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Municipal Solid Waste Composition Analysis and Its Importance: A Case of Kanpur

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***Abstract*: The generation of Municipal Solid Waste is getting increased day by day with economic growth, urbanisation and rising population. With 160,039 tonnes per day municipal solid waste getting generated in India and nearly 49.96 % of this waste getting treated, problem as well as scope for efficient management are enormous. There is still a huge gap in processing capacities at city level. Municipal solid waste management sector faces major challenge in India as many cities don't know what their waste composition is, for which they need to have processing facilities. Since MSW characteristics change with geography, economics, season, habits, policies, social behaviour, extent of recycling, and many other factors, it becomes very important and the foremost step for a city to trace the change in municipal solid waste composition and adopt strategies accordingly.**

Cities also lack much clarity and guidance on conducting waste composition and characterisation, since there are neither much common standards available to them nor any regulatory requirement to conduct such studies. In this paper, authors bring out the method of waste sampling and characterisation that was followed over 06 days at transfer stations in Kanpur, Uttar Pradesh, which can easily be adopted by other cities to establish baseline information and take better and informed decisions. The results of the municipal solid waste characterisation study targeting 72 subcategories of waste indicated organic food waste as 43.34%, non-biodegradables as 27.38%, construction and demolition waste as 4.61%, domestic hazardous waste as 6.76%, and fines or inerts as 16.19%.

The outcomes will not only help a city in finetuning the strategies for MSW management with waste composition study, but also help a city understand the procedure and steps involved in conducting such study on ground. This will help formulate strategies by state and national governments as well.

***Keywords:* Solid Waste Management, Waste Characterisation, Plastic waste, Organic waste, Circular economy, Material recovery facility**

I. INTRODUCTION

The generation of Municipal Solid Waste (MSW) is getting increased day by day with economic growth, increasing urbanisation and rising population [1]. In 2016, the worlds' cities generated 2.01 x 109 tonnes of solid waste, amounting to a per capita generation of 0.74 kg per day[1]. It is very evident from data's across the globe that as gross domestic product of a region rise, waste generation rates also increase [2]. The concern is serious, since annual waste generation is expected to increase by 70% from 2016 levels to 3.40 x 109 tonnes by 2050 [1]. High-income countries generate more solid waste than low or middle-income countries [3] The per capita waste generation rates of USA and Canada in 2018 were 2.58 kg per day and 2.33 kg per day respectively, making them the highest per capita generators of municipal solid waste in the world [4]. India's per capita waste generation varies from 0.2 kg per day to 0.6 kg per day in cities with populations from 0.1-5.0 million and it is increasing by 1.3% every year [5].

Issues related to inappropriate management of municipal solid waste span from local to global scale [6]. India's solid Waste disposal alone contributed 15,832,000 Tonne CO2 eq in 2016 towards Global warming through disposal of mismanaged biodegradable waste. Mismanaged waste from cities also lead to marine litter leakage of non-biodegradable waste from cities [7]. Improper waste management also cause more than 22 types of diseases [8], impacts social wellbeing. Overall, deteriorating the environment and impacting everyone around us. Waste management also has linkages with sustainable development goals (SDGs). Plastics entering marine environment originating from land-based activities, directly impacts SDG 14, and municipal solid waste management impacts directly on sustainable development goals (SDG) 6, 11, and 17 and indirect on SDG 5, 8, 9, and 12.

With 160,039 tonnes per day municipal solid waste getting generated in urban India, nearly 95.44% is collected and 49.96 % of generated waste gets treated [9]. The per capita waste generation of each city varies, and so does waste characteristics. The problem as well as scope for efficient management are enormous. Over and above cities are not aware of composition of waste they generate. In general, as per a study, conducted way back in 2005 by Central Pollution Control Board (CPCB) and National Environmental Engineering Research Institute (NEERI), municipal solid waste comprised of 51.3% compostable and 17.48% recyclables [10]. There has been no such study in recent past which establishes average waste characteristics of Indian cities [11]. Surprisingly, the "national action plans for solid waste management 2016" developed by central pollution control board was even backed by the 2005 study done by National Environmental Engineering Research Institute.

Several studies have been caried out across the globe to understand waste composition and characteristics, to help

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design effective systems for managing municipal solid waste [12]. However, solid waste management sector faces major challenge in India as many cities don't know what their current waste composition is, for which they need to have processing capacities, with appropriate technology [13]. This is also one of the reasons why many projects in solid waste management processing have failed in past. Further, physical composition of waste also needs to be determined appropriately, to match the processing demands for a city, in terms of capacities of material recovery facility, processing facilities for organic waste generated, linkups for domestic hazardous waste generated etc [1].

The characteristics of MSW change with geography, economics, seasonal, habits, policies, social behaviour, extent of recycling, and many other factors [1]. It becomes utmost important and the foremost step for a city to trace the change in MSW characterisation and adopt better informed strategies, to make processing and handling facilities efficient and sustainable. However, cities in India lack much clarity and guidance on conducting waste composition and characterisation, since there are not much common standards available to them [14].

The characterisation study by NEERI also reflect only broad category of waste, whereas city material recover facilities (MRFs) need clarity on different category and sub-category of waste which may be linked with markets. To fill-up this gap in the sector, this paper presents the municipal solid waste characterisation method that was followed at Kanpur, Uttar Pradesh to understand characteristics of waste reaching transfer stations in the city. Though, characteristics of waste will change from generating source till point of its disposal (due to ragpickers), transfer stations were strategically chosen to understand the characteristics of waste reaching at these secondary collection points, as material recovery facilities are required to be setup at this location, in near future. The intention of this characterisation study was also to help the city of Kanpur in conducting pre-feasibility study for setting up a material recovery facility in each zone.

Earlier study conducted under the project helped in identifying the material category and sub-category which are desired as outcomes from material recovery facilities, to understand availability of resources from the city and align the outputs for market linkages. This is first of its kind of study in India, which tracks as many as 72 categories as well as variations across 06 administrative zones throughout the city. This paper will be beneficial for other cities in establishing waste composition baseline and take better and informed waste management decisions across the country. Researchers, students, policy makers, scientists, waste management professionals will also be benefited through the methodology and outcomes depicted in this paper. Further, this will be beneficial for states and national level in making informed decisions to reduce Greenhouse gas (GHG) emissions and marine litter- moving towards achievement of Sustainable Development Goals. This paper will also help in preparing standard operating procedures in the country to undertake waste composition and help in developing waste management sector through better available data.

With an estimated population of 3.123 x 106 (as of 2021), the city of Kanpur is also the largest urban agglomeration in the state of Uttar Pradesh and the 11th most populous urban city in India, is one of the largest urban centres along the Ganga river system. Between 2013 and 2019 the per day municipal solid generation rate in the city has increased from 919 to around 1430 tonnes [15]. City has 06 zones with each zone having a waste transfer station. Although accurate, verifiable data is lacking, it is observed that the current system achieves a daily waste collection rate of around 79%. Of the total waste generated 12% to 14% is collected via door-to-door collection provided by Kanpur Nagar Nigam, private service providers engaged by city administration and a local Non-government organisations. The remaining collection coverage is achieved by informal waste pickers collecting recyclables and Nagar Nigam / contractors providing point-to-point collection from 3000+ community bins / areas, 130 secondary collection / transfer points and 6 transfer stations.

Kanpur generates 858 metric tonne (MT) household waste, 283 MT commercial waste, 286 MT street sweeping waste, and 3 MT waste from Ganga Ghats. Collection via door-to-door collectors and primary collection vehicles is about 260 MT, whereas 642 MT is collected via community bins. Street sweeping waste is entirely collected via primary collection vehicles. Besides this informal sector collects around 20 MT waste for recycling from door to door/ primary collection spots.

Of the 1,130 MT waste collected, around 60% is handled via secondary collection points managed by Nagar Nigam, 24% is collected via secondary collection points managed by private operators and remaining 16% is collected via transfer stations. Nearly 70 MT more recyclables are extracted from these points. Of total collection, around 1,060 reaches processing platforms and 635 MT is processed via composting, 396 MT mixed waste and 294 MT inert waste is sent for landfilling. As a product, 40 MT compost is generated from the city. Around 120 MT light combustible fraction is sent as refuse derived fuel to cement plants, 90 MT waste is sent for recycling. Figure 1 details out the waste material flow and its management in Kanpur across various functional elements.

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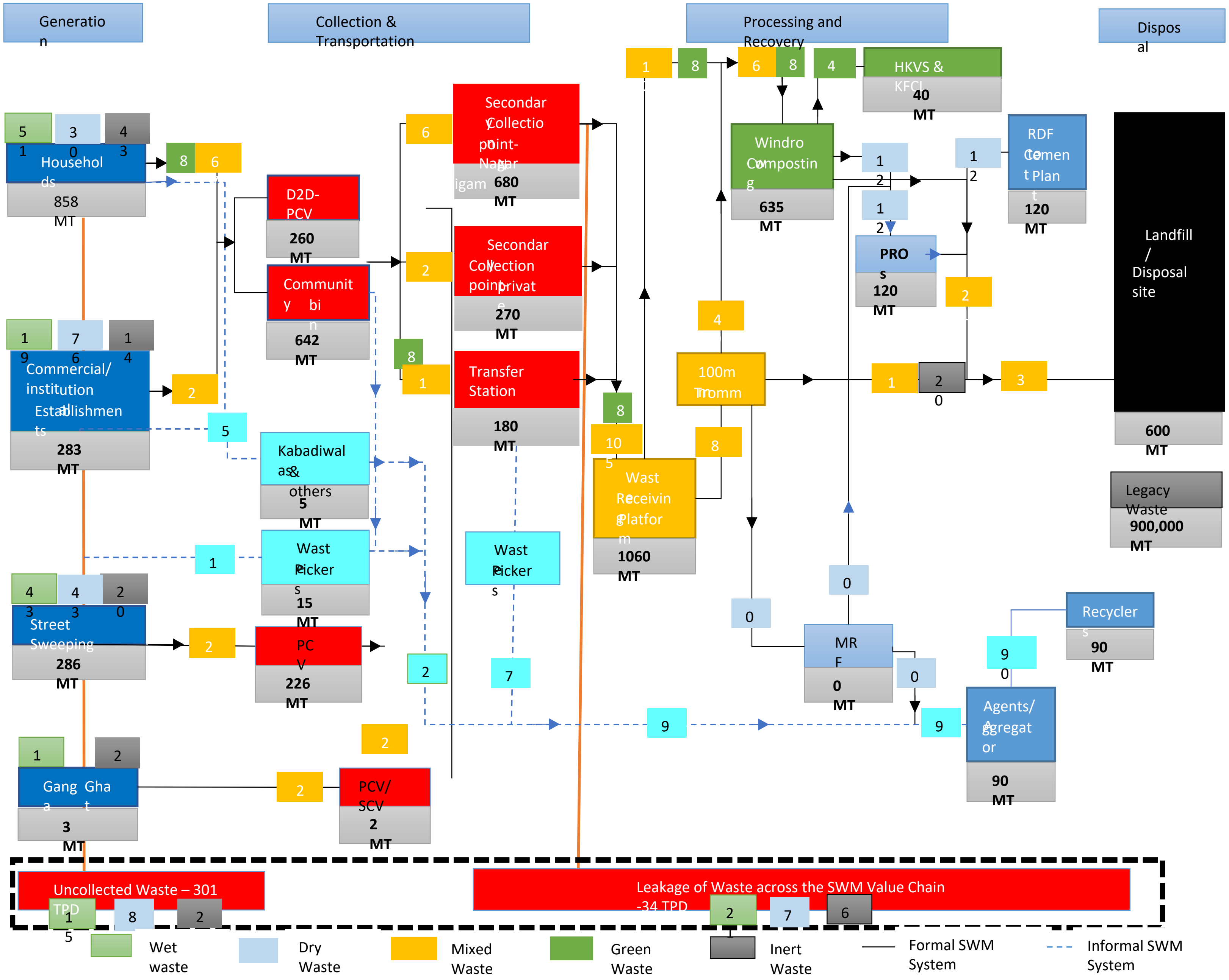

Figure 1 Waste flow diagram for Kanpur Nagar Nigam (Units in Metric Tonnes)

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II. MATERIAL AND METHOD

As per an earlier studies conducted in Kanpur in year 2006 the MSW composition indicated 47 – 56% organics, 3.18-3.58% paper, 0.48-2.72% Rubber, leather and synthetics, 4.5% plastics, 3.97% rags, 0.48% glass, 0.24 – 0.59% metal and 38.82 - 40.07 % inert materials [16]. The studies were not relevant for analysing management strategies for MSW management in Kanpur.

Kanpur Nagar Nigam, wanted to establish decentralised Material recovery facilities associated with each transfer station to help manage resource much more efficiently and achieve circular economy in waste management. Since the characteristics of waste reaching to transfer stations in city of Kanpur was not well established, a study was conceived. Number of samples for waste characterisation study was determined using statistical analysis. Due to limitation of resources and constraint of time under the project, the study adopted a confidence level of 80% with 20% acceptable margin of error using formula given in equation 1.

$$n = \frac{z^2 \times p(1-p)}{\epsilon^2} \qquad (1)$$

Where,

z is the z score, 1.282 for confidence level of 80% (as per Z table value for Confidence Intervals)

ϵ is the margin of error, 0.2

n is the sample size for infinite population

p is the population proportion generally adapted at 0.5

$$n = \frac{1.282^2 \times 0.5(1-0.5)}{0.2^2} = 10.27 \ \ say \ 11$$

Since the corporation of Kanpur wanted to establish decentralised material recovery facilities at each zone, samples were equally distributed among the six transfer stations. Two samples for each transfer stations were derived, making the total number of samples as twelve.

Field survey was conducted with the support from and city contractor managing transfer stations. Prior to the study, adequate approvals were taken from Kanpur Nagar Nigam. The sampling plan was derived in accordance with vehicle trips coming from residential, institutional and commercial areas to truly represent the waste arriving at each of the transfer station, as indicated in Table 2.

Materials required for conducting the waste characterisation on site included tools and equipment's as stated in table 1 below.

Table 1: Materials required for conducting onsite waste characterisation study

S.N.	Material/PPEs used during study	Quantity	Remarks
Materials			
1	Dustbin*Large	5 #	60 liters
2	Dustbin*small	30 #	30 liters
3	Garbage bags	25 pcs	1 pack contains 30 garbage bags
4	Sorting Table/ platform	1 #	2 m x 4 m
5	Chair/stool	7 #	As per number of staff
6	Weighing machine	1	Least count 10 gms max 100 kgs
7	Polythene	1#	8m*1.5m| Used for spreading out on table
8	Shovel	1	For quartering and waste collection
9	Broom	1	For housekeeping
10	Dust Pan	1	For housekeeping
11	Duster cloth	2	For housekeeping
12	Knife/Cutter	1	For cutting ropes/ tied waste packs
Personal Protective Equipment's			
1	Safety Gloves*Latex	150 pair	As per need
2	Safety Gloves*Cotton	20	Plastic coated gloves
3	Safety mask (N95)	20	One per person per day
4	Safety mask (Surgical)	120	Four per person per day
5	Safety goggles	10	One per person
6	Safety vest (Reflective jackets)	10	One per person
7	Shoe cover	150	Four per person per day
8	Head cap	150	Four per person per day
9	Hand Sanitizer Liquid	3 Bottle	500 ML per bottle
10	Hand Sanitizer Gel	2	200 ML per bottle
11	Hand wash	1	250 ML
12	First Aid kit	1	
13	Tissue paper	4 box	200 pulls per box

Twelve samples in weight range of 90 – 110 kgs each were collected for analysis. This selection of sample was based on configuration of waste sources served by each transfer station. For example, since zone 1 was receiving waste via 40 tipping vehicles, with 25 trips from commercial area and 15 trips from residential area. Samples were selected from one vehicle coming from residential area, and one vehicle from commercial area. This helped in keeping the analysis justified and representative of the waste received at transfer station. Table 2 highlights the size of sample and location. The configuration of waste coming to transfer stations (residential/commercial) helped in understanding the type of waste sample to be taken up for analysis.

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Table 2: Details of samples collected during waste characterisation study at Kanpur

Zone name (Zone No)	Transfer station Location	Date of field work	Sample size Net weight =Gross weight – tare weight (kg)		Remarks
			Sample 01	Sample 02	
Bhagwat Das Ghat (01)	Phool Bagh	11-01-2022	109.18	95.43	40 trips, 25 from commercial and 15 from residential, therefore selected 1 sample from commercial and 1 from residential.
Krishna Nagar (02)	Krishna Nagar	12-01-2022	97.640	114.620	100 – 100 trips, 10 from commercial and 90 – 100 from residential, therefore selected both samples from residential.
Karrahai (03)	Karrahai	13-01-2022	95.44	98.35	75 – 80 trips, 15 – 20 from commercial and 60 from residential, therefore selected both samples from residential.
Chunniganj (04)	Chunniganj	10-01-2022	100.83	112.30	45 – 50 trips, 5 – 10 from commercial and 35 – 40 from residential, therefore selected both samples from residential.
Janta Nagar (05)	Janta Nagar	14-01-2022	94.41	108.03	40 trips, mixed commercial and residential, therefore selected both samples mixed.
Panki (06)	Panki	15-01-2022	98.72	90.920	120 trips, 10 from commercial and 120 from residential, therefore selected both samples from residential.

The waste brought to transfer station via tippers was unloaded, mixed and quartered and then transferred into pre-weighed plastic trash bins until the target sample weight (90-110 kg) was reached. Waste from these bins was then transferred to the sorting table and hand-sorted into material categories and subcategories.

The steps followed for the sorting of waste samples included:

STEP 1: A precise location was selected at each transfer station to place the sorting table and weigh scale.

STEP 2: Appropriate personal protective equipment's including puncture resistant gloves, eye glasses, safety jackets, head caps, N95 and 3 layer masks and safety boots were provided to each team member.

STEP 3: Site was prepared, the location was cleaned for setting up the sorting tables (with cover sheet), and other necessary equipment like showels, knifes, sanitisers, plastic bins (around 10# of 60 liter capacity and 45# of 30 liter capacity), waste bags (17 #) were also placed appropriately.

STEP 4: The waste containers/bags used for collecting different waste types were marked with serial numbers and empty weights were recorded everyday (to mark tare weights on specific data sheet). This helped in eliminating errors due to broken bins or sticked materials to bins.

STEP 5: Total 72 pre-weighed bins/bags were kept around the sorting table for depositing the sorted material into different material types.

STEP 6: A sample of 90-110 kgs, as per standard test method [ASTM D 5231:92 (reapproved 2003)] was collected from fresh waste arriving the transfer station using quartering method for determination of composition of unprocessed MSW. This was ensured by weighing the filled bins before unloading them onto sorting tables.

STEP 7: 5 number of bins of 60 liter were initially used to collect the fresh waste sample and transferring it to tables.

STEP 8: Each team member (from team of 08 members) was given responsibility to segregate and collect 2-3 categories of waste materials, along with its subcategories.

STEP 9: The received waste samples were spread out on the sorting table, hand sorted by the team members and collected in bins assigned for different material categories.

STEP 10: Once sorting was done for a sample and no visual traces of any other material category were observed, the remaining sample was swept into the 'Fines' fraction for it to be accounted in others category.

STEP 11: The waste containers with the sorted material were weighed on a calibrated scale to obtain gross weights. These weights were recorded in the waste sample record sheet for each sample and net weight of each sorted category, correct up to two significant digits, was obtained by subtracting the tare weight (recorded in step 3) of each bin from the gross weight

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$$Net\ Weight\ (kg) = Gross\ Weight\ of\ bucket\ with\ waste(kg) - Tare\ weight\ of\ bucket(kg) \quad (2)$$

$$Percentage\ (\%) = \frac{Net\ Weight\ of\ a\ specific\ material\ (kg)}{Net\ Weight\ of\ Total\ Sample\ (kg)}\ x\ 100 \quad (3)$$

STEP 12: At the end of each waste characterisation, the segregated recyclables/materials were disposed of (or diverted to recyclers) as per directions from study team or KNN officials. Site was cleaned and sorting table was prepared for next sample. Overall, 02 samples were collected from one transfer station. Next day, new transfer station was targeted for characterisation.

STEP 13: Once data was received, analysis in terms of mean and standard deviation in data was conducted.

$$Mean\ of\ Value, \bar{x} = \frac{x1+x2+x3+\cdots xn}{n} \quad (4)$$

Where, n is the number of samples

x1, x2, x3 are weights of same material category in different samples

$$Standard\ deviation, s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(xi - \bar{x})^2} \quad (5)$$

Where, s = Sample standard deviation

n = Number of observations in sample

xi = i^{th} observation in the sample

$\bar{x}$ = Mean of the sample

III RESULTS AND DISCUSSION

The sample were analysed for overall 13 broad categories and overall, 72 subcategories of waste to understand the characteristics of waste coming at secondary collection points (transfer stations). The findings indicated plastics as 12.19%, paper and cardboard as 8%, metal as 0.42%, glass as 0.54%, rubber and tyre as 1.37%, e-waste as 0.23%, Textile as 4.63%, other non-biodegradable including used beverage cartons, leather, coconut shells, ceramic, wood , hair as 1.69% and c&d waste as 4.59%, organics as 43.6%, domestic hazardous waste as 7% (including 5.75% alone coming from sanitary waste), fines including inerts as 16.19%. The results from 06 zones and overall waste are reflected on table 2 below.

The analysis in various zones clearly reflected variation in characteristics within the city zones. The phool bagh-Bhagwat ghat (zone 1) which is one of the high-income areas of the city had highest quantity of plastics and lowest quantity of organics coming out to secondary collection point, compared to other zones.

Table 3: Composition and variation of waste characteristics over various zones in Kanpur

Waste Categories	Composition (%)						
	Zone 1-	Zone 2-	Zone 3-	Zone 4	Zone 5-	Zone 6	Average
Plastic	15.38	12.95	9.32	12.88	11.54	10.19	12.19
Paper & Cardboard	14.31	4.34	3.12	15.00	4.56	5.45	8.00
Metal	0.61	0.22	0.15	0.66	0.31	0.54	0.42
Glass	0.99	0.36	0.15	0.53	0.72	0.46	0.54
Rubber and tyre	5.06	0.36	0.16	0.25	0.98	1.06	1.37
E-waste	0.09	0.11	0.13	0.56	0.33	0.12	0.23
Textile	4.44	8.75	3.94	1.67	4.59	4.37	4.63
Other Non-Biodegradable materials	1.29	1.29	1.47	2.44	1.18	2.66	1.73
C&D waste (including earthen pots)	2.10	9.76	2.53	3.31	7.52	2.56	4.61
Organics	34.19	35.40	50.25	45.29	45.04	53.57	43.34
Domestic Hazardous Waste	3.60	8.34	9.44	3.96	6.76	8.49	6.76
Fines (combined with organics, dirt and miscellaneous materials less than 5 cm)	17.95	18.11	19.33	13.41	16.47	10.55	16.19
Others(to be defined)	0.00	0.00	0.00	0.02	0.00	0.00	0.00

Looking at the type of plastics coming to transfer stations, the highest quantity of subcategory of plastics reaching secondary collection points is attributed by low density polyethylene (LDPE) less than 60 micron (close to 49%), which is a low value plastic and often not recycled. This indicated low impact of single use plastic ban in the city in January 2022. Similarly, multilayer plastic consisted of nearly 16% of total plastics reaching secondary collection points. Polyethylene terephthalate (PET) bottles reaching transfer stations were only 1% by weight, and high-density polyethylene (HDPE) was not found, this was due to high value of PET bottles and HDPE in the local recycling market. HDPE milk pouches were around 5%, this was due to the fact that intra segregation levels were low and the team could trace LDPE bags tied up with all types of dry waste thrown in waste, indicating the need to have awareness and deposit return schemes for the city. Figure 2 indicates configuration of plastics generated from the city.

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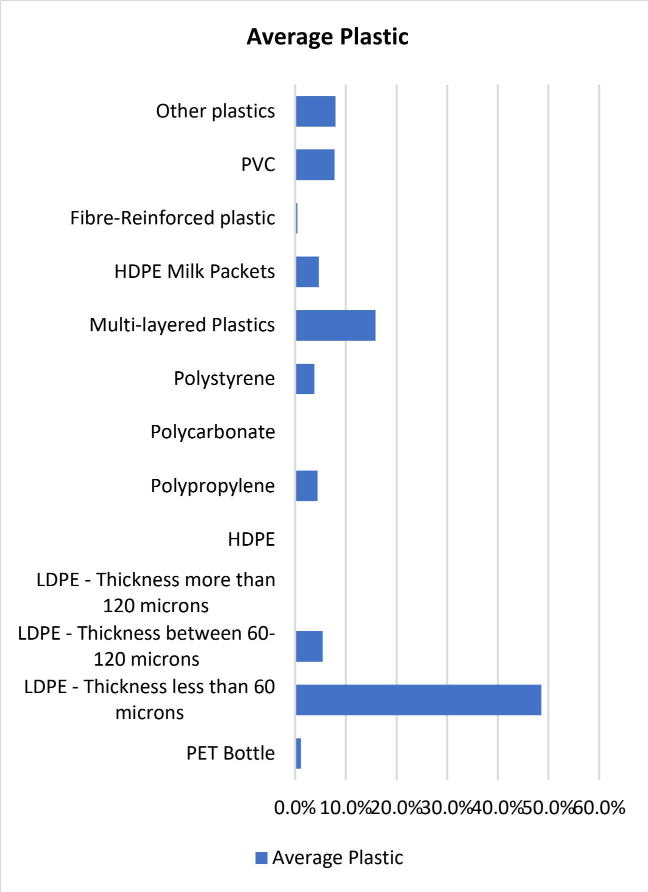

Figure 2: Average plastic waste composition reaching transfer stations in Kanpur

The overall waste characterisation study clearly reflected low value recyclables (6.5% LDPE, 0.5% polystyrene, 1% Polyvinyl chloride etc.) reaching transfer stations with a high amount (~44%) of organics. 5.76% Sanitary waste, and 1% domestic hazardous waste. Indicating a need for the city to develop appropriate strategies and models to deploy material recover facilities. The characterisation study overall helped in designing appropriate pre-feasibility studies for material recovery facilities with suitable business models. Table 3 below highlights all 72 subcategories of waste, the mean and standard deviation of each waste subcategories (w.r to all 12 samples) reaching transfer stations, which can be used by other cities to understand its waste composition.

Table 4 Kanpur waste characterisation data (10-15 January 2022)

S.N.	Waste categories	Waste sub-categories	Mean	Standard deviation
1	Plastic	PET Bottle	0.138%	0.17
2		Low-density polyethylene (LDPE) - Thickness less than 60 microns	5.846%	1.70
3		Low-density polyethylene (LDPE) - Thickness between 60-120 microns	0.636%	1.00
4		Low-density polyethylene (LDPE) - Thickness more than 120 microns	0.000%	0.00
5		High-density polyethylene (HDPE)	0.000%	0.00
6		Polypropylene	0.526%	0.30
7		Polycarbonate	0.000%	0.00
8		Polystyrene	0.444%	0.78
9		Multi-layered Plastics	1.897%	0.97
10		HDPE Milk Packets	0.573%	0.31
11		Fibre-Reinforced plastic	0.052%	0.11
12		Poly vinyl chloride (PVC)	0.983%	2.78
13		Other plastics	0.983%	0.59
14	Paper & Cardboard	Newspaper	1.866%	0.96
15		White Paper	0.474%	0.40
16		Colored Paper	0.217%	0.22
17		Books	0.062%	0.14
18		Magazines	0.000%	0.00
19		Cardboard- 3 ply	0.451%	0.42
20		Cardboard-5 ply	0.018%	0.06
21		Duplex board	1.728%	1.00
22		Other paper and cardboards	3.090%	4.63
23	Metals	Metal	0.000%	0.00
24		Iron	0.137%	0.11
25		Steel	0.059%	0.19
26		Aluminium	0.204%	0.20
27		Zinc	0.000%	0.00
28		Brass	0.000%	0.00
29		Copper	0.004%	0.01
30		Tin	0.017%	0.03
31		Other Metal	0.001%	0.00
32	Glass	Plain Glass	0.000%	0.00
33		Colored Glass	0.009%	0.02
34		Mirror	0.044%	0.15
35		Glass cullet (Broken glass)	0.475%	0.40
36		Other Glass	0.000%	0.00

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S.N.	Waste categories	Waste sub-categories	Mean	Standard deviation
37	Rubber And Tyre	2 & 3-wheeler tyre	0.000%	0.00
38		4-wheeler passenger	0.000%	0.00
39		4-wheeler commercial	0.000%	0.00
40		Rubber - Chappal	0.091%	0.13
41		Rubber - Gloves	0.000%	0.00
42		Rubber - Tubes	0.007%	0.02
43		Rubber - Shoe Bottoms	0.268%	0.53
44		Other rubber and tyre	0.965%	2.96
45	E-waste	Batteries-Lithium Ion	0.058%	0.10
46		Batteries-Conventional	0.000%	0.00
47		Wires	0.025%	0.03
48		Electrical Appliances	0.079%	0.12
49		Cell Phones	0.000%	0.00
50		Laptops	0.000%	0.00
51		Other e-waste	0.061%	0.13
52	Textile	Rags	1.277%	0.59
53		Clothes	3.143%	2.22
54		Other textile	0.214%	0.41
55	Other non-biodegradable materials	Used Beverage Cartons	0.055%	0.07
56		Leather	0.050%	0.17
57		Coconut Shell	0.647%	0.83
58		Ceramic	0.164%	0.25
59		Wood (Engineering wood)	0.785%	0.61
60		Hair - Length more than 6 inch	0.007%	0.01
61		Hair - Length less than 6 inch	0.043%	0.06
62	C&D Waste	C&D waste (including earthen pots)	4.593%	5.58
63	Organics	Food waste	40.817%	15.31
64		Green garden waste	1.969%	1.68
65		Wood waste (Tree branches etc)	0.254%	0.42
66		Other biodegradables	0.575%	1.57
67	Sanitary waste	Sanitary waste - diapers	5.259%	2.54
68		Sanitary waste - sanitary pads	0.502%	0.53
69	Other domestic hazardous waste	Bio-medical waste (generated from households)	0.527%	0.32
70		Other domestic hazardous waste	0.480%	0.40
71	Others	Fines (Unsortable small fragments (generally less than 5 cm or less in diameter); mainly composed of organic material and miscellaneous fines and dirt)	16.148%	8.30
72		Others (to be defined)	0.004%	0.01

The sample collection exercise in Kanpur, helped in understanding the waste profile as well as also reflected level of segregation and awareness among its residents. The team carrying out sampling at site could easily understand that city is getting mixed waste through door-to-door collection and citizens experience low source segregation. This is also the reason for having high quantity of fines (~16%) during segregation of materials on segregation tables. The segregation and analysis which indicated nearly 5.76% sanitary waste and 1% domestic hazardous waste gave an indication to city administration to have appropriate linkages for sanitary waste and domestic hazardous waste. This was stream has been drastically increasing in all cities. The analysis of recyclables that would reach the upcoming MRFs to be linked with each zone, reflects the type of waste that material recovery facility operator can expect at each site. Thus, helping not only the operator to understand the feasible mode of operation, but also helping city to understand what all materials should be linked with markets from the city material recovery facilities. This study helped the project in preparing pre-feasibility and sustainable economic model for an upcoming decentralised material recovery facility. This helped to understand the size and capacity of processing units for various category materials and required infrastructure.

IV CONCLUSION

In this paper, authors bring out the method of municipal solid waste sampling and characterisation that could be easily performed on site by any city. This method can easily be adopted by other researchers, professionals, and students to understand waste composition of cities and

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plan its appropriate management. This can easily help cities to understand the economics and pre-feasibility for establishing decentralised or centralised MRFs in urban areas and even identify market linkages for potential items which a city generates. This process can further be aided with digital platforms and established marketplaces, for making operations of processing units (including MRFs) even more sustainable.

The characterisation method clearly reflects using 72 sub-categories while planning, since these were different items demanded by various recyclers/ processors in the market. However, recyclers also demanded these materials in varying colours, conditions and packaging while MRFs offer materials to market. Cities should feel free to add more categories/sub-categories, in case there are specific recyclables demanded in the region. The sample size (90-110 kgs) also has an important role here, since all analysis were conducted on site itself. This study was limited to only 12 samples from transfer stations following 80% confidence level and 20% acceptable margin of error, due to limited funding resources. However, a large city should follow 90% confidence level and 10% acceptable margin of error to get accurate results.

The waste characterisation study can even be made more robust with involvement of proximate analysis of MSW. In case a city can get proximate analysis and identify moisture, fixed carbon and ash content of each waste category/sub category, this can really help understand the processing rejects and actual dry weight of recyclable contents. Even modelling exercises in the country which uses such data to estimate GHG emissions can be taken up to next tier, with close estimations of actual emissions. With mixed waste received at transfer stations in Kanpur, there was a lot of moisture which was absorbed by paper and other dry materials, possibly, with moisture content determination, the possible errors in findings of the study can also be reduced.

Such characterisation studies in cities help finetune waste management strategies, as well as identify linkages for untapped resources. Further, helping city to route materials back to circular economy loops. This also help achieve sustainable development Goals (SDGs) including SDG 14 which is directly linked with marine litter issues, and other SDGs 5,6,8,9,11,12,14 and 17.

There is a further need to conduct such studies in different season of the year and well as in different years to understand the variation and plan strategies better. Thus, helping cities achieve the goal of Swachh Bharat Mission 2.0 and become garbage free.

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