: Domestic Hazardous Waste

Figure 29: Residue Remaining

Figure 30: Residue Remaining

Figure 31: Dust

Figure 32: Dust

Figure 33: Bones

Figure 34: Bones

Figure 35: Paper Recyclable

Figure 36: Paper Non- Recyclable.

Figure 37: Bottle & Glass Recyclable.

Figure 38: Bottle & Glass Recyclable.

Figure 39: Metal Recyclable.

Figure 40: Metal Recyclable.

Figure 41: Bottle & Glass Non-Recyclable.

Figure 42: Bottle & Glass Non-Recyclable. (broken pieces)

Figure 43: Hairs.

Figure 44: Hairs.

Annexure-4: Detailed Description of Waste Composition

Income Area: High **Date of Survey Start:** 20.02.2021 to 23.02.2021 **Area Name:** Nazimabad, District Central

Item	HIGH INCOME High Income: Day-1			HIGH INCOME High Income: Day-2			HIGH INCOME High Income: Day-3			HIGH INCOME High Income: Day-4			
	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	(%)
1. Kitchen waste	115.31	5.516	109.794	76.998	5.53	71.468	115.38	6.27	109.11	64.22	2.54	61.68	52.52
2. Paper (recyclable)	5.53	1.274	4.256	10.675	2.55	8.125	6.13	1.19	4.94	3.09	1.27	1.82	1.55
3. Paper (Non-Recyclable)	0	0	0	0	0	0	1.53	0	1.53	0.1	0	0.1	0.09
4. Textile	5.785	1.274	4.511	5.15	1.275	3.875	4.165	0.595	3.57	5.57	1.27	4.3	3.66
5. Grass and wood	1.225	0	1.225	2.475	1.275	1.2	0.165	0	0.165	0	0	0	0.00
6. Plastic (recyclable)	0.18	0	0.18	2.665	1.275	1.39	7.33	3.465	3.865	18.14	3.125	15.015	12.79
7. Plastic (non-recyclable)	3.655	1.274	2.381	4.695	1.87	2.825	1.905	0.595	1.31	0	0	0	0.00
8. Polythene Bags	64.786	7.644	57.142	26.28	3.825	22.455	30.135	0	30.135	16.125	1.27	14.855	12.65
9. Leather and rubber	0	0	0	0	0	0	0.615	0	0.615	0	0	0	0.00
10. Metal (recyclable)	0.19	0	0.19	1.6	1.19	0.41	2.203	0	2.68	0	0	0	0.00
11. Metal (non-recyclable)	0	0	0				2.18	0	2.18	0	0	0	0.00
12. Bottle and glass (recyclable)	0.305	0	0.305				1.28	0.585	0.695	0.6	0	0.6	0.51

Item	HIGH INCOME High Income: Day-1			HIGH INCOME High Income: Day-2			HIGH INCOME High Income: Day-3			HIGH INCOME High Income: Day-4			
	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	(%)
13. Bottle and glass (non-recyclable)	0	0	2				1.255	0.595	0.66	0.975	0.59	0.385	0.33
14. Ceramic, stone etc.	1.08	0.583	0.497	2.105	0	2.105	0.345	0	0.345	0.065	0	0.065	0.06
15. Domestic hazardous wastes	0.12	0	0.12	3.015	1.19	1.825	3.26	0.84	2.42	0.426	0	0.426	0.36
16. Sieve Remaining			0				7.385	1.27	6.115	0	0	0	0.00
Miscellaneous			0									0	
Tetapack	2.285	1.274	3	2.065	1.275	0.79	0.695	0.595	0.1	0.895	0.585	0.31	0.26
Hairs	0.045	0	0.045	0.01	0	0.01	0.001	0	0.001	0.01	0	0.01	0.01
Pampers	56.377	2.34	54.037	15.195	1.275	13.92	32.705	1.865	30.84	17.151	1.775	15.376	13.09
Bones	1.675	0.41	1.265	2.605	0.43	2.175	6.585	2.14	4.445	2.5	0	2.5	2.13
Seive/Dust			0							0	0	0	0.00
E-Waste	4		4				0.065	0	0.065	0	0	0	0.00
Total	**262.548**	**21.589**	**244.948**	**155.533**	**22.96**	**132.573**	**225.314**	**20.005**	**205.786**	**129.867**	**12.425**	**117.442**	**100.00**

Income Area: Middle **Date of Survey Start:** 20.02.2021 to 23.02.2021 **Area Name:** Qayyumabad, District Korangi

Item	Middle Income Middle Day 1			Middle Income Middle Day 2			Middle Income Middle Day 3			Middle Income Middle Day 4		
	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket
1. Kitchen waste	51.572	2.968	48.604	31.59	1.869	29.721	55.935	3.124	52.811	65.5015	3.01	62.4915
2. Paper (recyclable)	6.104	2.548	3.556	8.405	1.275	7.13	3.45	1.27	2.18	5.955	1.27	4.685
3. Paper (Non-Recyclable)	0	0	0	0	0	0	2.005	0.585	1.42	5.39	0.47	4.92
4. Textile	7.292	1.274	6.018	4.04	0.42	3.62	5.765	0.583	5.182	11.19	1.27	9.92
5. Grass and wood	0	0	0	0	0	0	0.27	0	0.27	0.15	0	0.15
6. Plastic (recyclable)	3.16	0	3.106	0.89	0.42	0.47	2.525	1.27	1.255	3.931	1.74	2.191
7. Plastic (non-recyclable)	0.066	0	0.066	0	0	0	0.31	0	0.31	0.55	0.47	0.08
8. Polythene Bags	10.568	1.274	9.294	3.05	0.42	2.63	9.775	1.27	8.505	43.506	5.08	38.426
9. Leather and rubber	0.382	0	0.382	0	0	0	0.255	0.135	0.12	2.01	0.47	1.54
10. Metal (recyclable)	0.026	0	0.026	0	0	0	0	0	0	0.155	0	0.155
11. Metal (non-recyclable)	0	0	0	0	0	0	0	0	0	0	0	0
11. Bottle and glass (recyclable)	0	0	0	0	0	0	0.395	0	0.395	0.741	0.47	0.271
12. Bottle and glass (non-recyclable)	0	0	0	0	0	0	0.53	0	0.53	0.15	0	0.15
13. Ceramic, stone and soil etc.	0.214	0	0.214	0	0	0	10.95	0	10.95	1.615	0.47	1.145
14. Domestic hazardous wastes	1.536	0.42	1.116	0.145	0	0.145	1.79	0.585	1.205	1.21	0.47	0.74
15. Sieve Remaining	1.81	0.42	1.39				0	0	0	0	0	0

Item	Middle Income Middle Day 1			Middle Income Middle Day 2			Middle Income Middle Day 3			Middle Income Middle Day 4		
	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket
16. Miscellaneous									0			0
Tetapack	1.382	0.61	0.772	0.755	0.595	0.16	2.04	1.18	0.86	1.295	0.47	0.825
Hairs	0.02	0	0.02	0	0	0	0	0	0	0.02	0	0.02
Pampers	4.802	0	4.802	1.935	0.595	1.34	9.275	1.27	8.005	20.92	1.27	19.65
Bones	0	0	0	0.36	0	0.36	0	0	0	0	0	0
Seive/Dust	0	0	0				0	0	0	0	0	0
E-Waste	0.166	0	0.166				0	0	0	0	0	0
Total	**89.1**	**9.514**	**79.532**	**51.17**	**5.594**	**45.576**	**105.27**	**11.272**	**93.998**	**164.2895**	**16.93**	**147.3595**

Income Area: Low **Date of Survey Start:** 20.02.2021 to 23.02.2021 **Area Name:** Allahwala Town, District Korangi

Item	Low Income			Low Income			Low Income			Low Income		
	Low Day 1			Low Day 2			Low Day 3			Low Day 4		
	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket
1. Kitchen waste	58.885	4.242	54.643	63.5	3.739	59.761	39.92	1.865	38.055	27.825	1.74	26.085
2. Paper (recyclable)	4.55	0.59	3.96	9.175	2.55	6.625	6.325	1.865	4.46	3.525	1.27	2.255
3. Paper (Non-Recyclable)	0.74	0	0.74	0	0	0	0	0	0	0.71	0	0.71
4. Textile	7.415	1.274	6.141	7.415	1.87	5.545	5.86	1.19	4.67	11.505	1.27	10.235
5. Grass and wood	0	0	0	0	0	0	0.55	0	0.55	0	0	0
6. Plastic (recyclable)	1.905	1.274	0.631	1.675	1.275	0.4	1.135	0.595	0.54	2.685	0.94	1.745
7. Plastic (non-recyclable)	0	0	0	3.155	0.595	2.56	1.129	0	1.129	0	0	0
8. Polythene Bags	14.826	1.274	13.552	30.905	3.825	27.08	9.25	0	9.25	11.141	1.27	9.871
9. Leather and rubber	1.845	0.59	1.255	0.385	0	0.385	0.22	0	0.22	0.25	0	0.25
10. Metal (recyclable)	0.535	0	0.535	0	0	0	0.09	0	0.09	0.02	0	0.02
11. Metal (non-recyclable)	4.845	0.59	4.255	0	0	0	0.07	0	0.07	0	0	0
12. Bottle and glass (recyclable)	2.525	0.59	1.935	0	0	0			0	0.45	0	0.45
13. Bottle and glass (non-recyclable)	1.88	0.59	1.29	0	0	0			0	0.62	0	0.62
14. Ceramic, stone, and soil etc.	0	0	0	0	0	0	0.425	0	0.425	0.18	0	0.18

Item	Low Income Low Day 1			Low Income Low Day 2			Low Income Low Day 3			Low Income Low Day 4		
	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket	Amount(kg)	Wt. of bucket	amount- wt of bucket
15. Domestic hazardous wastes	1.6	0.59	1.01	1.19	0.595	0.595	0.4	0	0.4	0.2665	0	0.2665
16. Sieve Remaining	0	0	0	0	0	0			0			0
16. Miscellaneous									0			0
Tetapack	1.895	0	1.895	1.26	0.595	0.665	0.895	0.41	0.485	0.815	0.425	0.39
Hairs	0.001	0	0.001	0.001	0	0.001	0	0	0	0	0	0
Pampers	15	1.274	13.726	28.075	1.87	26.205	7.37	1.42	5.95	7.105	0.47	6.635
Bones	0.895	0.59	0.305	1.1	0.595	0.505	0	0	0	1.15	0.43	0.72
Seive/Dust	0	0	0						0			0
E-Waste	0	0	0						0	1.205	0.47	0.735
Total	**119.342**	**13.468**	**105.874**	**147.836**	**17.509**	**130.327**	**73.639**	**7.345**	**66.294**	**69.4525**	**8.285**	**61.1675**

Income Area: High-Income **Date of Survey Start:** 06.03.2021 to 12.03.2021 **Area Name:** Gulberg, District Central

Item	High Income Average - Central				
	Day 1	Day 2	Day 3	Day 4	Day 5
1. Kitchen waste	42.48	38.63	16.33	73.514	22.672
2. Paper (recyclable)	6.31	0.555	2.685	2.2	3.87
3. Paper (Non-Recyclable)	0.1	0.085	0.065	0.615	1.405
4. Textile	2.015	1.215	1.445	3.14	3.444
5. Grass and wood	0.085				0.15
6. Plastic (recyclable)	0.66	0.74	0.15	0.755	0.715
7. Plastic (non-recyclable)	0.31	0.265	1	0.175	0.525
8. Polythene Bags	8.545	9.35	7.265	8.29	12.865
9. Leather and rubber	1.34	0.245	0.315	0.23	0.535
10. Metal (recyclable)	0.295	0.28	0.075	0.145	0.128
11. Metal (non-recyclable)			0.035	0.2	
12. Bottle and glass (recyclable)			0.08	0.165	0.815
13. Bottle and glass (non-recyclable)	0.185				0.256
14. Ceramic, stone etc.	0.665	0.595			0.38
15. Domestic hazardous wastes	0.78	0.01	0.195	0.55	0.445
16. Residue Remaining (the material remaining on the sheet)	0.26	1.345	0.305	2.075	0.965
Tetapack	0.73	0.145	0.285	0.385	0.197
Hairs				0.09	
Pampers	9.965	9.305	4.23	10.535	13.686
Bones		1.34	0.08		0.64
Seive/Dust	0.28	0.735	0.18	0.39	0.969
E-Waste	0.045				0.088

Income Area: Middle-Income **Date of Survey Start:** 06.03.2021 to 12.03.2021 **Area Name:** North Nazimabad, District Central

Item	Middle Income Average - Central				
	Day 1	Day 2	Day 3	Day 4	Day 5
1. Kitchen waste	70.95	16.505	19.53	44.495	20.18
2. Paper (recyclable)	2.17	0.99	2.845	1.38	1.865
3. Paper (Non-Recyclable)	0.355	0.18	0.255	0.215	0.345
4. Textile	5.25	0.685	2.3	1.25	1.335
5. Grass and wood		0.475	0.405	0.27	0.03
6. Plastic (recyclable)	1.055	0.65	0.37	0.475	0.32
7. Plastic (non-recyclable)	0.5	1.2	1.03	0.245	0.85
8. Polythene Bags	16.68	9.58	3.215	5.92	5.77
9. Leather and rubber		0.03	0.51	0.4	0.32
10. Metal (recyclable)	0.205	0.035	0.07	0.08	0.075
11. Metal (non-recyclable)	0.4			0.212	
12. Bottle and glass (recyclable)		0.155		0.285	
13. Bottle and glass (non-recyclable)	0.41	0.085		0.365	0.345
14. Ceramic, stone etc.	1.1	3.141	0.9	0.765	0.305
15. Domestic hazardous wastes	0.395	0.07	0.12	0.295	0.4
16. Residue Remaining (the material remaining on the sheet)	1.505	0.23	0.81	0.55	0.6
Tetapack	0.115	0.41	0.275	0.09	0.285
Hairs			0.01		
Pampers	21.71	3.46	2.425	5.805	8.415
Bones	0.8	0.18			0.275
Seive/Dust	1.635	0.6	0.23	0.13	
E-Waste	0.185	0.04		0.025	
Total	**125.42**	**38.701**	**35.3**	**63.252**	**41.715**

Income Area: Low **Date of Survey Start:** 06.03.2021 to 12.03.2021 **Area Name:** Liaquatabad, District Central

Item	Low Income Average - Central				
	Day 1	Day 2	Day 3	Day 4	Day 5
1. Kitchen waste	36.955	23.865	14.116	32.45	35.83
2. Paper (recyclable)	3.235	2.56	1.955	1.025	3.57
3. Paper (Non-Recyclable)	0.57	0.31	0.08	0.025	0.095
4. Textile	1.785	1.285	2.445	2.655	2.935
5. Grass and wood	0.055	0.84	0.205	0.1	0.085
6. Plastic (recyclable)	0.945	0.045		0.525	0.29
7. Plastic (non-recyclable)	1.805	0.09	0.3	4.7	0.75
8. Polythene Bags	7.245	3.96	15.565	5.03	7.245
9. Leather and rubber	0.345	0.21	0.485	0.605	1.39
10. Metal (recyclable)	0.46	0.12			0.145
11. Metal (non-recyclable)	0.045	0.065			0.03
12. Bottle and glass (recyclable)					0.105
13. Bottle and glass (non-recyclable)	0.925				0.485
14. Ceramic, stone etc.					0.05
15. Domestic hazardous wastes	0.475	0.925	0.32	0.375	0.41
16. Residue Remaining (the material remaining on the sheet)	2.285	1.835	0.445	0.265	0.945
Tetrapack	0.38	0.325	0.165	0.085	0.52
Hairs		0.01			
Pampers	2.645	4.065	6.015	2.045	8.48
Bones		0.01	0.165	0.1	0.235
Seive/Dust	1.41	0.485	0.62	0.645	0.625
E-Waste		0.045	0.7		

Income Area: High **Date of Survey Start:** 06.03.2021 to 12.03.2021 **Area Name:** Model, District Korangi

Item	High Income Average - Korangi					
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
1. Kitchen waste	11.94	100.52	71.175	50.66	44.78	46.905
2. Paper (recyclable)	2.805	3.475	4.225	4.685	2.08	1.885
3. Paper (Non-Recyclable)	0.1	1.255	0	0.38	0.735	0.38
4. Textile	1.245	1.325	4.865	3.015	2.42	2.645
5. Grass and wood		0.055	2.133	4.85	0.038	0.53
6. Plastic (recyclable)	0.33	0.95	1.455	3.725	1.01	0.245
7. Plastic (non-recyclable)	0.52	1.68	2.13	1.845	0.655	0.8
8. Polythene Bags	2.16	15.59	9.925	8.25	9.065	12.615
9. Leather and rubber		0.42	0.405	1.285	0.65	
10. Metal (recyclable)	0.4	0.155	1.265	0.35	0.7	0.07
11. Metal (non-recyclable)		0.385	0	0.145	0.025	0.1
12. Bottle and glass (recyclable)		0.815	1.89	0	0.335	
13. Bottle and glass (non-recyclable)		0.415	0.326	0.78	0.973	0.59
14. Ceramic, stone etc.	0.365	0.905	0.845	0	0.335	0.23
15. Domestic hazardous wastes	0.07	0.91	0.485	0.51	0.33	1.865
16. Residue Remaining (the material remaining on the sheet)		9.17	3.655	0.81	0.56	1.735
Tetapack	0.245	1.195	0.715	0.625	0.411	0.55
Hairs	0		0	0		0.001
Pampers	4.705	38.185	17.15	17.37	15.223	14.795
Bones		0	0	0.235	0.16	0.299
Seive/Dust	10.105	0	2.015	0.39	0.122	9.875
E-Waste		0	0.63	0.38	0.012	
Total	**34.99**	**177.405**	**125.289**	**100.29**	**80.619**	**96.115**

Income Area: Middle **Date of Survey Start:** 06.03.2021 to 12.03.2021 **Area Name:** Shah Faisal, District Korangi

Item	Middle Income Average - Korangi					
	Day 2	Day 3	Day 4	Day 5	Day 6	Total
1. Kitchen waste	42.46	40.17	32.76	33.8062	37.505	186.7012
2. Paper (recyclable)	2.685	2.54	1.15	2.375	1.11	9.86
3. Paper (Non-Recyclable)	0.2	0.275	1.251	0.555	0.72	3.001
4. Textile	2.525	5.37	2.86	2.875	2.005	15.635
5. Grass and wood	0.79	0.02	0.095	0	0.38	1.285
6. Plastic (recyclable)	0.12	1.125	0.25	0.425	0.135	2.055
7. Plastic (non-recyclable)	0.465	0.68	0.68	0.32	0.23	2.375
8. Polythene Bags	8.745	9.735	15.285	5.8	11.28	50.845
9. Leather and rubber	0.685	0.435	0.14	0.12	0.305	1.685
10. Metal (recyclable)	0.205	0.075	0.06	0	0.045	0.385
11. Metal (non-recyclable)	0	0	0.035	0.5	0	0.535
11. Bottle and glass (recyclable)	0.735	0.67	0	0	0	1.405
12. Bottle and glass (non-recyclable)	0.91	0	0.06	0.34	0.32	1.63
13. Ceramic, stone and soil etc.	5.715	0	0.295	0.29	0.315	6.615
14. Domestic hazardous wastes	8.285	0	0.165	0.24	0.07	8.76
16. Residue Remaining (the material remaining on the sheet)	0	0.93	0.345	1.445	0.52	3.24
Tetapack	0.635	0.49	0.515	1.12	0.49	3.25
Hairs	0	0	0.02	0.01	0	0.03
Pampers	4.8	11.975	8.86	6.6	6.905	39.14
Bones	0	0.15	0.19	0	0.17	0.51
Seive/Dust	1.16	0.535	0.415	0.838	0.165	3.113
E-Waste	0	0	0.055		0.03	0.055
Total	**80.72**	**75.175**	**65.486**	**57.6592**	**62.7**	**341.7402**

Income Area: Low **Date of Survey Start:** 06.03.2021 to 12.03.2021 **Area Name:** Landhi, District Korangi

Item	Low Income - Korangi						
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Total
1. Kitchen waste	24.95	19.05	32.385	19.05	33.94	19.275	148.65
2. Paper (recyclable)	1.545	0.84	2.35	0.84	2.541	1.88	9.996
3. Paper (Non-Recyclable)	0.215	0.665	0.11	0.665	0.235	0.09	1.98
4. Textile	3.31	2.035	2.67	2.035	5.08	4.175	19.305
5. Grass and wood	0.665	0.525	1.215	0.525	0.035	0.045	3.01
6. Plastic (recyclable)	0.95	0.195	0.655	0.195	3.336	0.145	5.476
7. Plastic (non-recyclable)	0.115	0.215	0.475	0.215	1.115	0.585	2.72
8. Polythene Bags	3.745	8.205	8.575	8.205	1.675	7.56	37.965
9. Leather, rubber and composite items (Shoes)	2.92	2.805	2.11	0.805	0.595	2.085	11.32
10. Metal (recyclable)	0.1	0.06	0.085	0.06	0	0	0.305
11. Metal (non-recyclable)	0	0	0.04		0	0.09	0.13
11. Bottle and glass (recyclable)	0	0	0.5		0.285	0.235	1.02
12. Bottle and glass (non-recyclable)	1.265	0	0		0	0.375	1.64
13. Ceramic, stone and soil etc.	0.42	0	0	0.715	0.62	0.895	2.65
14. Domestic hazardous wastes	0.195	0.715	0.35	1.315	0.7	0.45	3.725
16. Residue Remaining (the material remaining on the sheet)	0.61	1.315	1.32		0.415	0.315	3.975
Tetapack	0.28	0.225	0.27	0.225	0.31	0.315	1.625
Hairs	0	0	0		0	0	0
Pampers	3.66	3.29	12.545	3.29	6.33	4.275	33.39
Bones	0	0	0.995		0	0	0.995
Seive/Dust	0	1.475	2.97	1.475	3.94	0.9	10.76
E-Waste	0.08	0	0.305		0.1	0.34	0.825
Total	**45.025**	**41.615**	**69.925**	**39.615**	**61.252**	**44.03**	**301.462**

Annexure-5: Waste Generation & Composition Survey Forms

Income Area: High **Date of Survey Start:** 20.02.21 to 23.02.2021 **Area Name:** Nazimabad, District Central

Sr. #	Day 1		Day 2		Day 3		Day 4	
	Household Size	Waste per HH (kg)	Household Size	Waste per HH (kg)	Household Size	Waste Amount (kg)	Household Size	Waste Amount (kg)
1	7	3.275	7	0.476	7	4	7	0.751
2	4	4.05	5	2.265	5	4.9	5	3.335
3	4	5.84	4	2.126	4	3	4	1.505
4	6	4.005	4	3.7	4	3.75	4	2.64
5	8	4.59	4	2.045	4	2.56	4	2.18
6	10	0.959	6	1.785	6	3.1	6	2.75
7	3	2.8	7	2.345	7	6.11	7	3.68
8	5	1.78	8	0.905	5	3.22	8	5.715
9	7	2.67	7	2.04	4	4.9	7	2.61
10	4	3.695	5	1.48	10	1.4	5	3.315
11	4	5.068	5	0.975	5	4.5	5	2.6
12	9	2.3	4	2.16	7	5.53	4	2.765
13	6	1.71	10	2.085	7	5.83	10	2.66
14	13	2.99	3	3.535	4	9.85	3	2.135
15	11	4.925	5	0.66	4	7.88	5	1.517
16	8	1.83	7	1.855	9	5	7	1.365
17	8	3.465	7	1.97	6	8	7	2.221
18	6	3.725	4	2.15	13	8.93	4	4.775

Sr. #	Day 1		Day 2		Day 3		Day 4	
	Household Size	Waste per HH (kg)	Household Size	Waste per HH (kg)	Household Size	Waste Amount (kg)	Household Size	Waste Amount (kg)
19	11	3.435	4	0.625	7	2.9	4	1.62
20	11	7.515	9	0.326	8	0.183	9	2.321
21	8	4.78	6	1.2	9	5	6	4.475
22	4	5.135	13	1.27	8	2.5	13	1.835
23	4	4.33	7	0.59	6	2.3	7	1.46
24	5	1.255	11	1.155	11	6.3	11	3.68
25	3	5.085	8	0.98	11	5.83	8	2.195
26	6	2.4	9	0.75	4	3	9	5.375
27	6	1.935	8	1.195	4	5.32	8	2.23
28	7	2.045	6	1.91	6	2.43	6	1.03
29	7	0.525	11	1.916	10	3.9	11	2.731
30	6	3.85	11	3.965	6	3	11	3.92
31	13	1.693	8	0.84	7	2.85	8	1.345
32	8	3.766	4	5.1	7	3.88	4	3.635
33	6	2.55	4	0.85	6	2.93	4	1.991
34	4	3.19	5	1.15	13	2.3	5	6.76
35	5	4.23	3	1.475	8	3.3	3	2.78
36	7	2.515	6	0.24	6	14.73	6	2.536
37	8	1.22	10	1.965	4	3.31	10	5.58
38	5	1.855	6	1.39	5	3.15	6	7.14
39	6	0.865	7	2.55	7	5.1	7	1.895
40	12	4.592	7	3.755	8	9.55	7	6.325
41	4	5.83	6	2.846	5	5.88	6	2.483

Sr. #	Day 1		Day 2		Day 3		Day 4	
	Household Size	Waste per HH (kg)	Household Size	Waste per HH (kg)	Household Size	Waste Amount (kg)	Household Size	Waste Amount (kg)
42	7	4.35	8	0.156	6	7.85	13	0.65
43	7	5.345	5	.690.	12	8.3	8	1.89
44	9	4.11	6	1.46	7	6.21	5	2.36
45	11	2.775	4	1.346	7	1.85	6	1.645
46	7	3.945	5	0.496	9	8	4	3.755
47	3	3.905	7	1.855	11	5.3	5	1.62
48	5	4.3	8	1.3	7	9.38	7	2.86
49	5	4.095	5	1.85	3	5.3	8	1.355
50	8	3.095	6	0.91	5	7.88	5	0.335
51	7	5.165	12	3.74	8	7.3	6	1.49
52	9	5.095	4	1.29	7	2.99	12	1.61
53	6	5.155	7	2.8	9	4	4	2.53
54	3	4.005	7	1.48	3	2.89	7	0.675
55	7	3.435	9	2.87	7	6.23	7	3.33
56	6	1.605	11	1.235	6	8.78	9	2.075
57	10	5.29	7	2.135	11	4.35	11	1.99
58	11	3.295	3	1.61	4	2.5	7	3.907
59	4	2.87	5	2.62	7	3.12	3	2.01
60	7	2.285	5	1.525	4	3.3	5	0.8
61	4	1.495	8	1.06	4	4.32	5	1.795
62	4	1.765	7	1.695	8	5.81	8	2.035
63	8	2.155	9	3.58	5	7.23	7	1.795
64	5	3.56	6	1.62	12	4.3	9	2.485

Sr. #	Day 1		Day 2		Day 3		Day 4	
	Household Size	Waste per HH (kg)	Household Size	Waste per HH (kg)	Household Size	Waste Amount (kg)	Household Size	Waste Amount (kg)
65	5	3.74	3	3.315	5	6.92	6	1.23
66	3	8.278	7	1.305	3	5.2	3	3.595
67	8	0	6	1.76	8	6.87	7	2.765
68	11	4.86	10	2.205	11	2.51	6	2.435
69	6	2.255	11	2.34	5	7.9	10	2.995
70	5	5.455	4	0.975	7	2.53	11	2.73
71	5	7.55	7	0.98	**478**	**351.223**	4	0.785
72	7	4.2	4	1.996			7	2.625
73	**482**	**253.706**	4	2.985			4	0.83
74			8	0.62			4	2.24
75			5	0.935			8	1.25
76			12	1.616			5	1.401
77			5	0.876			12	1.32
78			3	0.79			5	6.83
79			8	6.805			3	0.87
80			11	1.05			8	1.6
81			**533**	**141.786**			11	2.635
82							6	2.491
83							5	0.77
84							7	5.345
							564	**215.6**

Income Area: Middle **Date of Survey Start:** 20.02.21 to 23.02.2021 **Area Name:** Qayyumabad, District Korangi

Sr. #	Day 1		Day 2		Day 3		Day 4	
	Household size	Waste Amount	Household size	Waste Amount	Household Size	Waste Amount	Household Size	Waste Amount
1	5	2	5	2.775	5	4.85	5	5.425
2	5	2.44	5	4.259	5	4.425	5	2.59
3	6	7.45	5	3.535	12	4.33	5	3.755
4	7	3.08	6	3.25	5	7.33	6	3.235
5	6	1.75	12	1.825	7	8.735	12	3.16
6	4	2.275	5	1.835	6	3.69	5	2.665
7	4	4.695	7	3.72	4	5.315	7	2.105
8	13	4.725	6	5.83	10	1.94	6	1.968
9	5	7.11	4	0.62	6	5.38	4	6.9
10	7	8.645	4	0.29	13	2.185	4	4.665
11	10	1.075	10	7.72	5	8.99	10	3.91
12	10	2.11	6	2.37	7	0.935	6	3.25
13	11	8.11	13	6.38	11	4.85	13	5.355
14	11	4	5	3.635	10	4.455	5	3.1
15	6	2.49	7	1.025	5	3.095	7	3.54
16	9	5.265	11	2.385	10	3.45	11	4.215
17	4	2.25	10	3.09	11	4.35	10	3.25
18	2	1.7	5	3.55	7	1.0175	5	5.415
19	5	2	10	0.55	11	4.035	10	3.345
20	8	5	11	1.57	6	1.085	11	2.815
21	2	2.71	7	4.68	9	1.6	7	2.385

Sr. #	Day 1		Day 2		Day 3		Day 4	
	Household size	Waste Amount	Household size	Waste Amount	Household Size	Waste Amount	Household Size	Waste Amount
22	7	3.575	11	2.88	20	8.325	11	2.6
23	6	5.75	4	9.4	4	8.875	4	3.75
24	6	1.065	6	2.465	3	3.17	6	8.075
25	**159**	**91.27**	9	4.025	5	5.405	9	2.02
26			9	1.345	2	3.255	9	4.385
27			20	2.59	4	3.035	20	2.965
28			4	0.585	8	4.4	4	3.475
29			3	1.6	5	5.15	3	4.61
30			5	1.455	2	5.105	5	2.695
31			4	1.81	2	5.465	2	1.39
32			9	2.745	5	5.015	4	5.2
33			2	0.255	2	2.985	4	3.085
34			5	6.255	4	10.66	8	2.765
35			2	5.655	5	4.555	5	2.445
36			4	0.93	6	1.55	8	4.965
37			6	6.675	11	1.175	2	5.535
38			3	1.535	4	2.365	2	3.245
39			5	4.155	6	5.64	9	3.276
40			7	8.39	3	2.34	2	0.395
41			4	7.54	5	7.48	5	1.83
42			13	9.325	2	5.665	2	2.765
43			2	3.18	4	6.935	4	7.765

Sr. #	Day 1		Day 2		Day 3		Day 4	
	Household size	Waste Amount	Household size	Waste Amount	Household Size	Waste Amount	Household Size	Waste Amount
44			4	2.125	7	1.76	8	2.115
45			6	3	4	3.72	5	2.52
46			9	3.605	13	1.515	6	2.73
47			310	158.419	2	1.925	11	1.555
48					7	4.555	4	3.14
49					6	3.775	6	2.31
50					5	2.096	3	0.765
51					4	1.46	5	3.99
52					6	6.685	2	3.05
53					9	7.73	4	3.035
54					6	2.28	7	2.295
55					346	232.0935	4	3.99
56							13	1.26
57							2	2.88
58							7	2.166
59							6	5.37
60							6	2.695
61							4	3.42
62							5	5.98
63							4	1.425
64							4	3.235
65							6	3.71

Sr. #	Day 1		Day 2		Day 3		Day 4	
	Household size	Waste Amount	Household size	Waste Amount	Household Size	Waste Amount	Household Size	Waste Amount
66							10	4.775
67							17	2.15
68							5	3.235
69							6	3.461
70							9	1.928
71							6	5.36
							457	**240.8**

Income Area: Low **Date of Survey Start:** 20.02.2021 to 23.02.2021 **Area Name:** Allahwala Town, District Korangi

Sr. #	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected
1	7	2.49	7	1.12	7	2.175	7	0.516
2	6	3.16	7	1.42	7	4.03	3	1.475
3	17	3.25	3	3.535	3	2.15	5	1.505
4	6	0.29	5	0.415	6	0.98	7	0.255
5	4	0.72	7	0.54	6	2.12	8	0.53
6	3	2.54	8	0.505	4	3.765	9	0.405
7	3	2.45	9	0.925	3	1.34	6	0.585
8	6	1	6	0.768	3	5.545	6	0.54
9	7	11.76	6	5.34	5	1.635	6	0.795
10	6	3.77	6	2.355	6	1.215	17	2.585
11	4	2.71	17	2.125	7	4.91	6	2.115
12	6	0.08	6	2.17	4	6	4	0.635
13	7	5.525	4	2.85	6	0.655	3	1.236
14	5	2.435	3	1.09	4	4.815	3	1.155
15	6	1.39	3	2.17	7	4.075	5	0.515
16	4	0.58	5	1.12	6	0.416	6	1.35
17	3	1.75	6	0.615	6	0.775	7	0.855
18	5	2.31	7	2.485	7	0.98	4	0.145
19	2	1.395	6	1.295	4	3.375	6	1.68
20	4	1.71	4	2.055	6	0.796	4	0.77
21	7	1.295	7	2.465	4	3.29	7	2.75

Sr. #	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected
22	2	3.17	6	1.915	3	0.64	6	2.725
23	1	0.61	6	1.7	5	1.95	6	1.545
24	7	4.13	7	1.245	2	3.28	7	0.91
25	7	1.37	4	1.115	4	1.81	4	0.91
26	4	0.11	5	0.955	7	2.43	5	0.53
27	4	1.21	6	2.07	3	0.74	6	1.92
28	4	0.99	4	1.795	2	2.625	4	1.246
29	5	2.67	3	3.295	7	0.685	3	3.94
30	4	0.865	5	4.13	7	3.515	5	0.79
31	4	0.85	2	1.415	2	0.85	2	1.565
32	4	1.4	4	3.35	4	0.725	4	1.235
33	6	0.78	7	1.265	4	5.63	7	0.515
34	7	1.995	3	1.74	4	4.56	3	1.36
35	6	1.67	2	1.951	5	2.17	2	2.37
36	5	0.79	1	0.345	4	2.91	1	1.195
37	4	1.515	7	0.63	4	2.27	7	1.286
38	3	1.175	7	1.24	4	0.345	7	8.19
39	5	0.79	7	2.336	6	2.41	7	0.78
40	4	0.66	2	1.145	7	2.35	2	1.4
41	6	0.485	4	0.6	5	6.24	4	2.09
42	11	3.935	4	2.18	4	1.848	4	1.5
43	4	0.915	4	3.835	3	0.9	4	1.4

Sr. #	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected
44	6	7.07	5	1.455	5	5.425	5	0.33
45	4	0.495	4	0.566	4	3.275	4	0.875
46	4	3.31	4	0.39	6	3.285	4	3.74
47	5	1.555	4	1.13	11	5.945	4	1.9
48	4	1.22	6	2.21	4	2.785	6	1.34
49	3	5.2	7	1.335	6	4.93	7	0.215
50	5	0.455	6	4.925	4	5.47	6	2.416
51	12	2.74	5	0.7	4	3.756	5	1.14
52	15	7.475	4	3.81	5	2.66	4	0.125
53	10	1.455	3	1.905	4	7.15	3	1.97
54	5	2.49	5	1.695	3	5	5	0.095
55	4	1.24	4	1.125	3	2.05	4	1.555
56	6	3.715	6	0.75	266	157.656	6	0.595
57	308	123.115	11	5.05			11	1.235
58			4	1.74			4	2.985
59			6	1.7			6	3.565
60			4	0.91			4	0.795
61			4	2.635			4	1.59
62			5	0.66			5	3.29
63			4	0.615			4	2.02
64			3	0.44			3	1.415
65			6	3.63			6	0.97

Sr. #	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected	Household Size	Waste Amount Collected
66			3	2.175			3	0.57
67			5	0.96			5	0.755
68			12	1.64			12	0.839
69			3	0.915			3	1.17
70			6	2.115			6	0.655
71			15	1.221			15	2.31
72			7	2.555			7	1.925
73			10	2.941			10	0.985
74			6	1.135			6	3.815
75			5	0.795			5	3.42
76			19	1.035			19	2.035
77			8	0.88			8	2.48
78			5	0.45			5	0.575
79			8	0.915			8	2.466
80			4	0.245			4	3.65
81			7	1.47			7	0.73
82			5	0.615			5	0.89
83			4	0.82			4	0.48
84			6	0.755			6	3.006
			480	140.628			477	128.716

Income Area: High **Date of Survey Start:** 06.03.21 to 12.03.21 **Area Name:** Gulberg, District Central

Number of People	Weight Day 1	Weight Day 2	Weight Day 3	Weight Day 4	Weight Day 5
7	1.135	0.575	0.795	5.005	1.555
6	0.635	0.29	0	6.42	0.66
8	2.21	2.115	1.96	6.305	1.785
8	0.345	0.575	0.72	4.045	2.095
6	1.25	2.64	0.355	4.305	1.585
5	0.875	2.185	0	6.47	1.16
9	2.44	1.065	2.16	4.62	0.66
2	0.24	0.95	0.885	6.33	2.615
5	4.825	5.535	1.285	15.385	1.805
6	2.51	2.955	1.205	0	1.216
5	0.31	4.82	0.87	7.875	4.23
6	0.965	1.34	0.385	6.515	3.265
7	1.62	2.14	0.51	10.545	3.375
9	2.73	1.245	1.145	6.255	5.345
4	4.535	1.965	0.355	6.5	2.02
5	0.41	1.93	0.075	9.725	5.165
9	0.73	1.556	1.733	5.795	3.175
7	1.82	2.25	1.655	6.31	9.58
4	0.175	0.47	1.36	4.13	0.675
6	1.13	1.365	0.32	6.71	2.405
8	1.255	2.9	0.725	5.675	0.89
7	1.175	0.725	1.235	6.16	2.605

Number of People	Weight Day 1	Weight Day 2	Weight Day 3	Weight Day 4	Weight Day 5
8	0.105	1.87	1.556	6.405	3.545
5	1.7	2.33	3.225	4.24	4.415
2	1.67	3.19	0.66	8.5	2.195
4	1.925	5.59	0.2	0	1.08
8	1.03	1.73	7.81	5.895	0.535
9	15.865	0	0.53	1.605	3.22
6	2.755	4.92	0	4.705	2.53
3	0.815	1.33	0.615	2.642	1.095
4	4.205	1.07	1.535	2.545	2.155
2	0.295	1.845	3.155	2.26	1.85
3	0.545	3.195	0	1.765	2.87
3	0.545	2.61	0	1.075	2.57
6	1.3	1.785	0.645	2.195	2.61
Total	**66.075**	**73.056**	**39.664**	**184.912**	**88.536**

Income Area: Middle **Date of Survey Start:** 06.03.21 to 12.03.21 **Area Name:** North Nazimabad, District Central

Number of People	Wt. Day 1	Wt. Day 2	Wt. Day 3	Wt. Day 4	Wt. Day 5
7	1.895	0.295	3.73	3.655	0
4	2.71	2.165	3.055	1.235	0
9	3.515	5.645	0	1.055	0.88
5	4.21	1.485	0	1.555	0
7	3.995	4.575	0	2.54	7.78
1	2.36	0.915	2.69	3.48	0
3	6.89	1.735	0.33	1.915	1.06
6	6.075	0.42	0.675	2.695	0
6	3.675	0.495	1.5	1.235	0
9	3.89	2.43	1.475	2.215	1.805
7	3.385	1.425	1.145	4.315	1.895
7	2.22	0.95	2.69	2.01	1.875
5	2.385	1.17	1.185	3.23	2.465
6	2.94	0.24	2.6	8.985	1.725
9	3.665	1.965	0.7	1.23	
7	7.575	0.8	1.5	0.34	2.345
9	4.015	2.435	0.65	0.585	0.38
7	1.88	1.395	0.94	1.51	2.34
8	3.43	1.715	2.225	3.18	0.65
5	7.5	0.82	0.605	6.645	0
7	5.855	2.34	0.985	2.09	0.7
7	5.82	1.2	0.36	1.515	0

Number of People	Wt. Day 1	Wt. Day 2	Wt. Day 3	Wt. Day 4	Wt. Day 5
3	4.515	1.865	0.935	2.36	0
4	2.99	1.295	1.965	0.845	0
4	2.655	0	1.44	1.265	0
6	4.695	0	0.71	2.92	2.245
6	2.09	0	0.285	1.305	0
6	2.745	0.565	0.89	0.345	0
2	2.5	0	0.235	4.59	3.41
2	2.365	0.096	0	1.285	1.66
3	4.502	0	0	0.815	0.76
4	4.7	5	0	1.47	1.08
6	3.52	1.455	0	1.99	1.485
5	3.59	1.01	0	0.89	0.755
7	2.095	0	0	2.015	0

Income Area: Low **Date of Survey Start:** 06.03.21 to 12.03.21 **Area Name:** Liaquatabad, District Central

Number of People	Wt. Day 1	Wt. Day 2	Wt. Day 3	Wt. Day 4	Wt. Day 5	Total
3	2.795	0.515	0.89	0	0.64	4.84
3	2.28	1.41	1.095	1.33	0.22	6.335
2	0.31	0.795	1.7	0	1.135	3.94
8	1.87	1.15	0.956	0	0.885	4.861
6	3.615	1.595	1.445	0	0.635	7.29
4	2.115	2.075	1.15	0	0.84	6.18
3	0.645	1.815	0.835	3.665	1.79	8.75
5	2.38	0	1.45	0.885	1.935	6.65
3	0.585	8.515	0.21	3.36	0.245	12.915
5	1.685	0.86	1.145	0.315	2.225	6.23
3	0.425	0	2.42	0	1.79	4.635
4	2.07	3.54	2.96	0.343	1.305	10.218
2	1.5	0	0.505	1.235	2.965	6.205
6	2.925	1.42	1.28	4.515	0.615	10.755
5	2.635	0	15.7	2.59	1.46	22.385
4	1.205	2.145	1.07	6.135	1.045	11.6
5	1.37	0	0.945	2.05	1.87	6.235
8	2.21	0	2.55	0	0.89	5.65
6	0.545	0	0	1.975	1.89	4.41
2	4.17	1.145	6.725	3.29	0.485	15.815
6	0.39	0	0.12	1.06	1.71	3.28
3	0.56	2.615	1.06	0	0.385	4.62

Number of People	Wt. Day 1	Wt. Day 2	Wt. Day 3	Wt. Day 4	Wt. Day 5	Total
4	1.55	0.445	2.96	0	0.27	5.225
6	0.855	0	0.32	2.345	1.47	4.99
10	0.695	0	2.99	0.265	0.98	4.93
2	0.55	0	1.49	0.915	3.775	6.73
6	5.16	0	1.25	0.405	1.73	8.545
4	1.425	0	0.795	0.17	0.625	3.015
2	1.57	1	0.92	0.205	0.64	4.335
5	2.79	0.975	1.58	0.9	0.5855	6.8305
9	2.815	2.085	0.68	2.275	0.88	8.735
8	0.595	1.985	0.7	1.555	0.255	5.09
4	1.335	2.095	2.515	0.425	1.88	8.25
5	4.17	3.33	1.34	0	1.115	9.955
5	1.085	1.015	0.69	0.39	2.93	6.11
Total	**62.88**	**42.525**	**64.441**	**42.598**	**2.4**	**256.5395**

Income Area: High **Date of Survey Start:** 06.03.21 **Area Name:** Model Colony, District Korangi

Number of People	Wt. Day 1	Wt. Day 2	Wt. Day 3	Wt. Day 4	Wt. Day 5	Wt. Day 6	Total
8	2.25	5.95	1.14	2.755	3.889	8.295	24.279
12	0	2.325	4.895	1.815	5.64	0.925	15.6
4	0	1.25	3.395	4.965	1.58	1.25	12.44
3	0	9.225	1.78	3.57	3.055	3.32	20.95
7	3.03	3.5	5.895	1.255	2.13	2.285	18.095
6	0	3.86	4.3	8.79	0.11	1.63	18.69
9	0	2.155	4.915	1.865	3.115	2.11	14.16
9	1.11	3.865	0.99	2.24	2.115	1.09	11.41
4	2.42	2.825	2.1	4.465	2.175	3.275	17.26
8	0	2.99	4.9	5.39	4.44	1.095	18.815
9	0	2.345	1.205	2.8	5.095	7.755	19.2
6	0	3.445	1.595	2.685	6.12	2.71	16.555
5	0.32	5.095	3.29	2.326	5.37	0.185	16.586
6	0	6.22	6.76	3.015	4.32	3.995	24.31
9	0	7.74	1.4	1.115	2.36	2.125	14.74
4	0	2.895	3.4	1.99	5.135	3.055	16.475
10	0	3.78	3.99	1.69	2.95	3.57	15.98
7	0	2.35	5.52	1.015	3.495	1.93	14.31
7	0	4.27	2.83	2.95	1.965	2.155	14.17
3	0	8.835	2.515	4.93	3.68	4.64	24.6
9	2.415	2.56	3.405	0.855	0.92	2.41	12.565
3	0	3.57	0.745	4.3	1.515	1.825	11.955

Number of People	Wt. Day 1	Wt. Day 2	Wt. Day 3	Wt. Day 4	Wt. Day 5	Wt. Day 6	Total
11	0	8.575	7.275	2.775	2.265	2.895	23.785
8	16.295	3.59	0.97	4.79	6.015	3.25	34.91
4	0	3.025	2.875	5.175	4.785	1.64	17.5
5	0	3.795	2.25	4.79	5.565	3.105	19.505
7	0.63	5.64	2.74	3.825	3.757	2.09	18.682
8	0	6.935	1.21	1.81	7.73	1.45	19.135
10	0	7.32	3.36	2.695	5.565	2.56	21.5
11	0	4.925	7.45	2.69	7.265	1.065	23.395
8	0.645	5.055	1.605	1.845	6.92	3.2	19.27
8	1.435	9.615	4.35	4.12	2.095	4.665	26.28
6	0	4.755	1.41	0.435	4.73	2.495	13.825
6	4.075	2.345	1.24	1.255	3.63	1.46	14.005
12	8.195	1.645	2.07	0	3.315	2.995	18.22
Total	**42.82**	**158.27**	**109.77**	**102.986**	**134.811**	**94.5**	**643.157**

Income Area: Middle **Date of Survey Start:** 06.03.21 to 12.03.2021 **Area Name:** Shah Faisal Colony, District Korangi

Number of People	Wt. Day 1	Wt. Day 2	Wt. Day 3	Wt. Day 4	Wt. Day 5
6	2.146	1.33	2.605	1.663	1.34
8	0	0.915	1.685	2.5	1.265
3	2.445	3.09	1.615	0.685	2.006
6	0	1.05	1.42	1.52	1.875
6	3.75	1.915	2.19	5.03	1.34
4	4.165	1.67	1.28	2.975	1.62
6	1.16	1.195	1.75	0	2.36
5	3.875	2.84	0.875	0	1.905
5	0	1.4	1.43	1.31	1.78
3	0	2.29	1.275	1.615	1.39
5	5.095	1.025	2.88	0.505	1.575
5	0	2.635	2.655	2.155	1.255
12	4.82	1.7	1.175	1.81	0.865
10	2.805	2.21	2.36	1.94	1.195
5	6.3	2.065	1.895	2.815	2.24
6	0	3.605	1.775	1.125	1.12
7	0.99	4.84	1.51	1.725	2.2
5	0.895	2.99	0.675	2.22	1.79
2	0	1.99	1.69	1	1.21
2	6.23	1.97	2.98	1.62	2.36
5	5.405	2.98	2.665	0.985	1.255
8	0	3.195	3.18	0.725	0.95

Number of People	Wt. Day 1	Wt. Day 2	Wt. Day 3	Wt. Day 4	Wt. Day 5
5	0	0.545	2.285	2.305	1.21
8	0	1.935	1.09	1.295	1.11
6	0	2.81	1.64	1.635	1.35
5	0	2.665	2.545	1.355	1.78
4	8.544	1.49	2.225	0.905	2.355
7	1.345	3.195	1.205	2.11	3.105
6	3.75	3.535	2.87	1.82	3.22
5	0.48	2.475	2.64	2.745	1.775
5	4.675	0.575	1.855	2.48	1.985
5	0	1.085	2.695	1.85	1.735
5	2.375	2.85	1.085	1.67	1.18
5	2.06	2.52	2.91	2.215	1.45
2	2.305	2.09	1.615	2.995	2.52

Income Area: Low **Date of Survey Start:** 06.03.21 to 12.03.2021 **Area Name:** Landhi, District Korangi

Number of People	Wt. Day 1	Wt. Day 2	Wt. Day 3	Wt. Day 4	Wt. Day 5	Wt. Day 6
3	0.465	0.525	1.12	1.79	2.28	3.23
3	2.07	1.91	1	2.545	1.615	2.525
3	0	1.035	3.55	3.72	1.63	0.31
2	0	1.34	0.95	5.86	0.495	1.005
4	0	2.615	1.12	0.33	0.635	0.385
4	0.77	3.29	2.145	1.675	0.52	0.27
3	7.64	1.66	3.67	1.275	1.01	2.095
6	1.96	0.92	0.41	3.405	2.725	0.41
5	0	5.745	2.69	3.44	3.61	0.69
5	0	3.645	0.555	1.11	2.605	2.49
6	0.99	3.45	1.52	1.935	0.89	0.325
4	3.24	3.205	0.97	3.225	0.475	0.125
6	0	0.75	1.36	1.07	0.54	1.665
7	0.375	4.905	5.345	3.885	1.38	5.13
6	0	0.445	4.47	5.37	3.62	0.705
2	0	0.945	0.805	1.105	1.45	1.09
6	0	0.895	1.19	0.44	3.04	0.49
8	4.61	0.465	1.555	2.375	0.61	3.53
6	0	0.99	0.875	2.945	2.48	0.47
4	3.915	1.63	6.94	2.57	2.5	1.15
7	3.14	1.035	2.695	2.05	1.61	4.175
5	12.52	2.43	2.13	2.695	1.05	0.955

Number of People	Wt. Day 1	Wt. Day 2	Wt. Day 3	Wt. Day 4	Wt. Day 5	Wt. Day 6
5	1.862	5.085	0.295	7.11	1.625	0.325
9	0	5.115	2.355	1.64	2.834	1.74
4	7.875	3.78	1.075	2.625	3.405	2.52
5	4.93	0.554	1.025	1.44	3.38	1.79
4	0	0.605	2.1	0.85	1.98	1.11
5	0.205	1.24	2.63	1.705	0.93	0.805
2	0	0.815	3.35	0.335	0.67	0.66
2	1.33	4.415	1.875	2.14	1.755	1.47
2	0	0.77	5.965	2.68	1.175	4.27
5	0.735	5.535	3.475	0.545	0.37	5.665
5	0	1.325	3.105	0.64	2.05	1.37
4	0	0.44	6.43	0.95	1.625	0
8	0	0.735	5.075	4.39	0.925	0

Annexure 6: Chemical Analysis Report

Report of Analysis
Work Order : PKS2108797
[Report File No.: 0000012373]

To: PROJECT PROCUREMENT INTERNATIONAL
Office 26, 2nd Floor, Silver City Plaza, G-II, Markaz, Islamabad.

P.O. No.: BO2015826
Project No.: MUNICIPAL SOLID WAST
Samples: 6
Received: Mar 11, 2021
Pages: Page 1 of 7

March 26, 2021

Client Reference: BO2015826
Sample ID: Central North Nazimabad
Product: Municipal Solid Waste

SGS Minerals Sample ID: PKS2108797.001

Tests	Method	AR	Dry	AD
Moisture, Total %	Based on ASTM D3302	47.89		
Moisture, Laboratory Sample %	Based on ASTM D3173			4.25
Ash %	Based on ASTM D3174	18.39	35.30	33.80
Volatile Matter %	Based on ASTM D 7582	33.51	64.31	61.58
Fixed Carbon by Calculation %	Based on ASTM D3172	0.21	0.39	0.37
Sulfur %	Based on ASTM D4239 Method A	0.10	0.20	0.19
Gross Calorific Value kcal/kg	Based on ASTM D5865	2348	4507	4315
Net CV @ Constant Pressure kcal/kg	Based on ASTM D5865	1895	4173	3970
Oxygen (by difference) %	Based on ASTM D3176	7.98	15.29	18.41
		AR	Dry	AD
Carbon %	Based on ASTM D5373	21.33	40.94	39.20
Hydrogen %	Based on ASTM D5373	3.41	6.54	6.74
Nitrogen %	Based on ASTM D5373	0.903	1.734	1.660

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Report of Analysis

Work Order : PKS2108797

[Report File No.: 0000012373]

To: PROJECT PROCUREMENT INTERNATIONAL
Office 26, 2nd Floor, Silver City Plaza, G-II, Markaz, Islamabad.

P.O. No.: BO2015826
Project No.: MUNICIPAL SOLID WAST
Samples: 6
Received: Mar 11, 2021
Pages: Page 2 of 7

March 26, 2021

Client Reference: BO2015826
Sample ID: Korangi Shah Faisal
Product: Municipal Solid Waste

SGS Minerals Sample ID: PKS2108797.002

Tests	Method	AR	Dry	AD
Moisture, Total %	Based on ASTM D3302	61.27		
Moisture, Laboratory Sample %	Based on ASTM D3173			3.34
Ash %	Based on ASTM D3174	13.11	33.86	32.73
Volatile Matter %	Based on ASTM D 7582	23.00	59.38	57.40
Fixed Carbon by Calculation %	Based on ASTM D3172	2.62	6.76	6.53
Sulfur %	Based on ASTM D4239 Method A	0.09	0.23	0.22
Gross Calorific Value kcal/kg	Based on ASTM D5865	1261	3256	3147
Net CV @ Constant Pressure kcal/kg	Based on ASTM D5865	798	2983	2864
Oxygen (by difference) %	Based on ASTM D3176	10.45	26.98	29.05
		AR	Dry	AD
Carbon %	Based on ASTM D5373	12.38	31.97	30.90
Hydrogen %	Based on ASTM D5373	2.05	5.28	5.48
Nitrogen %	Based on ASTM D5373	0.649	1.676	1.620

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To: PROJECT PROCUREMENT INTERNATIONAL
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P.O. No.: BO2015826
Project No.: MUNICIPAL SOLID WAST
Samples: 6
Received: Mar 11, 2021
Pages: Page 3 of 7

March 26, 2021

Client Reference: BO2015826
Sample ID: Korangi Model Colony
Product: Municipal Solid Waste

SGS Minerals Sample ID: PKS2108797.003

Tests	Method	AR	Dry	AD
Moisture, Total %	Based on ASTM D3302	73.16		
Moisture, Laboratory Sample %	Based on ASTM D3173			3.88
Ash %	Based on ASTM D3174	3.44	12.81	12.31
Volatile Matter %	Based on ASTM D 7582	20.74	77.28	74.28
Fixed Carbon by Calculation %	Based on ASTM D3172	2.66	9.91	9.53
Sulfur %	Based on ASTM D4239 Method A	0.06	0.21	0.20
Gross Calorific Value kcal/kg	Based on ASTM D5865	1346	5015	4820
Net CV @ Constant Pressure kcal/kg	Based on ASTM D5865	810	4608	4407
Oxygen (by difference) %	Based on ASTM D3176	7.81	29.12	31.44
		AR	**Dry**	**AD**
Carbon %	Based on ASTM D5373	13.01	48.48	46.60
Hydrogen %	Based on ASTM D5373	2.13	7.92	8.05
Nitrogen %	Based on ASTM D5373	0.391	1.457	1.400

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Samples: 6
Received: Mar 11, 2021
Pages: Page 4 of 7

March 26, 2021

Client Reference: BO2015826
Sample ID: Central Liaquatabad
Product: Municipal Solid Waste

SGS Minerals Sample ID: PKS2108797.004

Tests	Method	AR	Dry	AD
Moisture, Total %	Based on ASTM D3302	41.08		
Moisture, Laboratory Sample %	Based on ASTM D3173			3.08
Ash %	Based on ASTM D3174	8.91	15.13	14.66
Volatile Matter %	Based on ASTM D 7582	45.37	77.01	74.64
Fixed Carbon by Calculation %	Based on ASTM D3172	4.64	7.86	7.62
Sulfur %	Based on ASTM D4239 Method A	0.09	0.15	0.15
Gross Calorific Value kcal/kg	Based on ASTM D5865	3343	5675	5500
Net CV @ Constant Pressure kcal/kg	Based on ASTM D5865	2879	5293	5112
Oxygen (by difference) %	Based on ASTM D3176	14.00	23.76	25.76
		AR	Dry	AD
Carbon %	Based on ASTM D5373	28.94	49.11	47.60
Hydrogen %	Based on ASTM D5373	4.38	7.43	7.55
Nitrogen %	Based on ASTM D5373	2.602	4.416	4.280

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P.O. No.: BO2015826
Project No.: MUNICIPAL SOLID WAST
Samples: 6
Received: Mar 11, 2021
Pages: Page 5 of 7

March 26, 2021

Client Reference: BO2015826
Sample ID: Central Gulberg
Product: Municipal Solid Waste

SGS Minerals Sample ID: PKS2108797.005

Tests	Method	AR	Dry	AD
Moisture, Total %	Based on ASTM D3302	48.99		
Moisture, Laboratory Sample %	Based on ASTM D3173			3.03
Ash %	Based on ASTM D3174	3.42	6.71	6.51
Volatile Matter %	Based on ASTM D 7582	44.53	87.30	84.65
Fixed Carbon by Calculation %	Based on ASTM D3172	3.06	5.99	5.81
Sulfur %	Based on ASTM D4239 Method A	0.17	0.34	0.33
Gross Calorific Value kcal/kg	Based on ASTM D5865	2745	5381	5218
Net CV @ Constant Pressure kcal/kg	Based on ASTM D5865	2242	4955	4787
Oxygen (by difference) %	Based on ASTM D3176	16.03	31.41	33.15
		AR	Dry	AD
Carbon %	Based on ASTM D5373	26.72	52.39	50.80
Hydrogen %	Based on ASTM D5373	4.23	8.29	8.38
Nitrogen %	Based on ASTM D5373	0.437	0.856	0.830

Analytical Services Laboratory
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Report of Analysis
Work Order : PKS2108797
[Report File No.: 0000012373]

To: PROJECT PROCUREMENT INTERNATIONAL
Office 26, 2nd Floor, Silver City Plaza, G-II, Markaz, Islamabad.

P.O. No.: BO2015826
Project No.: MUNICIPAL SOLID WAST
Samples: 6
Received: Mar 11, 2021
Pages: Page 6 of 7

March 26, 2021

Client Reference: BO2015826
Sample ID: Korangi Landhi
Product: Municipal Solid Waste

SGS Minerals Sample ID: PKS2108797.006

Tests	Method	AR	Dry	AD
Moisture, Total %	Based on ASTM D3302	58.97		
Moisture, Laboratory Sample %	Based on ASTM D3173			1.96
Ash %	Based on ASTM D3174	7.98	19.45	19.07
Volatile Matter %	Based on ASTM D 7582	29.68	72.34	70.92
Fixed Carbon by Calculation %	Based on ASTM D3172	3.37	8.21	8.05
Sulfur %	Based on ASTM D4239 Method A	0.07	0.18	0.18
Gross Calorific Value kcal/kg	Based on ASTM D5865	1938	4723	4631
Net CV @ Constant Pressure kcal/kg	Based on ASTM D5865	1453	4380	4283
Oxygen (by difference) %	Based on ASTM D3176	11.95	29.09	30.26
		AR	Dry	AD
Carbon %	Based on ASTM D5373	17.70	43.15	42.30
Hydrogen %	Based on ASTM D5373	2.73	6.66	6.75
Nitrogen %	Based on ASTM D5373	0.603	1.469	1.440

Analytical Services Laboratory
Ahsan Anis
Assistant Manager

Certified By : Iqbal Ashraf
Manager Laboratory

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ref: MINE/F029

SGS

Report of Analysis
Work Order : PKS2108797
[Report File No.: 0000012373]

To: PROJECT PROCUREMENT INTERNATIONAL
Office 26, 2nd Floor, Silver City Plaza, G-II, Markaz, Islamabad.

P.O. No.: BO2015826
Project No.: MUNICIPAL SOLID WAST
Samples: 6
Received: Mar 11, 2021
Pages: Page 7 of 7

March 26, 2021

Client Reference: BO2015826
Sample ID: Korangi Landhi
Product: Municipal Solid Waste

SGS Minerals Sample ID: PKS2108797.006

Comments

Sample not drawn by SGS Pakistan Private Limited.
This report is not valid for any negotiation.
Statement of conformity can be provided upon request (Condition applies).
This report pertains only to the sample (s) supplied and is issued without prejudice.
The remaining portion of the sample (s) will be disposed off after 15 days unless otherwise instructed (Conditions Apply).
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