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`Municipal Solid Waste Characterization and Quantification towards Effective Waste Management in Faridabad and Gurugram City, Haryana, India

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Abstract—*In India, the collection, transportation and disposal of MSW is unscientific. Urbanization contributes enhanced municipal solid waste (MSW) generation and unscientific handling of MSW degrades the urban environment and causes health hazards.*

The purpose of this research was to study the effects of four socio-economic characteristics (age, level of income, education, and occupation) of district residents on their attitudes, practices, and behavior regarding solid waste generation and to suggest the improvements in present waste management system in your city. An analysis of social factors affecting the quantity and composition of household solid wastes is reported in this paper.

Per household quantities of six hundred sixty seven household solid waste components are analyzed. Age, level of income, education and occupation are the major variables affecting the quantities of these components. The results indicate that among these solid waste components (leather, metals, plastics, organic matter, paper, rubber, and textiles) organic matter quantity is found to be at the top.

1. INTRODUCTION

1.1 Background

In every urban center, huge quantity of solid waste is generated during various activities. These wastes are to be stored, collected, transported, processed and disposed of in an environment friendly manner, so as to keep the city neat and clean. In spite of incurring huge expenditure, the services that are provided to the solid waste management are not fulfilling the requirement, causing public health hazards and nuisance.

Hence, there is a strong need to develop appropriate technology for the proper management of urban solid wastes. Solid waste management is a large, ongoing, vital public system spread over the entire city area and the system is responsible for maintaining the public surroundings. Hence, the system has to be planned rationally for a long and short term. Moreover, as the system handles huge quantities of solid waste, it is necessary to have detailed information on quantification and characterization of solid waste for proper handling of solid waste at different stages of the system. Presently, majority of Municipal Corporations/ Councils do not weigh their waste but the quantities are estimated on the basis of number of trips of trucks which carry the waste to disposal site. Moreover, the solid waste management system is not planned or executed rationally due to non-availability of authentic or relevant information on waste generation. As the solid waste quantities are increasing in all cities and towns due to urbanization and industrialization, these have raised concerns about the economic viability and environmental compatibility of the current waste management methodologies.

India is rapidly shifting from agricultural-based nation to industrial and services-oriented country. Municipal solid waste management (MSWM), a critical element towards sustainable metropolitan development, comprises segregation, storage, collection, relocation, carry-age, processing, and disposal of solid waste to minimize its adverse impact on environment. Unmanaged MSW becomes a factor for propagation of innumerable ailments (Kumar et al., 2009).In the developed countries, solid waste management (SWM) belongs to prominent thrust areas for pursuing research (Dijkgraaf & Gradus, 2004; Ferrara & Missions, 2005) and economic and technological advancements have initiated responsiveness of stakeholders towards it (Shekdar, 2009). High population growth rates, rapidly varying waste characterization and generation patterns, growing urbanization and industrialization in developing countries (Troschinetz & Mihelcic, 2009) are the important reasons for paying attention towards MSWM as more area is required to accommodate waste (Idris, Inane, & Hassan, 2004).Several studies suggest that reutilizing of solid waste is not only a viable option to MSWM (Kasseva& Mbuligwe, 2000; Sudhir, Muraleedharan, & Srinivasan, 1996) but also desirable—socially, economically, and environmentally (Kaseva & Gupta, 1996; Misra & Pandey, 2005; Schoot Uiterkamp, Azadi, & Ho, 2011). One of the significant problems in urban India is almost no segregation of

MSW and disposal of construction and demolition debris (C&D), plastic wastes, commercial and industrial refuses, and e-waste (Buenrostro & Bocco, 2003; CPCB, 2000a; Position paper on the solid waste management sector in India, 2009).

Annually, about 12 million tonnes of inert waste are generated in India from street sweeping and C&D waste and in the landfill sites, it occupies about one-third of total MSW. In India, MSWM is governed by Municipal Solid Waste (Management and Handling) Rules, 2000 (MSWR) and implementation of MSWR is a major concern of urban local bodies (ULBs) across the country.

1.2 Objective of the study

The objective of the present study is as:

- Demographic survey of the study area
- Characterisation and Quantification of solid waste generation of the study area and comparison of the same

2. LITERATURE REVIEW

India, being the world's second highest populated country and one of the fastest urbanizing countries is facing the problem of solid waste management. Solid waste generated in India is 1, 27, 486 TPD or 46.5 million tonnes per year as per 2012 status [1] and is expected to increase to 300 million tonnes per year by 2047 [2] thus increasing by 545% in 35 years. The estimated land requirement for disposal of such huge quantum of waste would be 169.6 km2. Out of the total waste generated in the country 89, 334 tonnes (70%) is collected, 15, 881 tonnes (12.50%) is being treated while 22, 271 tonnes (17.5%) is not being collected [1]. The efficiency of solid waste management depends on collection, segregation and transportation of solid waste [3]. In most of the cities, house-to-house collection and segregation are not fully practiced. There is a large gap in between waste collection and processing [4]. The average collection efficiency for MSW in Indian cities is about 72.5% and around 70% of the cities lack adequate waste transport capacities [5].

The Calorific value may vary from 800 kcal/kg to 1000 kcal/kg and density from 330 kg/m3 to 560 kg/m3 [6]. The per capita waste generation ranges from 100 gm to 500 gm based on population of locality [7]. However, the range of per capita generation in India is reported [8] as 0.3-0.6 kg/cap/day. Composting, vermicomposting, biogas plant, RDF – palletization are the recovery techniques adopted in the country [9]. In India only 7% of the total solid waste collected is composted [10]. Out of the 369 compost plants in India, 177 plants are in operation and 192 are being planned for construction. Goa is operating the maximum number of compost plants (34) in India. Most of the municipalities have no sanitary landfill facility and follow dumping for disposal of MSW [1]. Based on the studies compiled by CPCB in 2011, 59 landfills are constructed in the country, 376 landfills are planned and 1305 landfill sites are identified for future use. Delhi is generating a solid waste of 6000-8000 TPD @ 0.5 kg/capita/day with a biodegradable content of 38.6%, inert content of 31.7% with an overall moisture content of 43% [11]. Municipal Corporation of Delhi (MCD) has established various composting plants with a capacity of 1525 TPD in a total area of 28.7 hectares by using aerobic windrow composting technique.

Currently, only 10-15% of solid waste collected is being composted in Delhi with a conversion efficiency of 20% [10]. The compost that is generated is being sold @ Rs 2400-3000 per tonne [10]. The Government of Delhi also gave permission for 3 new plants for conversion of solid waste into electricity with a total capacity of 66 MW. Kolkata city generates approximately 5114.76 TPD @ 1.10 kg/cap-d of MSW. The biodegradable fraction of the solid waste is 44.29%, inert are 26.82% andmoisture content of 46% [12]. Mumbai is generating 7840 TPD @ 0.63 kg/capita/day with a biodegradable fraction of 38-42%. The solid waste generated in Mumbai is dumped in three dump sites covering a total area of 150 hectares while additional dump sites are proposed in an area of 82 hectares at Kanjur Marg and 40 ha at Mulund [13]. A total of 983 municipal and private vehicles engaged making 1396 trips per day to collect the solid waste [14].

The costs for maintenance of dumping ground, waste transportation and hire charges are accounting to Rs. 126 crores per annum and constitute nearly 28 per cent of the total budget allocated for SWM [13]. Nine states (Maharashtra, West Bengal, Tamil Nadu, Uttar Pradesh, Andhra Pradesh, Kerala, Delhi and Gujarat) account for around 71% of the solid waste generated in the country (1, 27, 486 TPD) as per 2012 status [1]. Maharashtra accounts for 21% of the 90, 901 TPD solid waste generated from these nine states while Gujarat accounts for 8% of the solid waste generation (Refer Fig.1).

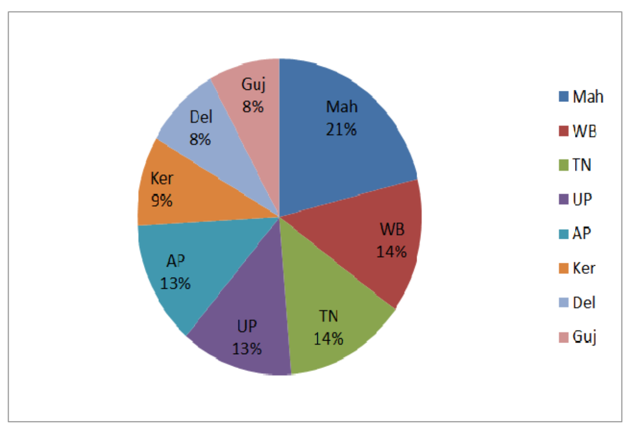


Fig. 1: Statistics of solid waste generation in India as per 2012

Statistics of SW generation in the country as per 2012 status Ramakrishna [9] studied the solid waste management from Rajam, a municipality in Srikakulam district, AP with a Moisture content of 46% [12]. Mumbai is generating 7840 TPD @ 0.63 kg/capita/day with a biodegradable fraction of

38-42%. The solid waste generated in Mumbai is dumped in three dump sites covering a total area of 150 hectares while additional dump sites are proposed in an area of 82 hectares at Kanjur Marg and 40 ha at Mulund [13]. A total of 983 municipal and private vehicles engaged making 1396 trips per day to collect the solid waste [14]. The costs for maintenance of dumping ground, waste transportation and hire charges are accounting to Rs. 126 crores per annum and constitute nearly 28 per cent of the total budget allocated for SWM [13]. Nine states (Maharashtra, West Bengal, Tamil Nadu, Uttar Pradesh, Andhra Pradesh, Kerala, Delhi and Gujarat) account for around 71% of the solid waste generated in the country (1, 27, 486 TPD) as per 2012 status [1]. Maharashtra accounts for 21% of the 90, 901 TPD solid waste generated from these nine states while Gujarat accounts for 8% of the solid waste generation (Refer Fig.1).For waste management in India, administration and regulation is governed by the Ministry of Environment and Forests and Climate Change (MoEF), the Ministry of Urban Development (MoUD), the National Environmental Engineering Research Institute (NEERI), CPCB, and State Pollution Control Boards (SPCBs) and ground level implementation responsibility lies with ULBs.

2.1 Solid Waste Management Strategies in India

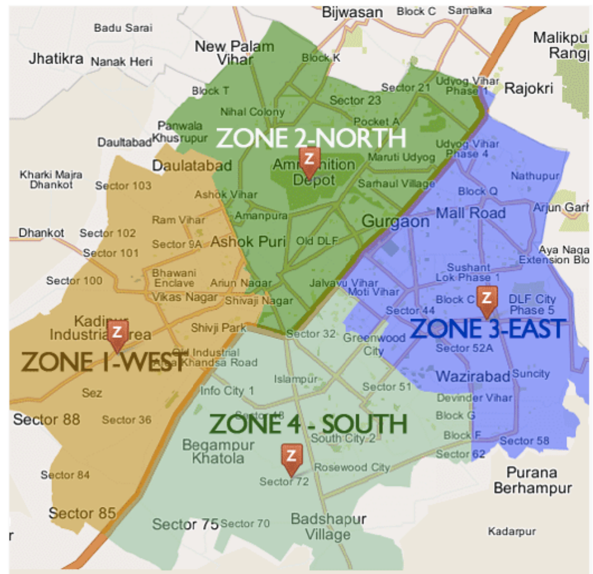
National waste management committee: The main objective of the committee constituted in

1990 was to identify the recyclable contents in solid waste picked up by rag-pickers. Strategy Paper: A manual on SWM has been developed by the MoUD in collaboration with the NEERI in August, 1995. Policy Paper: MoUD and the Central Public Health and Environmental Engineering Institute prepared a strategy paper for the treatment of wastewater, appropriate hygiene, SWM, and efficacy in drainage system. Master plan of Municipal Solid Waste: A stratagem was formulated by the combined efforts of MoEF, CPCB, and ULBs to develop a master plan for SWM with emphasis to biomedical waste in March, 1995. High Powered Committee: In 1995, a High Powered Committee constituted under the Chairmanship of Dr. Bajaj, to encompass a long-term strategy for the SWM using appropriate technology. All the above efforts, culminated into preparation of many acts and regulations to protect the Environment, which came into force time to time. The rules relevant to SWM in India are as follows: Hazardous Waste (Management, Handling and Transboundary movement) Rules (1989, amended January 2003, August 2010): It is to control, manage and handling of hazardous waste.

3. MATERIALS AND METHOD

3.1 Study Area

The sampling campaign covered residual waste collected from households in two municipalities, Gurugram and Faridabad. These municipalities have the same waste management system including the same source segregation scheme. They introduced a waste sorting system using a two-compartment wheeled waste bin for separate collection of recyclable materials from single-family house areas. One compartment was used for collection of mixed metal, plastic, and glass; theother compartment for mixed paper, board, and plastic foil. However, in multi-family house areas, a Molok system and joint full service collection points (joint wheeled container) were used for the collection of RHW and source-sorted materials for recyclables.



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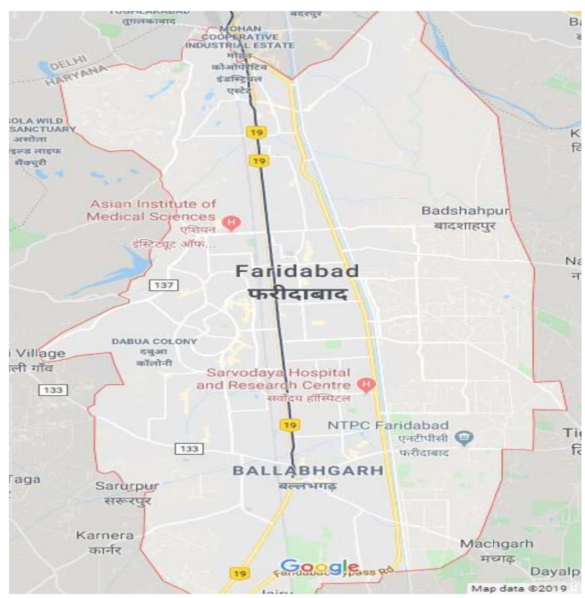


(b)

Fig. 2 (a-b): Study area location map (a) Gurugram (b) Faridabad

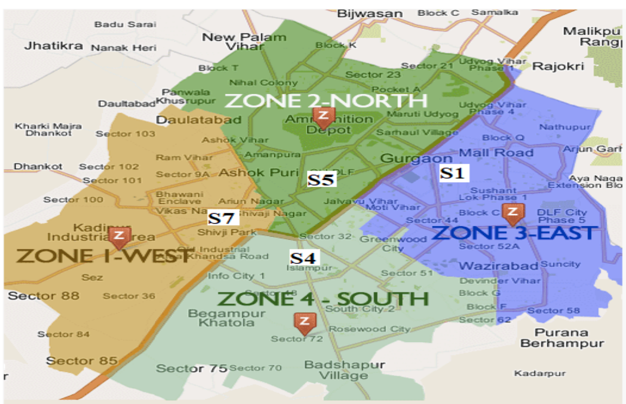
The area undertaken for present study has been divided in different zones before under taking the survey and execution of the study.

Gurugram City	Faridabad City
Zone 1-West	Zone 1-Old Faridabad
Zone 2-North	Zone 2-Nit Faridabad
Zone 3-East	Zone 3-Ballabhgarh
Zone 4-South	

3.2 Identification of Sampling Location in Study Area

Most of the qualitative data collected was from the waste characterization component of the survey, generated through an on-site weighing of waste generated by each household. All waste collected was emptied onto a tarpaulin sheet and weighed and recorded after confirming the type of waste (according to the classification table provided in the questionnaire).

Sampling locations are:
S1 – Labour chowk , sector 28, Gurugram.
S2 - YMCA Road , sector 8, NIT Faridabad.
S3 – East Chawla colony , Ballabhgarh , Faridabad.
S4 – Islampur , Gurugram.
S5 – Main bus stand , Gurugram.
S6 – Purani sabji mandi , Old Faridabad.
S7 –Shivaji nagar , Gurugram.



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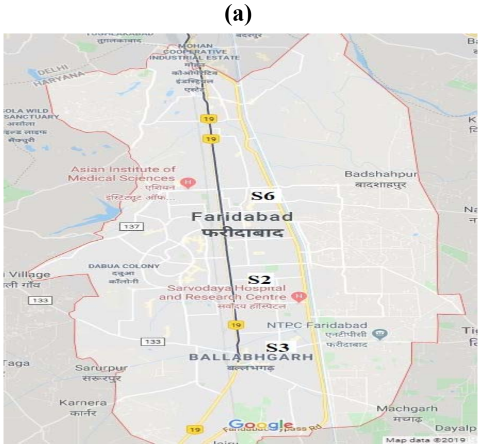

(b)

Fig. 3 (a-b): sampling location (a) Gurugram (b) Faridabad

3.3 Survey Preparation

The waste reduction study questionnaire survey was prepared for the study. A total of 672 surveys questionnaires were randomly administered among households around Gurugram and Faridabad area by conducting face-face interviews. One member of each household who was within the age bracket of 18-75 years was selected to be interview. The questionnaire design consists of three sections: Household solid waste management; Concerns about Solid Waste Management; Environmental health and demography. A survey methodology and questionnaire was then developed for further discussion and input from NPDT before finalization. The questionnaire was a combination of open ended and closed questions. Open-ended questions allowed respondents to give an opinion on any of the questions asked. Respondents' responses were "reconfirmed" by the interviewer through observations. Closed questions on the other hand were used to illicit exact answers to questions such age, sex, income etc.

The socioeconomic household survey and the waste characterization survey were combined and carried out at the same time over a period of seven days, from the 15-21 October 2019. Each team consisted of three members. The community of Faridabad was divided into three blocks. Each survey team was allocated to a certain block and was responsible for both the socioeconomic and waste characterization components of the survey. Survey equipment was provided, including weighing. The survey was a combined qualitative and quantitative data collection. It was carried out in the Hindi language. Face-to-face interviews and on-site weighing of waste by the survey team were the survey methods adopted. All answers and observations by the survey team were recorded immediately on the survey questionnaires.

Most of the qualitative data collected was from the waste characterization component of the survey, generated through an on-site weighing of waste generated by each household. All waste collected was emptied onto a tarpaulin sheet and weighed and recorded after confirming the type of waste (according to the classification table provided in the questionnaire).

3.4 Waste Sampling Procedure

The sampling campaign focused on the overall waste generation from the individual sub-areas and the associated housing types, rather than the specific waste generated in each household. To avoid changes of the normal waste collection patterns within the areas potentially leading to changes in household waste disposal behavior, the waste was collected following the existing residual waste collection schedules. A single MSW collection route was selected in each sub-area by the municipal authorities responsible for the solid waste management. The distribution of households along the selected routes was representative for each sub-area with respect to the volume of MSW bins and the size of the households. The number of selected households in each sub-area was between 50 and 150.

Based on these conditions (households samples representativeness and number of households), the number of selected households were computed and reported in Tables, which also shows the amount of waste collected and sorted from each sub-area. In total, 329 households in Gurugram and 343 households in Faridabad were selected. Overall, 672 households were distributed in study areas.

3.5 Waste Characterization

General and specific information on waste that contributes to the degradation of water quality in Haryana and Faridabad was lacking. Therefore, a waste characterization study was needed to provide the information required for the development of relevant community-based activities to address waste issues.

The waste characterization study being carried out as:

- Sources and generators of waste
- Quantities and composition of waste
- Current waste management practices (e.g. recycling, reduction, and disposal); and
- Future options for waste minimization programs

These issues were identified in the participatory problem analysis, and the waste characterization survey aimed to investigate these issues further.

3.6 Computation of Solid Waste

The solid waste generation rate is used to determine the quantity of waste to be managed, as a guide for designing final waste disposal facilities and planning other solid waste management processes, and as an indicator of solid waste generation pattern. In developed nations, the solid waste generation rate is determined by using some of the following methods: (i) Load-count analysis; (ii) Weight-volume analysis and (iii) Material balance analysis (Tchobanoglous 1976; Hagarty et al. 1973). In the rural communities in the developing nations, most of these methods may not be applied successfully because of the method of waste disposal. The determination of the solid waste generation rates in developing urban communities usually involves house-to-house visits to measure quantities of waste generated per household. The main components of this method include: (1) the determination of the number and capacities (volumes) of various temporary waste containers; (2) the estimation of wastes contained in any of these containers, at any given time; To calculate the mass of waste (W) generated or collected in all the containers per day, the following equation (Eq.1) was applied:

$$W = E\left(\frac{nvD}{y}\right) \quad kg \qquad (1)$$

n = total number of large containers, v = volume of each container (all the containers are of the same size), D = density of waste (kg m^{-3}) and y = average number of days required to fill a container

4. RESULTS AND DISCUSSIONS

4.1 Age Groups

The age distribution indicated that 16% of Faridabad population was under 5 years of age, and 2.8% were aged 70 years or over. More than 40-50% of the population lies in the age of 24 years or less, indicating that Faridabad has an "intermediate population". The population aged 25–69 made up 41% of the total population of Fridabad.

4.2 Education level

Primary education in Gururgram and Faridabad for ages 6–14 is fairly good percentage of school-age children (5–19 years old) who were in primary school (53%); 23% were in secondary school and 24% were not at school. About 3% of the total population of Gurugram and Faridabad had some technical training and university qualifications, while 30% had attended high school but left school without any formal qualifications.

4.3 Sources and level of income

Of those considered to be of working age (20–64 years), 31% were employed and 23% were Self-employed (including semi-subsistence and self employment, such as farming and fishing), and 46% were subsistence only. About 19% of the total population of Gurugram and Faridabad was engaged in home duties, while 4% were looking for jobs, with the remaining still at school, elderly people on pensions, or others. Table 4 indicates the number of people employed and the type of employment that the population of Gurugram and Faridabad was engaged in. Over half of those who were employed (60 %) were self employed in various categories.

4.4 Tables

Table 1: Variation of age range with number of persons

Age Range	Number of Persons	
	Gurugram	Faridabad
18-24	24	30
25-34	76	51
35-44	82	102
45-54	83	102
55-64	45	48
65-Above	19	10

Table 2: Variation of education level with number of person

EDUCATION LEVEL	NUMBER OF PERSON (GURUGRAM)				NUMBER OF PERSON (FARIDABAD)		
	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 1	ZONE 2	ZONE 3
No education	92	177	31	83	185	300	204
10th	307	426	141	178	361	240	300

12th	244	339	121	149	282	189	239
Graduation	170	230	78	90	154	120	124
Post-graduation	56	48	22	30	21	15	19

Table 3: Variation of education level with number of person (Zonewise)

EDUCATION LEVEL	NUMBER OF PERSON	
	GURUGRAM	FARIDABAD
No education	383	504
10th	1052	901
12th	853	710
Graduation	568	398
Post-graduation	156	55

Table 4. Variation of occupation with number of person

OCCUPATION	NUMBER OF PERSON	
	GURUGRAM	FARIDABAD
Farming	7	7
Government employee	43	36
House wife	7	2
Private job	131	95
Retired	5	2
Self employed	121	200
Student	5	1
Unemployed	4	1

Table 5: Variation of income with number of person

INCOME	NUMBER OF PERSON	
	GURUGRAM	FARIDABAD
1-25000	130	222
25000-50000	83	25
50000-75000	27	0
No responses	70	74

Table 6: Percentage of waste produced by type

Waste Type	Faridabad			Gurugram			
	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3	Zone 4
Paper	5.05	6.1	3.24	3.17	14.98	9.54	7.08
Leather	9.12	7.51	4.46	8.16	14.28	9.24	9.77
Plastic	7.83	8.22	4.97	10.96	6.07	9.14	6.63
O.M	54.14	58.1	70.04	33.06	40.49	45.75	54.97
Textile	5.52	5	7.87	17.22	11.76	11.24	5.39
Metal	8.61	7	4.25	13.77	4.47	8.84	9.37
Rubber	9.73	7.98	5.07	13.6	7.45	6.24	6.77

5. CONCLUSION

- From this survey we came to know that Faridabad generates more MSW than Gurugram.
- Majority of people in Gurugram belong to high class family thus they are aware of waste management whereas Faridabad being a market area lacks in waste management and produces more MSW.
- Literacy rate of Gurugram is comparatively higher than Faridabad thus they are aware of recycling.
- About 19% of the total population of Gurugram and Faridabad was engaged in home duties, while 4% were looking for jobs, with the remaining still at school, elderly people on pensions, or others.
- Tables indicates the number of people employed and the type of employment that the population of Gurugram and Faridabad was engaged in. Over half of those who were employed (60 %) were self-employed in various categories.
- The amount of organic matter produced by both the cities is maximum amongst all the parameters It is found to be maximam in the zone 3 of Faridabad while in zone 4 of Gurugram.
- The leather is found to be maximum in zone 1 and plastic in zone 2 in Faridabad city whereas the percentage of leather is found to be more in zone 2 and plastic in zone 1 in Gurugram city.
- The textile is found to be maximum in zone 3 and metal in zone 1 in Faridabad city whereas the percentage of textile is found to be more in zone 1 and metal in zone 1 in Gurugram city.The percentage of rubber is found to be more in zone 1 of both the cities , Faridabad as well as Gurugram.

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