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GEOGRAPHIES OF URBAN SOLID WASTE MANAGEMENT IN INDIA

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Abstract
Rapid urbanization and globalization increase consumerism in developing countries specially in India. As a consequence, municipal solid waste (MSW) has been exponentially increased in last two decades and posed a great challenge to manage. Government has taken many initiatives, policies and collaborated with private company to solve these issues of waste but lack of scientific approach, money, political will, conflict, interest of planners, it stands undisputed problem of urbanization. Different degree of environmental degradation takes place due to MSW in different ecosystems and also it affects health of urban people. This paper analyzes municipal solid waste generated in 59 cities of India which categorized into six regions to understand spatio-temporal quantum of waste generated by each city, nature of management and problem at regional level.

1 Introduction

The history of waste has been related to the emergence of the large cities, especially in developed countries. However, shifting to an epoch of Anthropocene, where the world is growing towards its urbanized future, one of the urban lifestyles' by-products, solid waste, is growing even faster than the rate of urbanization. Ten years ago (2000), there were 2.9 billion urban residents who generated about 0.64 kg of MSW per person per day. Today (2011), this number has increased to about 3 billion urban residents generating 1.2 kg/capita/day globally. By 2025, this will likely increase to 4.3 billion urban residents generating about 1.42 kg/capita/day of municipal solid waste (World Bank Report , 2018). Around the world, various regions have depicted different types and amount of waste generation, mainly because of the spatial and management variations. The developed countries have been quite successful in managing its municipal wastes. After the commitments made at the Earth Summit in Rio de Janeiro, 1992, the European Council in 2001 adopted the first EU sustainable Development Strategy. Among European Union member, Sweden has become very successful in implementing zero waste management. Accession of Sweden to European Union in 1995 has given greater impact on the waste management. Their Framework Directive, Landfill, Directive and Waste Incineration Directive have formed the core of the policy of "waste hierarchy"

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which has led Sweden to achieve zero waste management (Swedish Environmental Protection Agency, 2005).

India is one of the developing countries and most populous country in the world. India is undergoing fast economic transformation in recent years and presently it stands 5th largest economy in the world. The urban population of India 31.6 percent of the total population in 2011.The urban population grew from 28.6 crores in 2001 to 37.7 crores in 2011 whereas rural population increased from 74.3 crores in 2001 to 84.3 crores in 2011(Census of India, 2011). It is observed for the first time since independence that the absolute increase in population is more in urban areas than in the rural areas. Indian is one of the least urbanized country in the world though the urban population of India is more than total population USA. This growing rate of population in urban fused with economic transformation is one of the direct factors influencing the generation of the municipal solid waste (MSW) in India. Due to these rapid industrialization and urbanization, the generation of waste in India has steepened. In 2011 total municipal solid waste in India was around 1, 85,132 TPD (tonnes per day), by 2015 it has increased to 2,17,975 TPD which is expected to increase to 2,78,480 TPD in 2021(Annepu, 2012). 82percentof MSW have been collected through door-to-door collection and attained 48 percent segregation that have been processed with 37.23 percent (MoHUA, 2018-2019). At present, the composition of MSW consists of 50 percent compostable, 17 percent recyclables and 33 percent of inert wastes (CPCB, 2005).However, the quantity and quality of waste generation varies from place to place for various reasons.

The Environmental Protection Act, passed in 1986, aims to protect the environment and build a waste management system. The management of solid waste in India is now guided by the following rules: Solid Waste Management Rules, 2016, Plastic Waste Management Rules, 2011, E-Waste Management Rules, 2011, Biomedical Waste Management Rule, 1998, and Hazardous Waste Management Rules, 1989. The Swachh Bharat Mission (SBM) and the Jawaharlal Nehru National Urban Renewal Mission (JnNURM) have made the most significant contributions to the development of urban areas and the efficient operation of India's cleanliness mechanism. JnNURM, established in 2005, is a seven-year urban city development mission launched by SBM on October 2nd, 2014, to make the country open-defecation-free by 2019. It also provides door-to-door solid waste collection and raises awareness among inhabitants through public engagement. These policies and rules have helped states implement systematic waste management, which has resulted in various cities in India.

2 Objectives

The study has taken two objectives which are given bellows:

1. To study temporal and spatial variation of urban solid waste generation
2. To access level of management in different urban centers

3 Data Base and Methodology

The study is based on secondary data. There are 59 cities listed in 2001 census. The data of solid waste generation from these cities on daily basis were collected from the NEERI and Central Pollution Control Board (CPCB) and population of cities were collected from Census of India. The mechanism and nature of solid waste management in each city were accessed from different journals, research papers and governmental reports. These cities are spatially categorized into 6 regions of India in order to understand broader regional perspectives in solid waste generation and its management which influenced by their region characteristics of education, economic activities, environment, ethnicity etc. Minor statistical techniques were used like calculation of percentage. Map of India and location of cities was drawn with ArcGIS 10.2 version.

4 Study Area

In this study of Municipal Solid Waste generated in urban areas of India, include all the capitals of states and union territories along with all cities in 2001. All together 59 urban centers have been studied. These urban centers have been categorized into six regions based on different physiography, culture and economy. They are Northern region, Western, Southern, Central, Eastern and North Eastern Region. The Northern region and Western region have 12 urban centers each and the Central, Eastern and North Eastern have 8 urban centers. Southern region has 11 urban centers (Figure no. 1).

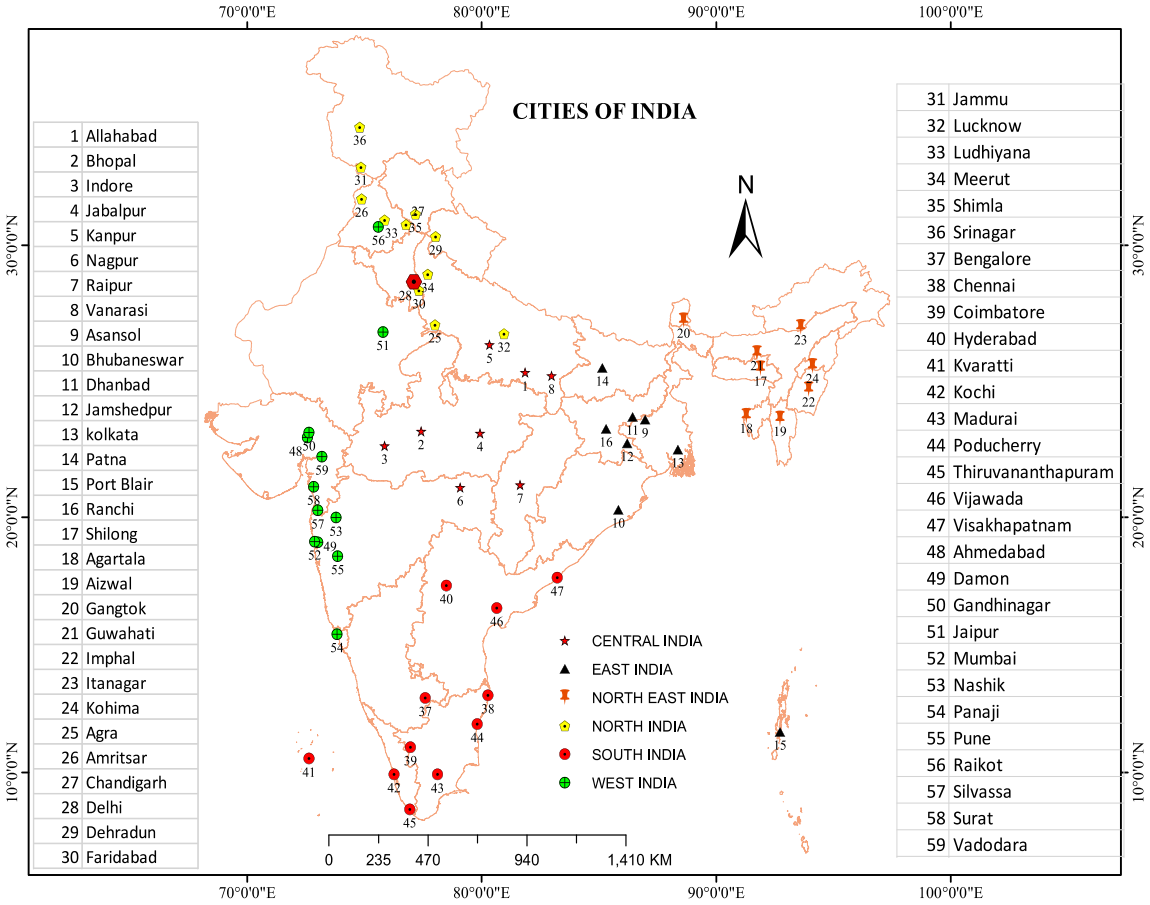

Figure 1. Capitals and Cities of India (Source: Survey of India, 2001)

5 Results and Discussion

5.1 Northern India

Delhi is the top waste-generating capital city, with 6800 tons per day in 2011 compared to 5922 TPD in 2005. According to a recent report, Delhi produced 10817 TPD (tonnes per day) of garbage in 2018–2019, with 10614 TPD collected, 5714 TPD processed, and 5225 TPD landfilled. The municipal corporation principally manages and disposes of its solid waste at the Okhla dumpsite. Delhi has three waste-to-energy plants with a capacity of 5250 TPD at Okhla, Ghazipur, and Bawana, which generate 52 MW of power (CPCB, 2018–2019). The waste is disposed of in four landfills: Bhalswa, Okhla, Gazipur, and Narela/Bawana. Three of these dumps are nearly saturated.

Lucknow, Uttar Pradesh's capital, produces the second biggest quantity of waste in northern India, at 1200 tonnes per day. Every year, the Lucknow Municipal Corporation spends 21% of its entire budget on garbage management (Francis, Singh, and Prakash, 2013). In 2019, 1500 tonnes

of garbage are generated every day, with 60–65 percent collected and disposed of at six disposal sites (Archana et al., 2014).

Shimla produces the least amount of waste among North Indian cities, with 50 tons per day in 2011. Located on a steep landscape, waste management is a very promising narrative for cities like Shimla. Door-to-Door Garbage Collection Bye-laws have been in effect since 2006, under the Himachal Pradesh Municipal Corporation Act of 1994. Shimla's health department guarantees that collected rubbish is transported door-to-door, reaching 86 percent of houses. Shimla Environment, Heritage Conservation, and Beautification (SEHB) partners with Hanjer Biotech Energies Pvt. Ltd. to provide processing, treatment, and disposal facilities. Hazardous waste from hospitals and clinics is also burned at the bio-medical incinerator facility. Proper presorting helps to ensure success, which is subsequently reinforced by the diversion of trash from landfills by in-vessel composting (Bharti et al., 2014).

Table 1. MSW and Population Northern Cities of India

	Cities in North India											
	Agra	Amritsar	Chandigarh	Delhi	Dehradun	Faridabad	Jammu	Lucknow	Ludhiana	Meerut	Shimla	Srinagar
MSW Generation (TPD) 2004-2005	654	438	326	5922	131	448	215	475	735	490	39	428
Census Population - 2001	1,275,134	966,862	808,515	9,879,172	426,674	1,055,938	369,959	2,185,927	1,398,467	1,039,405	142,555	898,440
MSW Generation (TPD) 2010-2011	520	550	264	6800	220	700	300	1200	850	520	50	550
Census Population - 2011	1,585,704	1,132,383	960,787	11,007,835	578,420	1,414,050	503,690	2,815,601	1,618,879	1,305,429	169,578	1,180,570

Source: (CPCB, 2004-2005, 2010-2011 and Census of India, 2011)

5.2 Central India

Kanpur has the largest trash creation rate in central India, at 1600 tonnes per day, while Raipur had the lowest at 224 tonnes per day in 2011. Kanpur Municipal Corporation has been managing trash in conjunction with A2Z Infrastructure Ltd., Gurgaon, since 2002. Today, this 20-year effort has demonstrated significant success in dealing with the waste created. The collection is 90% efficient in the city, with a 50% increase in door-to-door collection. Recycling and reuse have climbed to 85%, and rag pickers now have formal employment. GPRS-enabled devices and GPS systems are used to collect user charges and track vehicles that stop in each of the public bins mapped and tallied by service providers (SBM, 2018). The trash quantification in Allahabad and Bhopal is primarily based on the number of trips a vehicle makes to deliver the waste or on fuel use. As a result, the quantification of trash has declined. Such misleading trash quantities can be observed throughout India, owing to a lack of better waste records with local bodies due to statistical and resource constraints (Dasgupta, 2013).

Table 2. MSW and Population Central Cities of India

	Cities in Central India							
	Allahabad	Bhopal	Indore	Jabalpur	Kanpur	Nagpur	Raipur	Varanasi
MSW Generation(TPD) in 2004-2005	350	350	557	216	1100	504	184	425
Census Population - 2001	975,393	1,437,354	1,474,968	932,484	2,551,337	2,052,066	605,747	1,091,918
MSW Generation(TPD) in 2010-2011	509	574	720	400	1600	650	224	450
Census Population - 2011	1,112,544	1,795,648	1,960,631	1,055,525	2,767,031	2,405,665	1,010,087	1,201,815

Source: CPCB, 2004-2005, 2010-2011 and Census of India, 2011)

5.3 Southern India

Even when the generation is large, waste management in South India has had more success stories than elsewhere in India. Chennai has the largest garbage generation rate in the South Indian

region, at 4500 tonnes per day, followed by Hyderabad at 4200 tonnes per day and Bangalore at 3700 tonnes. Lakshadweep's capital, 6 Karavatti, generates the least amount of rubbish (2 percent). This is because the population is only 11,221 according to the 2011 Census of India. Kochi ranks second with 150 tons per day, followed by Thiruvananthapuram with 250 tonnes per day. One of Kochi's most essential aspects is trash segregation at the source, as well as household composting and bio-methanization procedures. The presence of aerobic bins, biogas plants, organic waste converters, and portable bio-bins in public locations such as marketplaces, building compartments, and housing colonies has made a significant contribution to this. Kudumbasree workers collect rubbish from residences door to door and dispose of it at the waste treatment plant at Brahmapuram, which has a capacity of 220 tonnes per day (Chedambath n.d. 2018).

Thiruvananthapuram is another city that has embraced waste-saving through decentralized garbage management. The single dumpsite in Vilappilsala was thereafter shut down. The Kerala Suchitwa Mission, which began long before the crisis in 2008, has implemented decentralized garbage management since 2013. The 2017 Freedom of Waste Campaign and Green Protocol outlawed non-woven polypropylene bags in addition to single-use plastic bags. Today, Clean Kerala Company operates a resource recovery plant in collaboration with TMC, where plastic and electronic trash are treated (Ramachandran 2019). Furthermore, the Anti-Littering Enforcement Team (ALERT) ensures that no littering occurs in water bodies or public spaces through continual patrolling. These have resulted in 83 percent of total garbage being biodegradable (Henam and Sambyal, 2019).

Despite exceptional examples of efficient waste management in South India, uncertainty and unpredictability have had a negative influence on the Greater Hyderabad Municipal Corporation's implementation of the action plan. Following the removal of all rubbish bins to create a bin-free city, waste is now stacking up along the roadside. It is resolved only once the contract with Ramky Environmental Engineers is operational (Tiwari, 2021).

Table 3. MSW and Population of Southern Cities of India

	Cities in South India										
	Bangalore	Chennai	Coimbatore	Hyderabad	Kavaratti	Kochi	Madurai	Pondicherry	Thiruvananthapuram	Vijayawada	Vishakhapatnam
MSW Generation(TPD) in 2004-2005	1669	3036	530	2187	3	400	275	130	171	374	584
Census Population - 2001	4,301,326	4,343,645	930,882	3,637,483	10,119	596,473	928,869	220,749	368,618	851,282	1,345,938
MSW Generation(TPD) in 2010-2011	3700	4500	700	4200	2	150	450	250	250	600	334
Census Population - 2011	8,425,970	4,681,087	1,050,721	6,809,970	11,210	601,574	1,017,865	241,773	752,490	1,034,358	1,730,320

Source: CPCB (2004-2005, 2010-2011 and Census of India, 2011)

5.4 Western India

Mumbai has the greatest trash generation rate in Western India. It produced 6500 tons per day in 2010–2011. The city generates 5% of the country's GDP. According to the 2009 State of the Environment Report, about 90% of the rubbish in Mumbai was collected. Despite this, more than half of Mumbai's population lives in slums without access to trash services, and there is a severe lack of landfilling. To address this high waste volume, the Maharashtra government enacted the Maharashtra Non-Biodegradable Garbage (Control) Act 2006 for citizens and the Maharashtra Plastic Carry Bags Rules 2006 for producers and sellers to reduce plastic trash (Themelis and Bhada, 2008).

Surat is one of the most productive cities in Western India, producing 1000 tonnes per day. However, trash management has improved since the implementation of the solid waste management project under JnNURM. Currently, 92 percent of waste is collected door-to-door, with 17 percent segregated. Surat Municipal Corporation also has a cooperation agreement with a private partner and operates a 600 TPD waste-to-energy facility (JnNURM, 2013). Surat has the Anudaan initiative, which offers monetary incentives to 600 communities that help sort and segregate trash in their own homes.

Rajkot Municipal Corporation and Ahmedabad Municipal Corporation are two Gujarat cities where waste management has led the way in the development of efficient waste legislation for both homes and solid waste management staff. Attendance logging using face recognition and an automatic sweeping machine is one of the first of its sort in India under SWM. The GPS system tracks not only the trucks but also the amount of work completed. Waste is disposed of on designated lands in the three municipal corporations, namely Ahmedabad, Surat, and Rajkot, in accordance with the City Development Plan (CDP), which are 1048 acres, 2718 acres, and 100 acres, respectively.

According to the 2011 Indian Census, Pune is India's ninth-most populous city and Western India's third largest trash generator. A significant approach to waste management in Pune is the inclusion of rubbish pickers in the Kagad Kach Patra Khastakari Panchayat (KKPKP), which was established in 1993. In 2008, the Pune Municipal Corporation began another move, approving solid waste collection and handling to improve door-to-door collection. By 2013, it had served 390,000 properties, and by 2016, it had reached 640,000 with the assistance of 3,000 rubbish pickers. Today, waste collection exceeds 87.5 percent, the composition of waste is 74.2 percent biodegradable, and plastic waste generation is just 8.31 percent (Moora and Barde, 2019).

Table 4. MSW and Population of Western Cities of India

	Cities in West India											
	Ahmedabad	Daman	Gandhinagar	Jaipur	Mumbai	Nashik	Panjim	Pune	Rajkot	Silvassa	Surat	Vadodara
MSW Generation(TPD) in 2004-2005	1302	15	44	310	5320	200	25	1175	207	16	1000	357
Census Population - 2001	3,520,085	35,770	195,985	2,322,575	11,978,450	1,077,236	59,066	2,538,473	967,476	50,463	2,433,835	1,306,227
MSW Generation(TPD) in 2010-2011	2300	25	97	904	6500	350	32	1300	230	35	1200	600
Census Population - 2011	5,570,585	44,282	206,167	3,046,163	12,442,373	1,486,053	70,991	3,115,431	1,286,678	98,265	4,467,797	1,670,806

Source: CPCB (2004-2005, 2010-2011 and Census of India, 2011)

5.5 Eastern India

Kolkata generates the most trash in the region, accounting for 75% of total generation across Eastern India's cities. Port Blair had the lowest trash generation rate in 2010–2011, at 45 tons per day. Kolkata is one of India's metropolitan cities, with a population of more than 14.1 million according to the Census of India, making it the third most populated metropolitan metropolis. The garbage collection area is limited to 60%, despite the fact that KMC spends 70–75% of its waste budget on collecting alone, 25–30% on transportation, and less than 5% on disposal of collected material. The waste is disposed of at the Dhapa disposal ground, which is located in Garden Reach. For hazardous waste handling, the West Bengal Control Board and the Haldia Development Authority built a 28-hectare complex in Haldia, 150 kilometers from the KMC area. Patna, Bihar's capital city, is one of the most inefficiently managed cities in terms of garbage. According to the 2011 Census of India, the population is 1,683,200. However, Table 5 reveals that trash generation decreased between 2005 and 2011, owing to a lack of resources. According to the NSWAI city study, trash generation would exceed 1500 tonnes per day by 2021 (Pandey, 2014). After a public-private partnership with A2Z Infrastructure Ltd., New Delhi, the UD&HD of Bihar worked in waste collection and treatment for one and a half years, which was eventually discontinued due to a lack of funding, and the same was assigned to Bihar Urban Infrastructure Development Corporation Ltd. (BUIDCO) in 2012 with Jindal ITF Urban Infrastructure Limited on a PPP basis, which was cancelled before the work began (Pandey, 2014). Patna Municipal Corporation currently allots 80 acres of land in Bairia for rubbish disposal. However, 75 percent of houses and 80 percent of commercial buildings and stores dump trash on public roadways. (Solid Waste Management in Patna, 2014). Patna is the dirtiest city among cities, with a population of over one million (Swachh-Survekshan, 2020).

Table 5. MSW and Population of Eastern Cities of India

	Cities in East India							
	Asansol	Bhubaneshwar	Dhanbad	Jamshedpur	Kolkata	Patna	Port Blair	Ranchi
MSW Generation(TPD) in 2004-2005	207	234	771	280	3670	220	45	140
Census Population - 2001	475,439	648,032	1,065,327	573,096	4,572,876	1,366,444	108,058	1,079,968
MSW Generation(TPD) in 2010-2011	210	400	150	338	2653	511	76	208
Census Population - 2011	564,491	837,737	1,162,472	631,364	4,486,679	1,684,222	140,572	1,456,528

Source: CPCB (2004-2005, 2010-2011 and Census of India, 2011)

5.6 North Eastern India

According to Table 6, among all the north-eastern cities studied, Guwahati produces the most municipal solid trash, while Gangtok and Kohima produce the least as of 2011. In Guwahati, larger corporate entities such as Indian Oil, Guwahati Refinery, and others have their own waste treatment systems. Despite this, Guwahati has a per capita garbage generation rate of 606 grams per day. West Boragaon is the city's only dumping site, yet it is inefficient for municipal solid waste generation. Furthermore, open dumping on the roadside and drainage system is common here (Gogoi, 2013).

In 2004–2005, Itanagar produced the least of all these cities. However, by 2011, the generation had grown by nearly tenfold. This is mostly due to the pull effect of the capital city, where population growth is consistent and garbage disposal is routinely performed through haphazard dumping, a lack of segregation methods, and a lack of scientific engineering in landfills. Imphal now produces the second biggest amount of trash generation in this region, at 15%, with disposal occurring haphazardly in the low-lying terrain at Lamphelpat. Although Aizwal generates 13% of the region's waste, the management system has taken the lead in addressing it. The authorities have launched pilot projects in several localities, with an investment of Rs 15 lakh for garbage facility building and infrastructure. There is also proper garbage segregation, with pickers receiving systematic segregation training (Centre of Science and Environment, 2016). Shillong alone sustains 82% of the total population in 14 percent of the whole geographic area. As a result, trash creation is extremely high. However, appropriate waste management is deficient, with just 45.91 percent (78.42 MT) of waste collected and disposed of in the 5-acre Marten sanitary landfill, which is insufficient for the Greater Shillong Planning Area. (Mipun et al., 2015) The general scenario in north-east India remains unsuitable for waste management, with less than 70% of rubbish collected and less than 20% processed and recycled (Centre of Science and Environment, 2016).

Table 6. MSW and Population of North Eastern Cities of India

	Cities in North-East India							
	Agartala	Aizwal	Gangtok	Guwahati	Imphal	Itanagar	Kohima	Shillong
MSW Generation(TPD) in 2004-2005	77	57	13	166	43	12	13	45
Census Population - 2001	189,998	228,280	29,354	809,895	221,492	35,022	77,030	132,867
MSW Generation(TPD) in 2010-2011	102	107	45	204	120	71	45	97
Census Population - 2011	399,688	291,822	100,286	957,352	264,986	59,490	115,283	143,229

Source: CPCB (2004-2005, 2010-2011 and Census of India, 2011)

According to the data above, South India generates the most garbage, followed by the Western and Northern regions (Figure 2). The northeastern area of India makes the least contribution. However, the quantification of waste in the records is quite inconsistent. This is due to a shortage of resources in urban local authorities, which prevents regular and efficient garbage account collection (Mani and Singh, 2016).

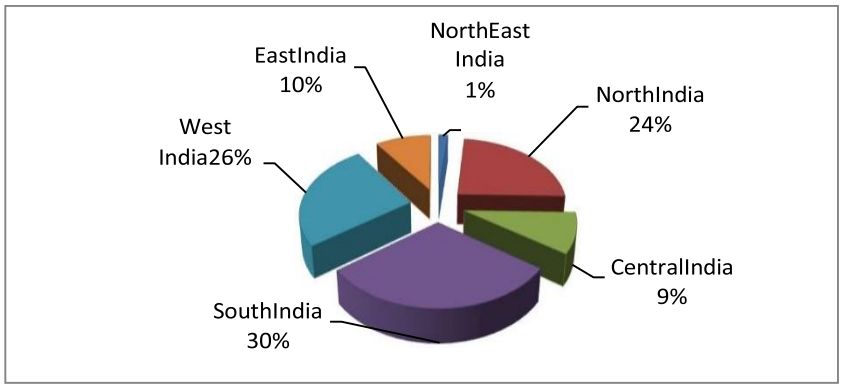

Figure 2. Distribution of generation of MSW in India

6 Conclusion

The Golden Quadrilateral cities of India, which include Chennai, Mumbai, Delhi, and Kolkata, generate the most rubbish. It has also been noticed that the population growth in cities is not necessarily proportional to the amount of waste produced. Delhi contributes 32% of the garbage among these four metropolitan cities, followed by Mumbai (30%), Chennai (21%), and Kolkata (17%). However, the population of these four cities reveals that Mumbai has a higher population count.

The bulk of Indian cities continue to use open dumping and burning to dispose of rubbish. While the bulk of western countries have already begun to address the diseases of affluence, India continues to suffer with waste collection and transportation (Kumar 2016). The overall scenario of waste management in Indian cities is such that there is no consistent and single super model to achieve the same outcome because, despite a similar growing consumerism pattern of globalization, there are subtle differences in the ways that people live, and as suggested by Mani and Singh (2016), rather than focusing solely on technical solutions, the focus should shift to the behavior of citizens, policymakers, and elected representatives.

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