Paper No.823

WASTE GENERATION AND CHARACTERIZATION

Ahsan Iqbal Bela

WASTE GENERATION AND CHARACTERIZATION

By:

Ahsan Iqbal Bela[1]

Abstract

Solid Waste management is a universal issue affecting every person in the world. Poorly managed waste leads to incidents of contaminating land and water resources, clogging drains and causing flooding, transmitting diseases via the provision of a suitable environment for the breeding of vectors, increasing respiratory problems through airborne particles from improper burning of waste and affecting economic development such as adverse impact on tourism industry etc. Waste generation and characterization are fundamental information required for furnishing efficient solid waste management systems for any city/area. Several waste characterization studies have been carried-out in Pakistan in the recent past, however, the authenticity of these studies is questionable mainly due to adopting an unsuitable sampling strategy and not following approved standards. The study presented in this paper was conducted under the Punjab City Program (PCP) of the Punjab Municipal Funded Company (PMDFC). The PCP is a World Bank-funded framework project focusing on urban management and improvement of municipal infrastructure for satisfactory service delivery in sixteen cities of the Punjab. The author of this paper was the overall incharge of the presented Waste Generation and Characterization study. The study was designed and executed in accordance with the American Society for Testing and Material (ASTM) *International Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste.* A door-to-door waste sampling strategy was adopted in the study. Forensic Waste Logging Laboratory was developed within the premises of Municipal Committee (MC) of Muridka, Punjab. The author of this paper delivered the required training to the concerned MC staff for the safe and smooth execution of the study. Waste sampling and waste logging activities were supervised and ensured strict health & safety measures were in place during the execution of work in the purpose-built Forensic Waste Logging Laboratory.

Introduction

About 36% of the population of Pakistan is living in urban areas. Punjab is the most populated province of Pakistan and many urban areas of Punjab have no or limited organized arrangements of collection and disposal of domestic waste. In order to improve the overall situation of the municipal services in general and Solid Waste Management (SWM) in particular, sixteen (16) cities of Punjab have been selected by the Government of Punjab under the framework project Punjab Cities Program (PCP), with assistance of World Bank (WB) loan agreement.

In low to middle-income countries like Pakistan, solid waste management practices are rapidly evolving. Current practices of municipal solid waste disposal in Punjab, Pakistan are mainly comprised of the collection of municipal waste and dumping in the outskirts of city area at control or un-controlled waste dumping site. There is no operational engineered landfill site in Punjab. All dumping sites in Punjab have high risk of damaging environment of the area including contaminating water resources, land resources and transmitting diseases via the provision of a suitable environment

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for the breeding of vectors etc. There is massive room for improvement in the efficient management of solid waste in Punjab, Pakistan.

Waste Generation and Characterization are mandatory information for the development of bespoke efficient solid waste management systems for any city or area. During recent past, several studies were conducted to determine the waste characterization of big cities of Punjab. However, the authenticity and validity of these studies are questionable mainly due to inappropriate waste sampling and not strictly following recommended standards i.e. ASTM standards.

Study Approach

The socioeconomic status of urban areas of Pakistan varies significantly, in terms of people's living style, house sizes, environment, available welfare facilities etc. Variation in socioeconomic conditions is directly related to waste generation and characterization. affects and characteristics of waste generated from certain areas. For example, domestic waste produced from residential areas of high per capita income or comparatively bigger houses would comprise more recyclable waste i.e. bottles, cans, food packing waste etc., and therefore the density of the waste would be lower than the waste from low-income small houses areas usually rich with wet organic waste and raise the unit weight of the waste. Similarly, waste from houses accompanied by gardens would have a higher percentage of green waste etc.

A solid waste management map was developed by reviewing the aerial images and observations made during site visits conducted with the Municipal Committee (MC) of Muridka. The purpose of zoning the city area for waste sampling was to ensure that collected waste samples represent the area.

Muridke City was divided into three different zones based on the socio-economic conditions of the area.

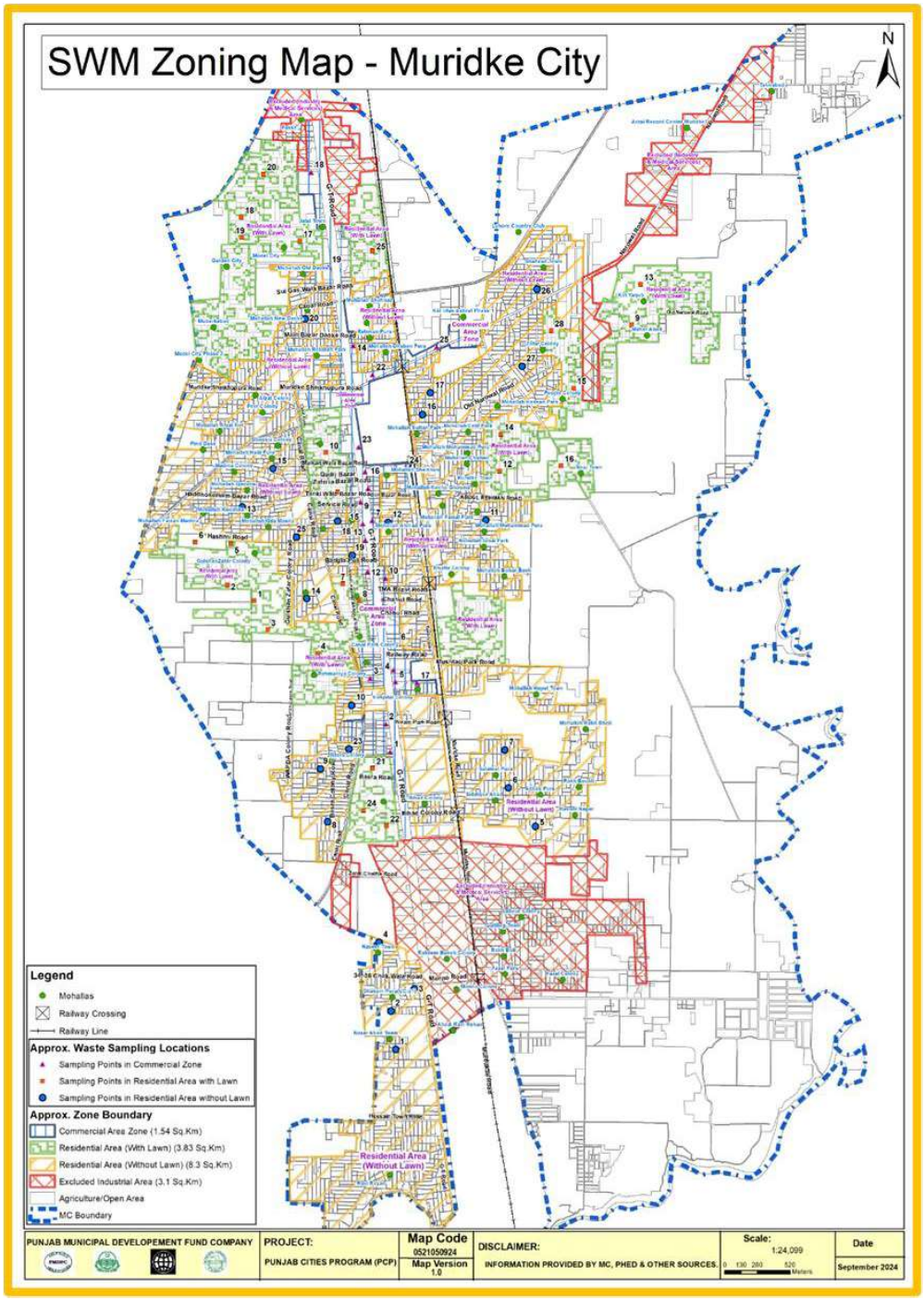
- Residential area without lawn;
- Residential area with front or back lawn; and
- Commercial area.

A door-to-door sampling methodology was adopted in this study. Waste samples collected from each zone were analyzed separately. 20 to 25 numbers of randomly selected dwellings in each zone were sampled twice i.e. during weekdays and once during weekends. Approximate sampling locations are shown in the below GIS map.

Work-specific risk assessment was carried out and documented before commencing work on the study. Where possible, eliminating the risk by altering the scope of work, method of executing work activities etc. was preferred rather than minimizing the risk with control measures. However, where the risk cannot be managed during the design phase of the project, suitable control measures were proposed, including using required personal protection equipment (PPE), regular environmental monitoring, etc. The risk assessment was explained to the staff working on this study before commencing work on the study.

The training was also delivered to the MC’s staff about how to complete the proforma/logging sheets and other key parameters that need to be followed during the execution of the study. The author of this paper delivered the required training, prepared the required documentation, liaised with the environmental laboratory for

third-party testing, monitored the whole process of the study and furnished the final report at the completion of the study.



Analysis of Waste Samples

According to *ASTM Designation: D5231-92 (Reapproved 2016) "Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste"* accumulated weight of samples of approximately weight 90kg from each zone of the city was collected and analyzed for waste characterization component of the study. About 2kg of composite waste samples from each zone were transported for third-party testing i.e. Solution Environmental & Analytical Laboratory for three tests including Calorific Value test, Carbon and Nitrogen Ratio test and the moisture content test. Samples were transported to the laboratory within 24 hours of the sample being prepared/collected, this is particularly important for moisture content testing. Heavy-duty printed plastic waste sampling bags of size 10 liters were used for waste sampling.

Waste Generation

The weight of collected waste samples was measured in the purpose-built Forensic Waste Laboratory and the production of waste per day per person was calculated using the collected data (completed proformas). Per capita waste production was calculated by dividing the total collected waste by the number of persons responsible for generating the waste sample.

Future waste production of Muridke city was envisaged by using the population growth rate from the Bureau of Statistic Punjab and possible increase in per capita waste generation due to the infrastructure development and living style of the local community. The per capita waste generation is likely to increase in the future due to the improvement in living standards and anticipated changes in lifestyle. According to the World Bank publication *"What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050"* it is predicted that the per capita waste generation of low- and middle-income countries is likely to increase by 40% or more by 2050. This factor was applied in calculating future waste production in the area.

Waste Generation in Zone - Residential without Lawn

Sample ID	Sampling Location	Total no. of residence/persons responsible of waste	Weight of waste sample (kg)		Average waste produced per day (kg)	Waste production per capita per day (kg)
			Weekend Sample	Week Day Sample		
1	Street No. 10, Canal Park, Muridke	8	1.16	2. 56	1.86	0.22
2	Street No. 2, Gulshna Zafar, Muridke	6	5.27	1.63	3.45	0.57
3	Chattah Park, Gulshna Zafar, Muridke	17	8.87	3.58	6.23	0.37
4	School Wala Bazar, Gulshna Zafar	8	3.56	7.30	5.43	0.68
5	Street No. 13, Mahala Canal Park,	4	0.30	0.31	0.31	0.1

Sample ID	Sampling Location	Total no. of residence/persons responsible of waste	Weight of waste sample (kg)		Average waste produced per day (kg)	Waste production per capita per day (kg)
			Weekend Sample	Week Day Sample		
6	Street No. 13, Canal Park, Muridke	6	0.86	1.49	1.18	0.20
7	Street No. 12, Canal Park, Muridke	1	Not responded	0.18	0.18	0.18
8	Basrah Calony, Butt Chowk, Muridke	6	Not responded	0.98	0.98	0.17
9	Basrah Caloney, Street No. 20	7	3.03	1.56	2.29	0.33
10	-	-	-	-	-	-
11	Iqbal Nager, Muridke	7	NR	2.56	2.56	0.37
12	Mushtaq Park, Muridke	8	NR	1.84	1.84	0.23
13	Padoka Bazar, Muridke	8	3.26	2.95	3.11	0.39
14	-	-	Not responded	Not responded	-	-
15	Hadoka Denga Bazar, Muridke	12	4.15	7.94	6.05	0.51
16	Street No. 12, Sultan Park, Muridke	6	2.16	2.72	2.44	0.41
17	Main Bazar, Sultan Park	7	2.08	1.40	1.74	0.25
18	Tanki Bazar, Muridke	6	3.5	3.21	3.36	0.56
19	Service Bazar, Muridke	6	1.73	2.37	2.05	0.34
23	Allah Ho Bakery Wala Bazar, Muridke	8	1.69	2.58	2.14	0.27
25	Canal Park, Muridke	9	-	1.35	1.35	0.15
26	Shahzad Town, Muridke	6	2.02	1.98	2.00	0.34
Average Waste Generation per Capita						0.332

Waste Generation in Zone - Residential with Lawn

Sample ID	Sampling Location	Total no. of residence/persons responsible of waste	Weight of waste sample (kg)		Average waste produced per day (kg)	Waste production per capita per day (kg)
			Weekend Sample	Week Day Sample		
1	Gulshan Zafar Colony St. No. 2, Muridke	14	NR	4.24	4.24	0.31
2	Gulshan Coloney St. No. 3, Muridke	7	1.73	2.59	2.16	0.31
3	-	-	NR	NR	-	-
4	Gulshan Coloney St. No. 5, Muridke	11	1.82	2.35	2.09	0.19
5	Hashmi Road, Hadoka, Muridke	9	1.12	4.37	2.75	0.31
6	Ha shmi Road, St. No. 2, Muridke	5	0.34	0.89	0.62	0.13
7	Canal Park, Bangla Road (water supply office)	6 workers	Not responded	0.63	0.63	-
8	Residence next to Jinnah Ideal School, Canal Coloney	6	0.82	NR	0.82	0.14
9	Muharama Abad, Muridke	7	3.31	2.16	2.735	0.39
10	Pera Mandi Bazar, Muridke	4	Not responded	1.91	1.91	0.48
11	Pera Mandi Bazar, street No. 2, Muridke	5	Not responded	3.51	3.51	0.71
12	Pande Muridke, Muridke	9	0.97	2.64	1.81	0.21
13	Kot Yaqob, Muridke	7	2.19	3.12	2.655	0.38
14	Main Bazar, Pande Muridke, Muridke	5	1.05	2.00	1.525	0.31
15	Muhala Iqbal Park, Pande Muridke	5	2.62	1.28	1.95	0.39
16	Warich Street, Pande Muridke, Muridke	4	Not responded	3.16	3.16	0.79
17	Model City, St. 1, Muridke	6	Not responded	2.60	2.60	0.44
18	Model City, st. 5, Muridke	11	3.50	5.01	4.26	0.39

Sample ID	Sampling Location	Total no. of residence/persons responsible of waste	Weight of waste sample (kg)		Average waste produced per day (kg)	Waste production per capita per day (kg)
			Weekend Sample	Week Day Sample		
19	Model City, St. 6, Muridke	7	0.54	0.71	0.625	0.1
20	Model City, St. 2, Muridke	12	2.89	9.07	5.98	0.5
21	Bilal Park, Main Bazar, Muridke	6	2.47	2.13	2.3	0.39
22	Bilal Park, Soi-gas Bazar, Muridke	5	3.32	1.34	2.33	0.47
24	Allaha Ho Bakery Wala Bazar, Muridke	4	3.55	-	3.55	0.89
27	Hassan Park, Chungi, Muridke	7	3.13	2.15	2.64	0.38
28	Zafar park, Muridke	5	2.61	2.39	2.5	0.5
Average per capita Waste Generation						0.396

Waste Generation in Zone - Commercial Area

Sample ID	Sampling Location	Approximate Total no. of Customer + Staff	Weight of waste sample (kg)		Average waste produced per day	Waste production per capita per day
			Weekend Sample	Week Day Sample		
1	Malik Hotel, GT Road Muridke	100 on weekdays 200 on weekend	3.79	6.14	4.965	0.066
2	Punjab Tikka Restaurant, GT Road, Muridke	80 on week days 120 on weekend	0.42 (not complete sample)	6.43	6.43	0.064
3	Own-way Bakery, GT Road, Muridke	50	0.41	Not responded	0.41	0.0082
4	Gourmet Bakery, GT Road, Muridke	250 on weekdays 500 on Weekend	2.13	0.37 (only provided cash counter receipts waste)	2.13	0.0057
5	Lahore Hotel, GT Road, Muridke	60 on weekdays 150 on weekends	0.41	0.33	0.37	0.0074
6	Madina Photo Estate	About 50	0.40	0.28	0.34	0.0068
7	(Number was not used)					

Sample ID	Sampling Location	Approximate Total no. of Customer + Staff	Weight of waste sample (kg)		Average waste produced per day	Waste production per capita per day
			Weekend Sample	Week Day Sample		
8	Razwan Tailer	30	0.44	0.84	0.64	0.043
9	Adil Hotel, GT Road, Muridke	200	0.83 (not complete sample)	2.93	2.93	0.015
10	Sofi G Khoa Wale Chana Mutton (restaurant), Muridke	350	0.19 (not complete sample)	2.37	2.37	0.0068
11	Tariq Sweet Bakers, GT Road Murdike	300	NR	NR	-	-
12	HFC Fast Food Restaurant, GT Road Muridke	60	NR	NR	-	-
13	Sadiq Sweet Bakers, GT Road, Muridke	200	9.36	6.10	7.73	0.039
14	Fruit Shop, GT Road, Muridke	150	0.67	-	0.67	0.0045
15	Junjoa Peco Centre, Main Bazar, Muridke	100	1.40	0.39	0.895	0.009
16	General Store, GT Road Muridke	200	3.56	3.45	3.505	0.017
17	Madina General Store, GT Road, Muridke	300	Not responded	3.22	3.22	0.011
18	Almadina Hotel, GT Road, Muridke	150	4.51	3.96	4.24	0.029
19	Baber Fruit Shop, GT Road, Muridke	100	2.99	3.26	3.13	0.032
20	Zain Fruit Shop, Sui Gas Wala Bazar, GT Road, Muridke	150	5.94	1.80	3.87	0.026
21	Nufees Cloths Shop, GT Road, Muridke	100	1.77	0.43	2.2	0.022
22	Lucky Store, GT Road, Muridke	300	0.42	0.84	0.63	0.003
23	Mujahid Hotel, GT Road, Muridke	350	2.37	2.45	2.41	0.007
24	Hafiz General Store, Old Narowal Road, Muridke	300	3.48	Not responded	3.48	0.012

Sample ID	Sampling Location	Approximate Total no. of Customer + Staff	Weight of waste sample (kg)		Average waste produced per day	Waste production per capita per day
			Weekend Sample	Week Day Sample		
25	Solano Restaurant, Narowal Road, Muridke	250	3.12	Not responded	3.12	0.013
	Average waste produced per person per day in commercial zone					0.024

Current Municipal Waste Generation of Muridke City

Average waste production in Residential Zone without Lawn (Thickly Populated Area)	0.332 kg/day/capita
Average Waste Production in Residential Zone with Lawn	0.396 kg/day/capita
Average Waste Production in Residential Area (thickly populated area and houses with lawn)	0.364 kg/day/capita
Waste Production in Commercial Area	0.024 kg/day/capita
Assuming only residents of Muridke City are contributing to waste production in the commercial zone of the city	
Average Daily Waste Production per Capita of Muridka City contributing in producing of municipal waste	0.388 kg/day/capita
Projected population of Muridke City in 2023 using 2017 Census	189,200
Daily total municipal waste produced in Muridke city in 2023	72,086 kg

Estimated Municipal Waste Produce in 2050 by Muridke City

Current Daily per Capita Waste Production in Muridke City	0.388 kg/capita/day
Estimated Daily per Capita Waste Production in 2050 (40% increase in today's per capita waste production)	0.543 kg/capita/day
Projected Population of Muridke City in 2050 using 2017 census data	334,100
Total Estimated Daily Municipal Waste Produce in 2050	181,500 kg

Waste Characterization

Waste samples were collected twice from each randomly selected dwelling i.e. during weekdays and during weekends. The total weight of the waste analyzed (logged) in the Forensic Waste Logging Laboratory of each zone of the city was approximately 90kg. After analyzing collected samples in the Forensic Waste Logging laboratory, a composite sample of about 2kg (without recyclable and construction waste) of each zone was sent to Solution Environmental and Analytical Laboratory (SEAL) for three

tests i.e. Calorific Value test, Carbon and Nitrogen Ration test and Moisture Content test.

Forensic Waste Logging Laboratory was developed within the premises of Plant & Equipment yard of MC Muridka for activities including waste logging and calculating waste density.

The bulk density of waste samples from each zone was calculated in the laboratory using a calibrated barrel. Composite samples from each zone were weighed and transferred into the calibrated 60-liter capacity barrel. The barrel was lifted to a height of 30 cm, dropped repeatedly three times, and then measured the waste volume. The bulk density (kg/m^3) was calculated by dividing the weight by the volume of waste.

The laboratory was operative between June and August 2024 and waste logging was completed during this period for Muridke city. The completed waste logging sheets for every waste sample were added together and a final waste logging sheet for each zone was furnished for each zone separately.

Waste Characterization of Residential Zone without Garden

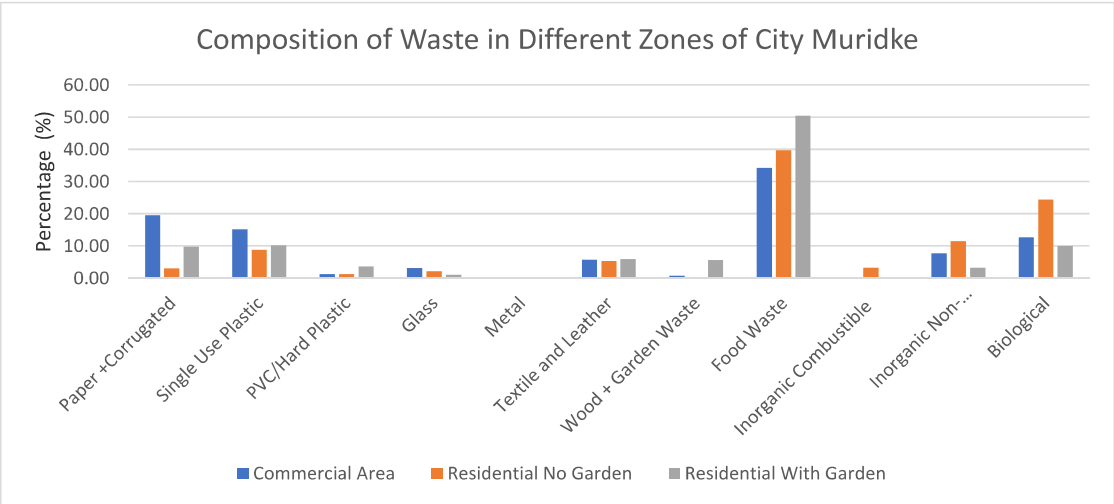
PMDFC - Waste Logging Sheet			
City:	Tahsil Muridka, District Shiekhupura	**Filled by:**	Ahsan Bela
Zone ID:	**Residential without Lawn (densely pouplated area)**	**Total Weight of Waste Analysed**	**89.47kg**
Odour: Y / N	**Olfactory Rating from 1 to 5: 3 to 4 typical domestic waste smell**		
Presence of any Leachate/liquid waste:	Y / N	*No noticable liquid waste recorded in waste samples*	
Components	**Description and weight in kg (%)**		
Mixed paper	0.48kg (0.5%) - pieces of printed paper (book, copies, advertisement etc.)		
Newsprint	0.22kg (0.3%) - pieces of news paper		
Corrugated	2.01kg (2.3%) - boxes of daily usage/food items items e.g. cake, biscuts, milk pack, medicin or cover of register etc.		
Plastic	7.87kg (8.8%) - one time use plastic e.g. shopping bags, crisp packets, soap or shampo packs e		
PVC (Plastic) Hard Plastic	1.04kg (1.2%) - recyclable plastic e.g. plastic bottles, pieces of hard plastic (broken toys, ball poi		
Glass	1.89kg (2.1%) - broken glass and medicine bottle etc.		
Aluminium	Negligible - bottle cap		
Ferrous	0.2kg (0.3%) - nails, pieses of metal		
Other Organic/Combustibles (Textile, Leather etc)	4.76kg (5.3%) - pieces of cloths, leather, broken shoe, piece of foam, dust mask etc.		
Wood	0.14kg (0.2%) - pieces of wood, broken floor broom etc.		
Garden Waste	Negligible -		
Food Waste	35.55kg (40%) - Fruite and vegitable waste, kitchen waste e.g. egg shell, pieces of bread etc.		
Construction Waste	0.29kg (0.3%) - stones, broken tiles etc.		
Other Inorganic - None Ferrous, none Aluminum metals	10.26kg (11.5%) - coal small pieces/granular form, combustible dirt		
Other Inorganic / Non-Combustibles -Fines and Inert	2.9kg (3.3%) - soil, non-combustible dirt, broken pottery		
Biological/Disposable Diapers	21.8kg (24.4%) - diapers, bones etc.		
Potential for Energy Recovery, Recyclable Waste and Compostable Waste%:	overall the waste most appropriate for waste to energy option (about 50%) including single use plastic, textile/leather, biological and other combustible inorganic. Food waste and other non-combustible inorganic are suitable for composting treatment i.e approximately 43% of total waste. Recyclable waste comprises on only about 7-8% of total waste		
Possible Presence of Asbestos Containing Material:	**Y/N**	No obvious sign of asbestos contamination identified during waste logging process	

Waste Characterization of Residential Zone with Garden

PMDFC - Waste Logging Sheet			
City:	Tahsil Muridka, District Shiekhupura	**Filled by:**	Ahsan Bela
Zone ID:	Residential with front or back Lawn (loosely pouplated area)	**Total Weight of Waste Analysed**	96.17kg
Odour: Y / N	**Olfactory Rating from 1 to 5: 3 to 4 typical domestic waste smell**		
Presence of any Leachate/liquid waste:	Y / N	*No noticable liquid waste recorded in waste samples*	
Components	**Description and weight in kg (%)**		
Mixed paper	1.4kg (1.5%) - pieces of printed paper (book, advertisement etc.)		
Newsprint	0.57kg (0.6%) - pieces of news paper		
Corrugated	7.48kg (7.8%) - boxes of daily usage items (tissu box, cake, cigret, juices, milk pack, spices etc.), board games (ludo)		
Plastic	9.74kg (10.1%) - shopping bags, packets of biscuts, crisps, oil packets etc.		
PVC (Plastic) Hard Plastic	3.49kg (3.6%) - piece of pipe, bottles, cap of bottles, plastic container for food etc.		
Glass	0.96kg (1%) - bottle, pieces of broken glass.		
Aluminium	0.07kg (0.1%) - bottle cap		
Ferrous	Nill		
Other Organic/Combustibles (Textile, Leather etc)	5.74kg (6%) - pieces of cloths, dust mask, pieces of leather,		
Wood	1.2kg (1.3%) - pieces of wood		
Garden Waste	4.2kg (4.4%) - plant waste (branches, leaves, grass etc.)		
Food Waste	48.56kg (50.5%) - vegetable and fruite waste, kitchen waste (egg shell, cooked waste rice etc.)		
Construction Waste	0.63kg (0.7%) - pieces of brick		
Other Inorganic - None Ferrous, none Aluminum metals	0.11kg (0.1%) - dry batries		
Other Inorganic / Non-Combustibles -Fines and Inert	2.42kg (2.5%) - soil, dirt		
Biological/Disposable Diapers	9.61kg (10%) - diapers and bones		
Potential for Energy Recovery, Recyclable Waste and Compostable Waste%:	The waste contain high percentage of compostable items including food waste, garden waste and non-combustible inorganics, adding up to 57.4% of the total waste. Therefore Composting should be the first option of treating the waste. Percentage of Recyclable waste (paper, corrugated, hard plastic, glass and construction waste) is about 15%. RDF can be produced from approx. 25% of the waste.		
Possible Presence of Asbestos Containing Material:	**Y / N**	No obvious sign of asbestos contamination recorded during waste logging activity.	

Waste Characterization of Waste from Commercial Area

PMDFC - Waste Logging Sheet					
City:	Tahsil Muridka, District Shiekhupura		**Filled by:**	Ahsan Bela	
Zone ID:	Commercial Area		**Total Weight of Waste Analysed**	92.12 kg	
Odour: Y / N	**Olfactory Rating from 1 to 5: 1 (overall samples were not smelled significantly)**				
Presence of any Leachate/liquid waste:	Y / N	*No noticable liquid waste recorded in waste samples*			
Components	**Description and weight in kg (%)**				
Mixed paper	8.28 kg (9%) - paper bag, recipts, tissue, packing paper,				
Newsprint	1.26 kg (1.4%) - news paper				
Corrugated	8.39 kg (9.1%) - brown boxes, boxes for oil packets, drink boxes (jucies, milk etc.)				
Plastic	13.9 kg (15.1%) - shopping bags, crisp packets,				
PVC (Plastic) Hard Plastic	1.07 kg (1.2%) - disposable cutlery, plastic glass,				
Glass	2.89 kg (3.2%) - broken glass and bottle				
Aluminium	Nill				
Ferrous	Nill				
Other Organic/Combustibles (Textile, Leather etc)	5.29 kg (5.75%) - pieces of cloths, leather				
Wood	negligible				
Garden Waste	0.66 kg (0.7%) - leaves, thin branches				
Food Waste	31.53 kg (34.2%) - Fruite and Vegitable waste				
Construction Waste	Nill				
Other Inorganic - None Ferrous, none Aluminum metals	Nill				
Other Inorganic / Non-Combustibles -Fines and Inert	7.1 kg (7.7%) - soil, dust, mixture of waste flour and soil				
Biological/Disposable Diapers	11.7 kg (12.7%) - bones from food waste				
Potential for Energy Recovery, Recyclable Waste and Compostable Waste%:	Higher percentage of recyclable waste was detected including paper, glass and recyclable plastic (about 24% of total waste). Food waste (mainly comprising on fruit/vegitable waste) and non-combustible inorganic can be treated with aerobic composting and obtain good quality of compost. The approx. percentage of compostible waste is about 40%. RDF can be produced from remaining combustible and non-recyclable waste.				
Possible Presence of Asbestos Containing Material:		**Y / N**	No obvious sign of asbestos contamination recorded during waste logging activity.		



Unit Weight of Waste of each Zone

Zone	Weight of Composite Sample (kg)	Volume of Waste after 3 drops from 30cm (m^3)	Unit weight of Waste
Residential Without Lawn	4.17	0.02	208.5 kg/m^3
Residential with Lawn	6.79	0.035	194 kg/m^3
Commercial Area	4.58	0.040	114.5kg/m^3

Three types of tests including Calorific Value, Carbon Nitrogen ratio and Moisture Content tests were conducted by an approved laboratory from EPA Punjab. Services of Solution Environmental & Analytical Laboratory was hired for execution of above three tests.

Laboratory Based Waste Testing Results

Type of Test	Unit	Residential Zone without Lawn	Residential Zone with Lawn	Commercial Area
Calorific Value	MJ/Kg	22.3	15.0	28.7
C and N Ratio	-	52.64:1.98	33.1:0.46	48.2:1.25
Moisture Content	%	13.10	47.10	12.3

Results Analysis

Thickly Populated Residential Area: Data analysis and test results evaluate that about 50% of the waste from this zone is suitable for treating waste energy option and producing Refuse Derived Fuel (RDF) from the waste. The calorific value was measured at 22.3 MJ/Kg which is well above the required minimum value i.e. 8MJ/Kg by the International Solid Waste Association (ISWA). The waste also contains a higher percentage of green waste i.e. vegetable and fruit waste and can produce good quality compost using aerobic composting technique. A low percentage of recyclable waste was identified in the waste i.e. about 7% of total waste. This is mainly because

recyclable/valuable items are possibly segregated by the residents (waste producers) themselves and sold to the local vendors.

Carbon and Nitrogen Ratio (C&N ratio) of the waste (without recyclable waste) was detected to be 26 which is just within the recommended range for composting i.e. 25 – 35. Carbon sources (green/plant waste) may need to be added to obtain the optimum result of composting.

The moisture content was calculated to be 13.1%, which is well under the required range for composting, 40 – 60 percent. Water needs to be sprayed on waste for composting treatment. At lower moisture content, microbial activities become limited, if the moisture content is high, the process is likely to shift to anaerobic degradation and cause a foul smell.

The unit weight of waste was 208.5 kg/m3 which is higher than waste from other zones of the city. Therefore, comparatively smaller vehicles (from a volume point of view) may be required for the transportation of waste for this zone, unless a compactor is used which compacts the waste, and the waste's unit weight is irrelevant.

Loosely Populated Residential Area: The analysis of data and test results evaluate that the most suitable option for treating waste from this zone is aerobic composting. About 57% of waste was found suitable for producing good quality compost. However, the laboratory-based testing revealed that the C&N ratio is 71 which is well above the recommended range i.e. 25-35, and, therefore, nitrogen sources may need to be added e.g. chicken manure, cow dung, sludge from domestic wastewater treatment, etc. The moisture content was found 47.1% which is within the recommended range and no need for pre-treatment (drying or wetting) will be required.

About 15% of recyclable waste was identified in the waste from this zone and organized segregation of recyclable waste is recommended. A two-bin system may be introduced in this zone for the segregation of recyclable waste at the source i.e. at door step of the waste producer. However, it is important to launch a public awareness campaign in parallel for the success of the two-bin system at the start.

The calculated unit weight of the waste was 194 kg/m3, which is lower than waste from congested living areas, and, therefore, a comparatively bigger volume of containers and lorries will be required to transport similar tonnage of waste.

Commercial Area: The analysis of data and test results evaluate that the waste from this zone carries a high percentage of recyclable waste and comprises approx. 24% of total waste. Organized segregation of recyclable waste is highly recommended. A major chunk of recyclable waste is paper/corrugated waste and should be segregated at sources i.e. at shops, restaurants etc.

Developing different waste streams will save efforts/energy of segregating waste for particular treatments e.g. composting or Refuse Derived Fuel (RDF). Separate collection of fruit and vegetable waste from markets and shops and transporting it directly to the composting facility will be beneficial. About 40% of waste from commercial zones is suitable for composting. C&N ratio is acceptable; however, nitrogen sources may need to be added in small quantities. Moisture content is low and wetting of waste will require pre-treatment for composting.

The calorific value of the waste was also detected high. Plastic and animal bones (from restaurant waste) are good sources of RDF production.

The unit weight of waste from this zone is 114.5 kg/m3 which is lighter than waste from residential areas of the city. This is mainly because of the presence of a higher percentage of paper and plastic waste. However, the unit weight of waste varies a lot from place to place within the commercial zone e.g. vegetable/fruit waste does not contain much paper or plastic waste, and therefore the unit waste will be much higher than the calculated average unit weight i.e. 114.5 kg/m3.

Recommendation

To improve waste management practices in the city, a bespoke waste management plan needs to be furnished in light of the following recommendations:

Sr. No	City Zone	Recommendations
1	Residential Area without Lawn (congested living area), tentatively low per capita income	• Consider waste to energy option i.e. producing Refuse Derive Fuel (RDF) from the comparatively stable combustible organic or inorganic waste. It was determined that about 50% of waste is suitable for producing RDF. The measured Calorific value of the waste is also supporting this option. • About 40% of waste can be composted with an aerobic composting process. However, lower moisture content was recorded and therefore, pre-treatment in the shape of damping of waste may be required.
2	Residential Area with Lawn (open living area) comparatively high per capita income area	• More than 50% of waste is suitable for producing good quality compost with an aerobic composting process. Moisture content was recorded within the optimum range, however, nitrogen sources may require to be added as the waste was determined rich in carbon concentration (green waste). • Two-bin waste collection system clipped with a public awareness campaign may be introduced in the area as a higher percentage (about 15%) of recyclable waste was identified in the waste.
3	Commercial Area (mainly comprised of restaurants, food shops, garments and household stuff shops)	• Develop a separate waste stream for waste collection/transportation to minimize mixing of different waste and recycle paper, glass, and other recyclable waste. • Waste from vegetable and fruit markets should be collected

Sr. No	City Zone	Recommendations
		separately and transported directly to the composting treatment facility. • Calculated Calorific value is also high and plastic waste + restaurant's waste (including a high percentage of bones) may be treated for producing RDF.

Additional investigations are also recommended particularly to determine the *seasonal impact* on waste generation and composition by conducting second phase of the study during the winter season. Further, laboratory-based testing is also recommended to raise confidence levels on the calorific value and moisture content test results of the waste.