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SPATIAL ANALYSIS OF SOLID WASTE GENERATION PATTERNS IN A FAST-GROWING INDUSTRIAL CITY-DURGAPUR, INDIA

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Abstract: Unprecedented population growth, rapid industrialization, urbanization and increase in the economic development, changes in lifestyle, food habits, and living standard and consumption patterns lead to gigantic volume of solid waste generation with diverse stream. Adequate management of solid waste is essential for the cleanliness of the environment and sustainability and it is largely dependent on the data availability of the quantity of generated solid waste and nature of composition. The objective of the present study is to assess the spatial pattern of solid waste generation in a fast-growing industrial and urbanized area, Durgapur city. It is found that Durgapur city currently generates 246965 kg/day of solid waste and there is a significant spatial variation of solid waste generation in different borough and wards of the city. It is also found that the quantity of solid waste generation is largely associated with density of population and socio-economic status. This study will be useful for decision-makers who need to accurately forecast the waste generation in order to effectively design a regional solid waste management system with limited data availability.

Keywords: Unprecedented population growth, Rapid industrialization, Urbanisation, Solid waste generation, Solid waste management.

1. INTRODUCTION

The changing lifestyle and consumption pattern of population have significantly changed both the quantity and quality of solid waste generation around the globe. Solid Waste generation rate generally increases with economic development. The increase in the economic development of people leads to rise in purchasing power that causes changes in lifestyle, food habits, living standard and consumption patterns. Owing to diverse lifestyles and purchasing power of products, the high income generated countries generate more waste than the low income generated countries due to different lifestyle. There is also a variation of solid waste generation within the country due to diverse population composition, socio-economic level, living standard, and consumption behaviour. Proper management of solid waste is essential for the cleanliness of the environment and sustainability and it is largely dependent on the data availability of the quantity of generated solid waste, composition. As the organics materials are putrescible and are food for pests, insects or microorganisms, need to collect and dispose of properly on a daily basis. The volume of recyclables materials like paper, cardboard and plastic in MSW represents how often they need to be collected. Recyclables waste materials represent an immediate monetary value to the collectors (Sk, M. M. 2020).

Approximately 2.01 billion MT of municipal solid waste (MSW) is generated per annum at a global scale and by 2050 the total solid waste generation is expected to reach at 3.40 billion MT. Out of the total solid waste generated, nearly 33-40 percent of solid waste is openly dumped and burned without proper management worldwide while in low-income countries it reaches up to 93 percent (Kaza et al. 2018). Mismanagement of solid waste produces persistent environmental pollutants (POPs) such as dioxin that leads to severe health and environmental hazards (Rada et al. 2018; Kanchanabhan et al. 2011). Indian cities are facing the severe challenge of MSW management with rapid population growth, urbanization, and economic growth. In 2018, the total quantity of generated municipal solid waste was estimated at about 1.50 lakhs MT per day (Shrivastava 2019) and it will be adding 300 MT for every year till 2047 (CPCB 2000). The per capita waste generation in different cities of India is 350–600 g per person per day. The annual increase rate of per capita solid waste generation in India during the last few decades has been recorded at a rate of 1.33% (GoI, 2009). Proper disposal of MSW has become a challenging issue for every urban body in India.

Unprecedented population growth and urban development in Durgapur city has led to gigantic volume of solid waste generation. The total volume of solid waste generation by Durgapur city is 247 MT/day for the year 2016 with per capita 404 grams solid waste generation. Insufficient collection, storage, processing of waste, lacking of optimized routes for transportation of waste and absence of scientific sanitary landfill for suitable disposal in the defined area have created a precarious situation both for environment and health. Therefore, a clear understanding of quantity, characteristics, and future estimation of solid waste generation is essential for designing any suitable plan for SWM in order to avoid environmental pollution and health hazards.

2. OBJECTIVES

The main objective of the present study is to assess the spatial pattern of solid waste generation, types, composition, and different sources of solid waste generation in a fast-growing industrial and urbanized area, Durgapur city.

3. STUDY AREA

Durgapur city was once known as 'Ruhr of Bengal' due to the presence of numerous large and small scale industries. Durgapur, the dream child of the great visionary Dr Bidhan Chandra Roy, an important industrial centre achieved the status of multi-functional character having its inception as unifunctional centre for industrial activity. It is located in the eastern part of Paschim Bardhhaman district of West Bengal. It is bordered by Jharkhand State in the West, East Bardhaman in the East, Birbhum in the North and Bankura in the South (*Fig.1*). Durgapur Municipal Corporation (DMC) covers a geographical area of 154.20 Sq. Kms which is 9.62 percent of the total area of the district. Though, it covers a small geographical area, it accommodates 563557 populations, which is 19.55 percent of the population of the district. DMC is located between the latitudes of is 87° 13' E to 87° 22' E longitude and 23°28' N to 23°36' N latitude. The city is situated beside the left bank of river Damodar at a distance of 160 Km from Kolkata, the state capital. Durgapur is one of the significant post-independent industrial towns and came into existence as a notified area authority (NAA) in 1962 and was upgraded to the status of a Municipal Corporation in 1996. The total area of Durgapur Municipal Corporation (DMC) is 154.20 square Km which is administratively divided into forty-three (43) wards and five (5) boroughs.

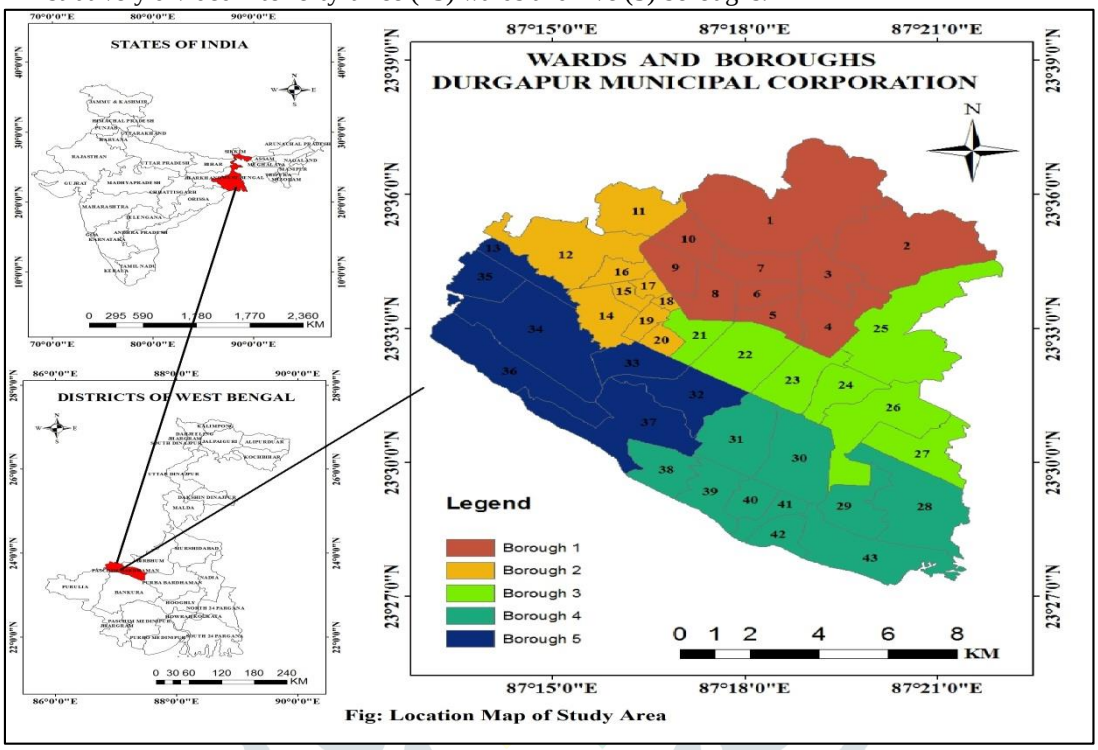

Fig.1 Location map of Durgapur Municipal Corporation (DMC)

3. DATABASE AND METHODOLOGY

The present study is carried out based largely on secondary sources of data obtained from Durgapur Municipal Corporation, Details Project Report (DPR), CPCB, Planning Commission Report, NEERI reports, relevant websites, and different journals and books. For mapping making, ArcGIS 10.2 has been used.

4. RESULTS AND DISCUSSION

In order to achieve the objectives of the present study, as mentioned above, this work is divided into three subheads to highlight (i) solid waste generation in India; (ii) solid waste generation in West Bengal and (iii) solid waste generation in Durgapur City.

4.1 Solid Waste Generation in India

At the time of independent, Indian towns and cities generated approximately 6 million tonnes of solid waste; but due to rapid increase rate of population, urbanisation, industrialisation and changing life styles, the total volume of solid waste has increased six times which is about 48 million tonnes in 1997 with 4.25 % annual growth rate, and it is predicted to increase to 300 MT by 2047 (Sharholy et al. 2008). In 2004-05, Central Pollution Control Board (CPCB) with collaboration of NEERI conducted a survey to estimate total solid waste generation from 59 cities including 35 metro cities and 24 state capitals in India *(Table 1)*. The survey revealed that the capital city- Delhi and Mumbai generated the largest volume of municipal solid waste, which is about 5922 and 5320 tons/day, respectively, followed by Chennai (3036 tons/day) and Kolkata (2653 tons/day). The maximum generation of solid waste in these megacities is due to high density of population and floating population (Berneche-Perez et al 2001; Hoornweg and Bhada-Tata 2011). The quantity of produced MSW in 59 cities is shown in the *Table 1*. The annual increase rate of per capita solid waste generation in India during the last few decades was recorded at a rate of 1% to 1.33% (Shekdar 1999) and with this increasing rate of solid waste, India is likely to experience a rise of MSW generation from 40,000 tons to over 125,000 tons annually by 2030 (Shristi 2000). However, if we estimate the per capita solid waste generation of India, it reveals that the highest solid waste generation per day per capita was in Port Blair, Kochi, Chennai and Vishakhapatnam; while lowest generation rate was found in Nashik, Imphal, Rajkot and Guwahati.

Table1: Quantity and per capita of municipal solid waste generation at different cities in India

S. No.	City	Municipal Solid Waste (Tones per day)			Per capita SWG/day (in kg)*
		2004-2005*	2010-11**	2015-16***	
1	Agartala	77	102	250	0.40
2	Agra	654	520	790	0.51
3	Ahmedabad	1302	2300	2500	0.37
4	Aizwal	57	107	160	0.25
5	Allahabad	509	350	450	0.52
6	Amritsar	438	550	600	0.45
7	Asansol	207	210	220	0.44
8	Bangalore	1669	3700	3700	0.39
9	Bhopal	574	350	700	0.45
10	Bhubaneswar	234	400	550	0.36
11	Chandigarh	326	264	370	0.40
12	Cheennai	3036	4500	5000	0.57
13	Coimbatore	530	700	850	0.57
14	Daman	15	25	-	0.42
15	Dehradun	131	220	292	0.31
16	Delhi	5922	6800	8700	0.57
17	Dhanbad	77	150	180	0.39
18	Faridabad	448	700	400	0.42
19	Gandhinagar	44	97	105	0.22
20	Gangtok	13	26	-	0.44
21	Guwahati	166	204	627	0.20
22	Hyderabad	2187	4200	4000	0.57
23	Imphal	43	120	-	0.19
24	Indore	557	720	850	0.38
25	Itanagar	12	102	-	0.34
26	Jabalpur	216	400	550	0.23
27	Jaipur	904	310	1000	0.39
28	Jammu	215	300	368	0.58
29	Jamshedpur	338	28	-	0.31
30	Kanpur	1100	1600	1500	0.43
31	Kavaratti	3	2	-	0.30
32	Kochi	400	150	-	0.30
33	Kohima	13	45	-	0.17
34	Kolkata	2653	3670	4000	0.58
35	Lucknow	475	1200	1200	0.22
36	Ludhiana	735	850	850	0.53
37	Madurai	275	450	450	0.30
38	Meerut	490	520	500	0.46
39	Mumbai	5320	6500	11000	0.40
40	Nagpur	504	650	1000	0.25
41	Nashik	200	350	500	0.19
42	Panjim	32	25	-	0.54
43	Patna	511	220	450	0.37
44	Pondicherry	130	250	-	0.59
45	Port Blair	76	45	-	0.76
46	Pune	1175	1300	1600	0.46
47	Raipur	184	224	230	0.30
48	Rajkot	207	230	450	0.21
49	Ranchi	208	140	150	0.44
50	Shillong	45	97	-	0.34
51	Shimla	39	50	-	0.27
52	Silvassa	16	35	-	0.32
53	Srinagar	428	550	550	0.48
54	Surat	1000	1200	1680	0.41
55	Thiruvanandapuram	171	250		0.23
56	Vadodara	357	600	700	0.27
57	Varanasi	425	450	500	0.39
58	Vijayawada	374	600	550	0.55

59	Vishakhapatnam	584	334	350	0.59
	Total MSW	39031	50592	-	

Source: Municipal Solid Waste Study conducted by CPCB through *NEERI-Nagpur (2004-2005), ** CIPET during 2010-11 *** Ministry of Statistics and Programme Implementation, Govt. of India. (ON1964) and other literatures

The per capita solid waste generation rate is largely associated with the wealth, socio-economic status, living standard, consumption pattern. The per capita waste generation in different cities of India approximately is 350–600 g per person per day (CSE 2014-15). The annual increase rate of per capita solid waste generation in India during the last few decades was recorded at a rate of 1.33% (GOI 2009). Table 2 shows the population and per capita solid waste generation rate based on population size of cities and towns in India.

Table 2: Per Capita waste generation rate based on population size of cities and towns

Original Classification	Classification	Population	Per Capita kg/day
Class 1	Metropolitan	> 5,000,000	0.605
	Class A	1,000,000- 4,999,999	0.448
	Class B	700,000- 999,999	0.464
	Class C	500,000- 699,999	0.487
	Class D	400,000- 499,999	0.448
	Class E	300,000- 399,999	0.436
	Class F	200,000- 299,999	0.427
	Class G	150,000- 199,999	0.459
	Class H	100,000- 149,999	0.445
Class 2		50,000- 99,999	0.518
Class 3		20,000- 49,999	0.434
Class 4		10,000- 19,999	0.342

Source: NEERI, 2010

The quantity and composition of solid waste vary from city to city and even within the city, and this variation is mainly due to different composition of population, level of socio-economic and cultural aspects, living standard, consumption pattern etc. (Berneche-Perez et al 2001; Buenrostro et al 2001). Municipal Solid waste is categorized into three groups such as compostable waste, recyclables and inert materials. Compostable of biodegradable materials include food waste, vegetables, garden, park waste. Recyclable materials consists of paper, cardboard, plastic, metals, and glass. Inert materials comprises of ash, stone, and silt etc. The high income generated cities of India were found more MSW generation per day per capita with maximum proportion of packaging materials and recyclable solid waste while in low and medium income generated cities produce lower proportions of packaging and recyclable materials. Table 3 shows the composition of solid waste in different regions of India. It is found that maximum proportion of urban MSW in India is biodegradable materials (51.3 %) followed by recyclable materials (17.5%) and inert waste (31%). The average moisture content in solid waste is 47% while the average caloric value of urban MSW is about 7.3 MJ/kg (1,751 Kcal/kg).

Table 3: Composition of MSW in India and Regional Variation

Region/City	MSW (TPD)	Compostable (%)	Recyclables (%)	Inert (%)	Moisture (%)	Cal. Value (MJ/kg)	Cal. Value (kcal/kg)
Metros	51,402	50.89	16.28	32.82	46	6.4	1,523
Other cities	2,723	51.91	19.23	28.86	49	8.7	2,084
East India	380	50.41	21.44	28.15	46	9.8	2,341
North India	6,835	52.38	16.78	30.85	49	6.8	1,623
South India	2,343	53.41	17.02	29.57	51	7.6	1,827
West India	380	50.41	21.44	28.15	46	9.8	2,341
Overall Urban India	130,000	51.3	17.48	31.21	47	7.3	1,751

Source: Annepu, 2012

Due to the changing economic status, living standard and consumptions pattern, the quantity and composition of solid waste in India is also changed with due time immemorial. The packaging and plastic materials proportion has increased rapidly while biodegradable and inert materials decreased. The proportion of recyclable materials like paper, plastic have increased in India while organic or biodegradable wastes have reduced in last few decades (*Table 4*).

Table 4: Change in composition of municipal solid waste in India (in %)

Year	Biodegradables	Paper	Plastic/rubber	Metal	Glass	Rags	Others	Inert
1996	42.21	3.63	0.60	0.49	0.60	-	-	45.13
2005	47.43	8.13	9.22	0.50	1.01	4.49	4.02	25.16
2011	42.51	9.63	10.11	0.63	0.96	-	-	17.00

Source: Planning Commission Report (2014)

4.2 Solid Waste Generation in West Bengal

The population of West Bengal as per 2011 census is about 91,276,115 persons, which comprises of 31.89 % urban populations. There are 125 urban local bodies (ULBs) in West Bengal including 7 municipal corporations and 118 Municipalities. Total generation of Municipal solid waste generation in West Bengal in 2017 was about 9500 tonne per day and approximately 8075 tonne solid waste is collected every day (MSPI-GOI 2017). Per capita MSW generation in various towns of the state ranges from 250 to 1700 gram per

day (ILGUSC-UWB 1999-2000). Kolkata Municipal Corporation (KMC) is the largest city in terms of both population and area in West Bengal. KMC generates approximately 3520 MT of solid waste per day with per capita waste generation is about 873 gram followed by Howrah Municipal Corporation (600 MT), Siliguri Municipal Corporation (313 MT) and Durgapur Municipal Corporation (247 MT), respectively (*Table 5*). A major fraction of solid waste in First class city of West Bengal is ash, fines and others (57.83%) followed by compostable waste (*Table 6*).

Table 5: Status of Solid Waste Generation in Municipal Corporations of West Bengal

Sr. No.	Name of the MC	Area (Sq. Km.)	Population	Waste (MT/D)	Per Capita Waste/day (gm)
1	Asansol Municipal Corporation (AMC)	326.48	11,53,138	220	320
2	Bidhannagar Municipal Corporation (BMC)	60.5	632,107	200	655
3	Chandernagore Municipal Corporation (CMC)	22	1,166,771	45.5	281
4	Durgapur Municipal Corporation (DMC)	154.20	5,66,517	247	404
5	Howrah Municipal Corporation (HMC)	63.55	13,70,448	600	655
6	Kolkata Municipal Corporation (KMC)	206.08	>4.5 Million	3520	873
7	Siliguri Municipal Corporation (SMC)	41.90	513264	313	390

Source: http://www.wburbanservices.gov.in/, internal report from different Municipal Corporation

Table 6: Composition of Municipal Solid Waste Generated in Class-I Cities in West Bengal

Waste Component	West Bengal (%)
Paper	3.22
Textiles	0.63
Leather	0.39
Plastic	2.10
Metals	0.17
Glass	0.35
Ash, Fines and Others	57.83
Compostable matter	36.00

Source: Compiled from the statistics released by Status of Municipal Solid Waste Generation Collection Treatment and Disposal in Class-I Cities, CPCB (2000), Ministry of Environment & Forests retrieved on 01.03.2022

4.3 Solid Waste Generation in Durgapur City

As per Census 2011, DMC is the second-largest Municipal Corporation in West Bengal in terms of its area after Kolkata Municipal Corporation (187.33 sq. km) and ranks third in terms of its population after Kolkata (44,86,679 persons) and Howrah Municipal Corporation (10,72,161 persons). The city had 41,696 populations in 1961 but now the population increased thirteen times which are approximately 563557 populations in 2011. Durgapur city came into existence after the post-independent as a result of the industrial complex yet it has become the hub of educational and health centres nowadays. The city also performs a multitude of functions like commerce, transportation. As a result of the rapid population explosion, industrialization, urbanization and economic growth, the city people currently generates a sizeable amount of urban refuse. As per the DMC report, the urban residents produced approximately 90,155 MT of solid waste in 2016 with 404 gm SW per capita/day. The average per capita solid waste generation in Indian cities vary from 0.2 to 0.6 kg per day (Talyan et al. 2008; Jha et al. 2008). However, in due time immemorial changes in lifestyles and consumption pattern due to rapid growth in economic and urbanization have resulted in increasing per capita waste generation by 1.3 per cent annually (Singh et al. 2011; Mohanty et al. 2014). At present, the city generates 247 MT of waste per day at the rate of 0.40 Kg per capita per day and decadal population growth of 32.10 % (*Table 7*).

Table 7: Waste Balance in Durgapur City (2016)

S. No.	Description	Volume
1	Total Waste Generated (2016)	247 TPD
2	Per Capita Generation	404 gm
3	Collection Efficiency	76%
4	Extent of segregation of MSW	0%
5	Extent of MSW Recovery	74%
6	Extent of scientific disposal of MSW	0%
7	Organic Levels	56.2%
8	Density(kg/m3)	415
9	Moisture Content	35.6%

Source: Data compiled by researcher from different sources (2018)

4.3.1 Types of Solid Waste Generated in Durgapur City

The knowledge of physical characteristics of solid waste is inevitable parameter for taking any decision for suitable solid waste management. Therefore, MSW of DMC is categorised into two broad types namely organic or biodegradable and inorganic or non-biodegradable waste materials. It is estimated that out of total generated waste about 73.67% organic, and 26.33% inorganic wastes (*Table 8*).

Table 8: Types of MSW based on the components of waste in DMC (2016)

Organic	Percent %	Inorganic	Percent %
Food waste + Garden waste	56.20	Plastics	7.87
Rags/clothes/cotton	4.69	Metals	1.17
Paper	9.97	Glass & Ceramics	4.01
Coconut shells	2.81	Rubber & synthetic	1.69
Total	**73.67**	Leather	0.70
		Stone, debris &boulders	9.64
		Any other (vhar)	1.23
		Total	**26.33**
Combined of Organic + Inorganic= 73.67 % + 26.33 %=100%			

Source: Details Project Report, DMC (2018)

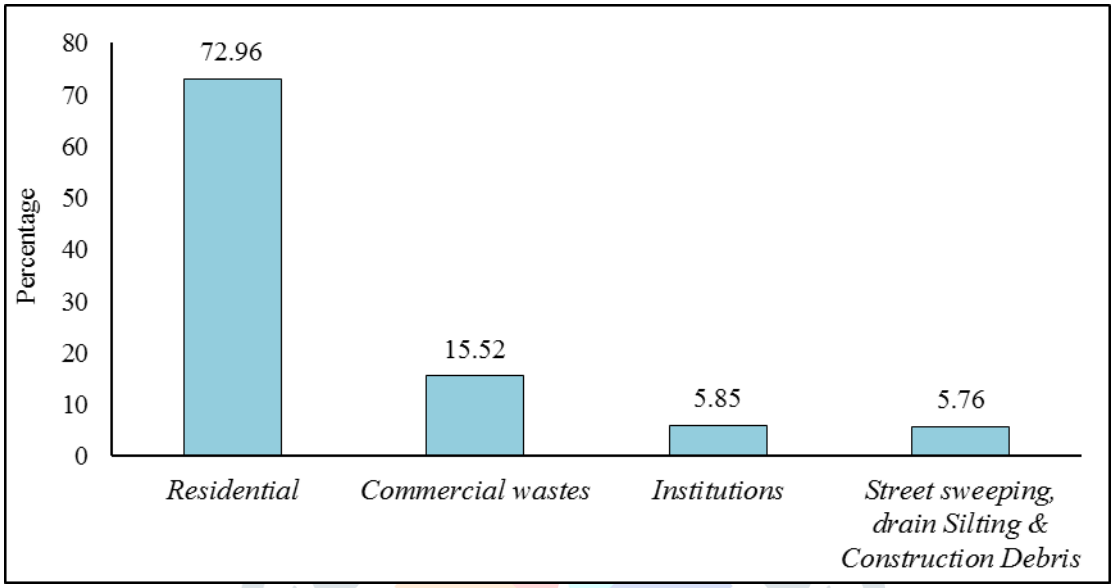

Fig. 2 Types of solid waste based on the components of waste in Durgapur city

4.3.2 Sources of Solid Waste Generation in Durgapur City

Identification of sources of solid waste generation is an indispensable part of the integrated waste management system to keep the urban environment green and for the betterment of social well-being. The major sources of solid waste generation in Durgapur city are households, markets, commercial establishments/shops, hotels, restaurants, institutions, function/marriage halls, offices, and hospitals. Households of different categories including independent bungalows, independent houses of low, middle and high-income groups, tenements, individual flats, apartments, and huts or economically weaker section dwellings, primarily generate domestic wastes. Residential wastes share a major portion of the waste accounting for 72.96 per cent (*Table 9 & Fig. 3*). Residential wastes include kitchen wastes, packaging (bottles, cans, milk pouches, and chips), papers, cardboard, rubber, glasses, and old clothes. After households, commercial establishments play the second most contributors in the city, accounting for 15.52 per cent of the total wastes. Commercial establishments include wholesale and retail shops, general shops, pan shops, food products, bakeries, dairies, juice shops, hardware, electrical and electronics, workshops, and cloth merchant. Street sweeping, drain silting, and construction debris is one of the major sources of solid waste generation in Durgapur city, which generates 5.76 per cent of total solid waste. Solid waste dumping on the street is common everywhere in the city.

Table 9: Major sources of solid waste generation in Durgapur city

S. No.	Sources	Waste Generation (%)
1	Residential	72.96
2	Commercial wastes	15.52
3	Institutions	5.85
4	Street sweeping, drain Silting & Construction Debris	5.76
	Total	100.00

Source: *DPR, Durgapur Municipal Corporation, 2018.*

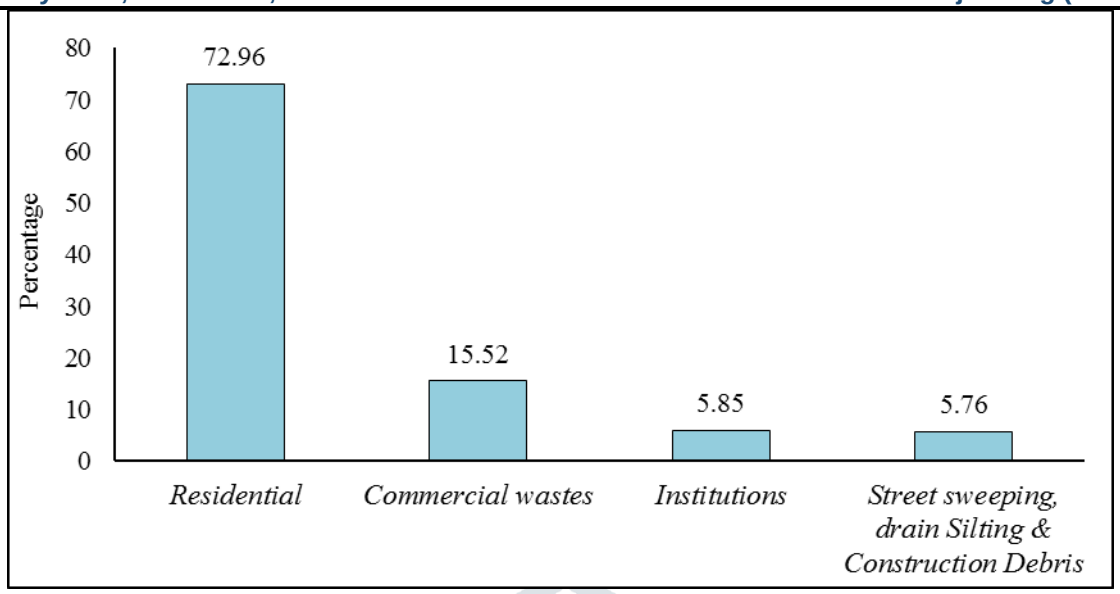

Fig. 3 Major sources of solid waste generation in Durgapur city

4.3.3 Spatial Pattern of Solid Waste Generation in Durgapur City

For the present analysis, secondary sources of data have been derived from the office of the DMC to evaluate and assess the quantum of solid waste generation at borough as well as ward level.

4.3.3.1 Borough-wise waste generation trends

As per the data provided by DMC, the total solid waste generation in Durgapur city is 246965 kg/day for the year 2016. Borough-wise solid waste generation trends in the city has been shown in *Table 10*. Borough number 1 has the highest generation of solid waste accounting for 24% of the total solid waste in the study area followed by borough no. 4, 2, 3 and 5 respectively. Borough-1 covers the industrial township with the highest number of population 147163, which produces the maximum volume of waste while borough number 5 with population 93950 has the minimum volume of waste generation (*Fig. 4*). The quantity of solid waste generation is directly linked with the number of population in the city.

Table 10: Borough-wise waste generation trends in Durgapur city

Boroughs	Wards covered	Total wards	Population (2016)	Municipal waste Generated (Kg/day)	Per cent (%)
1	1-10	10	147163	59454	24.00
2	11,12,14-20	9	122958	49675	20.00
3	21-27	7	115784	46777	19.00
4	28-31,38-43	10	131444	53103	22.00
5	13,32-37	7	93950	37956	15.00
Total		**43**	**611300**	**246965**	**100.00**

Source*: Calculated by the researcher based on the obtained data provided by DMC, 2018.*

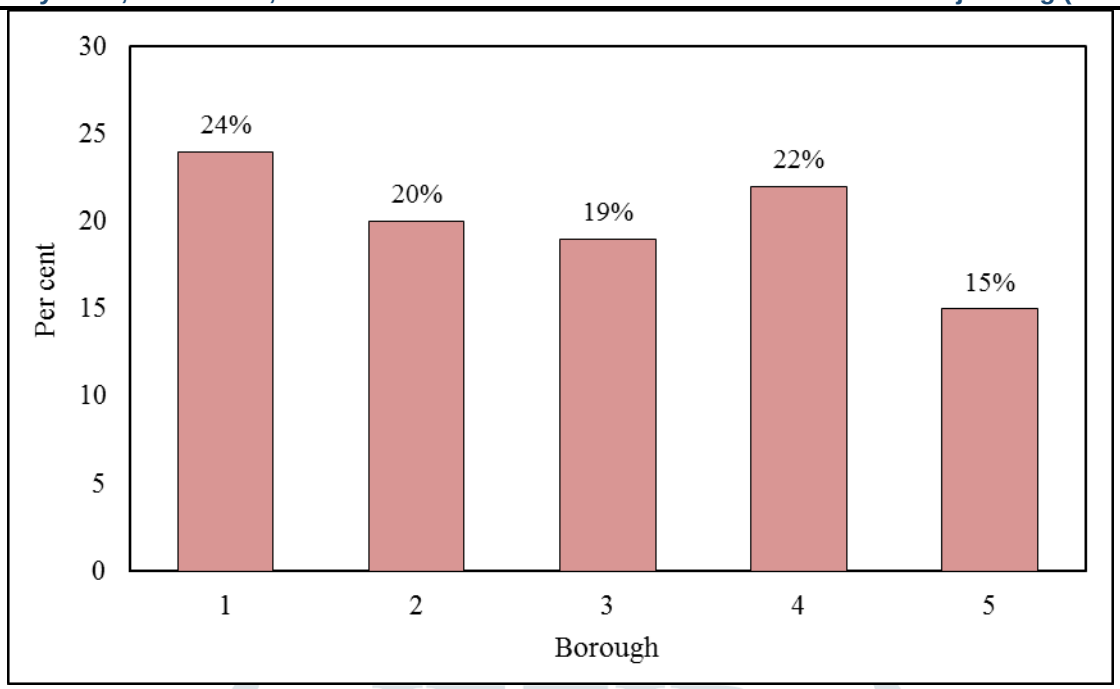

Fig. 4 Borough-wise waste generation trend in Durgapur city

4.3.3.2 Ward-wise waste generation trends

There is a significant spatial variation of solid waste generation in different wards of the city (*Fig. 5*). The wards which witness higher population generate a high quantity of solid waste and vice-versa. So, there is a positive relationship between the population and solid waste generations in the study area. Ward number 14 generates maximum volume (9457 kg/day) of solid waste while ward number 2 having the least amount (2567 kg/day) of solid waste generation in the city due to variation in the number of population.

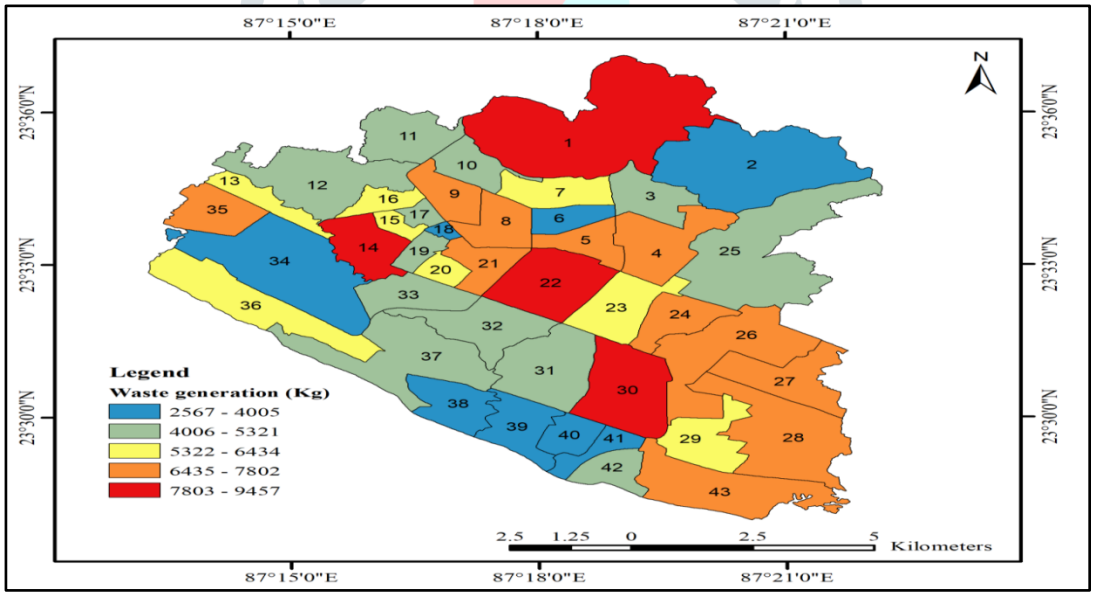

Fig. 5 Map showing the solid waste generation in Durgapur city

CONCLUSION

After foregoing analysis regarding the spatial pattern of solid waste generation, nature and characteristics of solid waste in Durgapur city, it is found that rapid population growth coupled with industrialization and urbanization have been the causative factor for solid waste generation in the concerned area. The urban residents daily generate 247 tons of solid waste with 404 gm solid wastes per capita/day. The major sources of solid waste generation in the city are households, markets, commercial establishments, shops, hotels, restaurants, institutions, function/marriage halls, offices and hospitals. There is a significant spatial variation of solid waste generation in different boroughs and wards of the city. The wards which witness higher population generate a high volume of solid waste. The major portion of solid waste in the city is rapidly degradable waste (59.01%) as food, garden waste and coconut shells followed by recyclable materials (15.44%) such as plastics, metals, glass, ceramics, rubber, synthetic, and leather etc., slowly degradable waste (14.66%) such as paper, rags/clothes/cotton, and miscellaneous waste (10.87%) such as stone, debris boulders, and any other (vhar). There is a significant spatial variation of solid waste composition in different parts of the city. This study will be useful for decision-

makers who need to accurately forecast the waste generation in order to effectively design a regional solid waste management system with limited data availability.

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