# Municipal Solid Waste Management in Developed Countries and India - An overview of current practices, challenges, opportunities, and threats

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**Abstract**

Waste Management has become a burning issue all over the world for the last few decades. The repercussions of many years of unrestricted and irresponsible industrialisation, globalisation, and consumerism are being faced today. Many countries have started taking precautions to reduce the dire environmental and health effects caused by improper and irrational waste management. This paper's primary objective is to analyse the Indian municipal solid waste management systems (MSWs), their challenges, threats, current systems in place, and, more importantly, to understand the opportunities to improve and implement better strategies. However, it is also essential to understand how developed countries are faring with managing their waste and where India stands in comparison globally. In this paper, waste generation and the composition statistics of 5 selected countries - the USA, Canada, Germany, China, and India, are also evaluated with an overview of their respective management practices.

**Keywords –** Solid Waste Management, Municipal Solid Waste, Energy Recovery, Recycle, Circular Economy, Waste Segregation, Waste Composition, Waste-To-Energy, Waste Management Practices, Informal Sector

## 1. Introduction

Waste is a material or by-product that is eliminated or discarded as no longer applicable or required after completing a process and, waste management is its monitoring, transportation, treatment, recycling or disposal. The waste of one process can be a core ingredient or catalyst of another process. With the rapid growth in urbanisation and globalisation, there is an exponential increase in the amount of waste generated worldwide.

Waste can be categorised into multiple types: Municipal Solid Waste (MSW), Construction & Demolition Waste, Hazardous Waste, Bio-medical Waste, E-Waste, Plastic Waste, Radioactive and Battery Waste. This paper will mainly review the Municipal Solid Waste management generation and practices adopted by some of the world's major countries: the USA, Canada, Germany, China, and India. However, the focus will be on the key takeaways for India compared with other countries and what strategies we should be adopting or creating moving forward by following the precautionary principle if necessary.

MSW consists of various types of waste: recyclable, biodegradable, non-biodegradable, inert, and hazardous materials, mostly from commercial and domestic households. However, each

country may have its way of defining MSW, e.g., India has excluded C&D waste from MSW since introducing the new 2016 MSW rules (MoEF, 2016a)

Over the last few years, waste management has received much attention from all the countries due to its extreme impacts on the environment, health, and potential long-term economic effects. Waste management failure can be associated with an unchecked, rising population, indiscriminate consumption of resources, lack of awareness about hygiene, the poor policies implemented by the government, and public irresponsibility in abiding by the rules.

## 2. Research Methodology

The type of research adapted in this paper is descriptive methodology. Below, Section 2 will cover an overview of the MSW management scenario in India, The United States, Germany, Canada and China by presenting the figures and comparing the waste generated, its composition, and management practices. Further, section 3 presents the highlights of waste management in India, followed by Section 4, which will explore future opportunities, challenges, and threats in the waste management systems of India.

The data used for the purposes of this paper is from secondary data only. The data of the five countries have been gathered from various sources such as newspaper articles, blogs, journals, websites, government surveys & reports and are compiled for this study. In this paper, there are 35 such references from sources mentioned above.

The data collected will be used to analyze and compare the waste management practices and techniques, waste generation and waste composition of the mentioned countries. Among other authentic sources, data from Ministry of Housing and Urban Affairs (MoHU) of government of India has been used to analyze performance of Indian states too.

## 2. Municipal Solid Waste Management Scenario around The World

A study by the World Bank Group of 2016 (Kaza et al., 2016) suggests that the world generates 2.01 billion tonnes of municipal solid waste annually, which will likely grow to 3.40 billion tonnes by 2050. At present, the waste generated worldwide per capita ranges from 0.11 to 4.54 Kilograms.

The type and amount of waste generated by a country or a state depend on various factors such as its population, lifestyle, culture, day-to-day economic activities, geographic location, and socioeconomic status. In contrast, its management depends on the government's intellect, awareness, sensitivity, and citizens' cooperation.

According to the World Bank Group study, the highest per-capita waste generated is always by the countries or states with a high average income and vice-versa. The simple reason for this is that with more money, the affordability and scope of consumption increase, leading to extra waste generation. Some of the significant waste generators in the world are developed countries like Canada, the USA, China, Germany, and a developing nation like India.

### 2.1 Waste Generation in USA, Canada, Germany, China, and India

In 2018, the USA generated 292.4 Million Tons of Municipal Solid Waste despite having a population of only 327 Million (See Figure 1). Figure 2 illustrates the total waste and per capita waste generated in these countries. The per capita waste generation of the USA is 2.24 kg/day, which is very high considering the global average, which is 0.74kg/day. The total waste generated in 2018 increased by 9% from the previous period when the waste generated was 268.7 Million, according to a report by Environment Protection Agency (EPA) (EPA, 2018). According to sensonseo global waste Index 2019 (Sensonseo, 2019), the USA had the highest per capita waste generation globally in 2019.

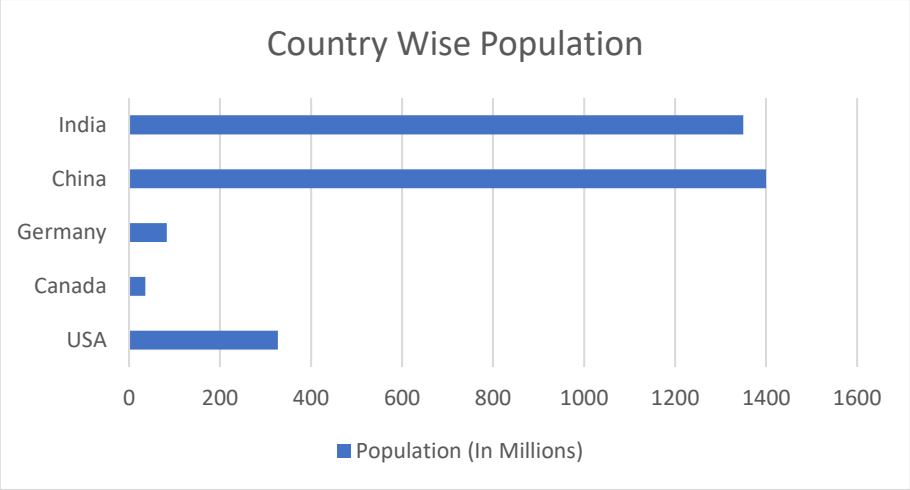


Figure 1. The population of India, China, Germany, Canada and the USA (Adopted from Worldometer, 2021)

Canada generated 34 Million Tons of MSW in 2016 with a population of 36 Million (ECCC, 2020), and their per capita waste generation stood at 1.94kg/day. While the per capita waste generation is high, Canada's overall waste generation is also estimated to be one the highest in the world.

MSW generated by Germany in 2018 was 50.3 MT (UBA, 2020), and their per capita waste generation was at 1.72 kg/day for a population of 83 Million. Thus, despite their low population, they too have a very high per capita waste generation.

On the contrary, countries like China and India, with very high populations, 1.4 Billion and 1.35 Billion, have a low per capita waste generation, 0.43 kg/day and 0.54 kg/day, respectively, compared to the global average. In 2015, China generated 220 MT of solid waste (Kaza et al., 2016), and India generated 62 MT of waste according to data released by the Press Information Bureau of Government of India (PIB, 2020) in 2020.

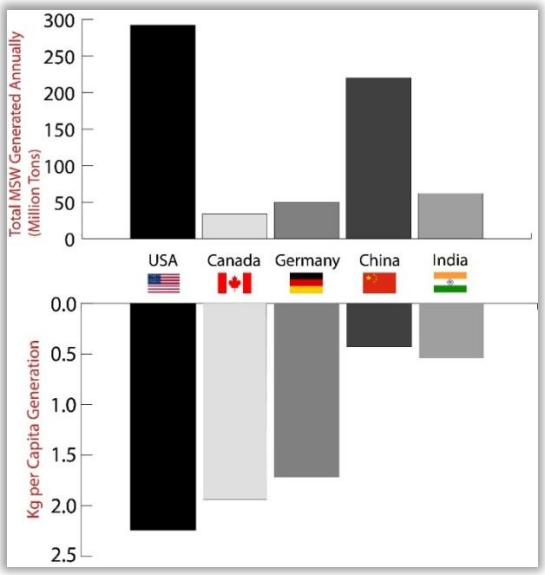


Figure 2. Total Municipal Solid Waste Generated and the per capita generation in the countries (Adopted From (EPA, 2018), (ECCC, 2020), (BMU, 2018), (Zhu, Y et al., 2021), (Planning Commission, 2014))

### 2.2 Composition of The Waste

Analysing the composition of waste is vital in determining and planning the waste management strategies of the countries. Composition of waste is highly influenced by the lifestyles and consumption choices of the citizens, along with their commercial activities. The data of MSW generated in each of the five countries is given below. Since each country has its own definition and parameters for MSW, different countries may have different categories of waste.

| **Country (Year)** | **Food & Green (Biodegradable)** | **Paper& cardboard** | **Glass** | **Plastic** | **Metal** | **Rubber, Textiles & leather** | **Wood** | **Other (Inorganic, bricks, Inert Etc.)** |
|---|---|---|---|---|---|---|---|---|
| **USA (2018)** | 33.70% | 23.05% | 4.19 % | 12.20 % | 8.76% | 8.96% | 6.19 % | 2.95% |

Table 1. The physical composition of MSW waste generated in the USA (Adopted From EPA, 2018)

According to the Environment Protection Agency (EPA, 2018), in 2018, the bulk of the waste generated in the USA came from food & other biodegradables and paper & cardboard, which covered a total of 33.7% and 23.05%, respectively. Plastic constituted 12.2% of the total waste generated, whereas the waste generated by wood, metal, and rubber, textiles, and

leather was 6.19%, 8.76% and 8.96%, respectively. Glass waste also made a significant contribution at 4.19%. See Table 1.

| **Country (Year)** | **Food & Green (Biodegradable)** | **Paper** | **Glass** | **Plastic** | **Metal** | **Rubber, Textiles & leather** | **Wood** | **Building Material** | **Hazardous and Electronic Waste** | **Pet Waste and Diaper Waste** | **Other (Organic and Inorganic)** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Canada (2016)** | 27.7% | 10% | 1.8% | 13.4 % | 3.2% | 2.7 % | 11% | 8.6% | 2.9% | 6.1% | 12.4% |

Table 2. The physical composition of MSW waste generated in Canada (Adopted From ECCC, 2020)

On the other hand, in 2016, Canada's Food & biodegradables and paper & cardboard waste covered 27.7% and 10%, respectively. Wood and plastic waste covered a total of 11% and 13.4%, respectively. Building material accounted for 8.6%, whereas metal, glass, rubber, textiles and leather, contributed a small amount each, i.e., 3.2%, 1.8% and 2.7 %, respectively. There are other organic and inorganic wastes that Canada generated, which accounted for a total of 12.4%. Pet waste and Diaper waste accounted for 6.1% of total waste generated. Hazardous and Electronic Waste contributed 2.9%. This data is collected from the ECCC (Environment and Climate Change India) (ECCC, 2020). See Table 2.

Although the statistics provided above are of different years, we can see how differently the neighbouring North American countries report their MSW data and how the consumption is also different.

| **Country (Year)** | **Household, Household like commercial waste and Other Biodegradable (Garden and Park waste)** | **Paper** | **Plastics and Light packaging** | **Waste from bio-bins** | **Bulky Waste** | **Glass** | **Other (Composites, metals, textiles etc.)** | **Electrical and Electronic components** |
|---|---|---|---|---|---|---|---|---|
| **Germany (2015)** | 43.3% | 17.6% | 13% | 9.1% | 5.4% | 5.4% | 4.6% | 1.3% |

Table 3. The physical composition of MSW waste generated in Germany (Adopted From BMU, 2018)

In 2015, The European country, Germany, generated more than half of their waste in the form of biodegradables and Household waste (43.3%) and paper (17.6%). Plastic and packaging waste contributed 13%, whereas the waste from glass, bio-bins and bulky waste material was 5.4%, 9.1% and 5.4%, respectively. 1.3% and 4.6% of total waste were covered by electrical & electronic components and other wastes such as metals, textiles, composites, Etc. (BMU, 2018) See Table 3.

| **Country (Year)** | **Food & Green (Biodegradable)** | **Paper** | **Glass** | **Plastic and rubber** | **Metal** | **Textiles** | **Wood** | **Dust and Bricks** | **Hazardous Waste** | **Others** |
|---|---|---|---|---|---|---|---|---|---|---|
| **China (2017)** | 46.8% | 11.3% | 3.3% | 12.5% | 1.1% | 3.5% | 3.2% | 16.2% | 0.9% | 1.3% |

Table 4. The physical composition of MSW waste generated in China (Adopted From Zhu, Y et al., 2021)

Having the highest population in the world, in 2017, China generated almost half of its waste through bio-degradable (46.8%). 16.2% of total waste generated was of dust and bricks, paper and plastic and rubber contributed 12.5% and 11.3, respectively. Materials such as Glass, Metal, Textiles, Wood and Hazardous waste covered 3.3%, 1.1%, 3.5%, 3.2% and 0.9%, respectively. (Zhu, Y et al., 2021) See Table 4.

| **Country (Year)** | **Food & Green (Biodegradable)** | **Paper** | **Plastics and Rubber** | **Metal** | **Glass** | **Rags** | **Others (Inerts etc)** |
|---|---|---|---|---|---|---|---|
| **India (2011)** | 52.3% | 13.8% | 7.9% | 1.5% | 0.9% | 1% | 22.6% |

Table 5. The physical composition of MSW waste generated in India (Adopted From Planning Commission, 2014)

With about 1.35 billion people, second only to China, in 2011, 52.32% of the total constituted biodegradable waste. 13.8% of waste comprises paper, whereas plastics & rubber, metal, glass and rags waste contributed 7.9%, 1.5%, 0.9% and 1%, respectively. Other materials such as inerts covered a total of 22.6% (Planning Commission, 2014). See Table 5.

The above tables give us a clear indication of the kind of consumption prevalent in each country.

Biodegradable waste contributed the most to the overall Municipal Solid Waste generated by each country. Paper & cardboard waste was significant in countries like the USA and Germany, whereas plastic waste had an almost equal share in all the nations. Each country also generated a considerable amount of inorganic and inert waste, among others.

**2.3 Management Practices**

Different countries have adopted different methods to tackle their respective waste management crisis depending on their economic capability, data available, and their seriousness to address the situation. However, to manage waste and maintain a circular economy, most countries follow the 3 R's strategy to reduce, reuse, recycle, or the waste management hierarchy.

Despite various technological advancements in the USA, they still have not found appropriate solutions to their waste problem as around 50% of their waste is landfilled, only about 23.6 % is recycled, 8.5 % composted, and 11.8 % combusted or incinerated with energy recovery (EPA, 2018). In the past, the USA also sent a lot of their solid waste to China for recycling, but that has been discontinued as China no longer imports discarded plastics, yarn, cotton, ash, waste wool, slag from steelmaking, or paper. (Katz, 2019)

According to the National Waste Characterization Report (ECCC, 2020), Canada has a shocking rate of 73% of waste that is sent to landfills. The remaining 27% was recycled, composted, or sent to WTE plants. Canada had about 10,000 landfills in 2019.

Germany has been a leader in managing waste. Though it operates with a small population compared to other countries, it intends to minimise or prevent waste by taking early precautionary measures. Since mid-2005, landfilling of untreated organic waste has been banned in Germany. In 2017, they had 68 waste incineration plants, 32 substitute fuel plants, 45 bio-mechanical waste treatment plants and, about 0.5 million tonnes of waste were landfilled (BMU, 2018). They had one of the best recycling rates of 67% as of 2018 (UBA, 2020). They also follow the circular economy approach, which aims at extending the life cycle of products and reducing waste to a minimum by reusing, repairing, and refurbishing used products, thereby providing an economic value for the product at every stage. (Statusbericht, 2020)

The waste generated in China is mainly sent to landfills (Approx. 53%), and around 30% of the waste is incinerated. It is unclear how much of its waste China recycles, but they aimed to recycle about 35% by the end of 2020. (BBC, 2019)

77% of India's waste is found in open dumps and landfills, which is very unhygienic, as this is where the informal sector or the rag pickers segregate the waste for the recyclables and hand it over to the municipal authorities. Only around 5% of India's waste is recycled, and 18% is composted (TOI, 2020). India has about 22 functional landfill sites according to the

2020 -21 annual report by the Ministry of Environment, Forest & Climate Change (MoEF). (MoEF, 2021) (see Figure 3)

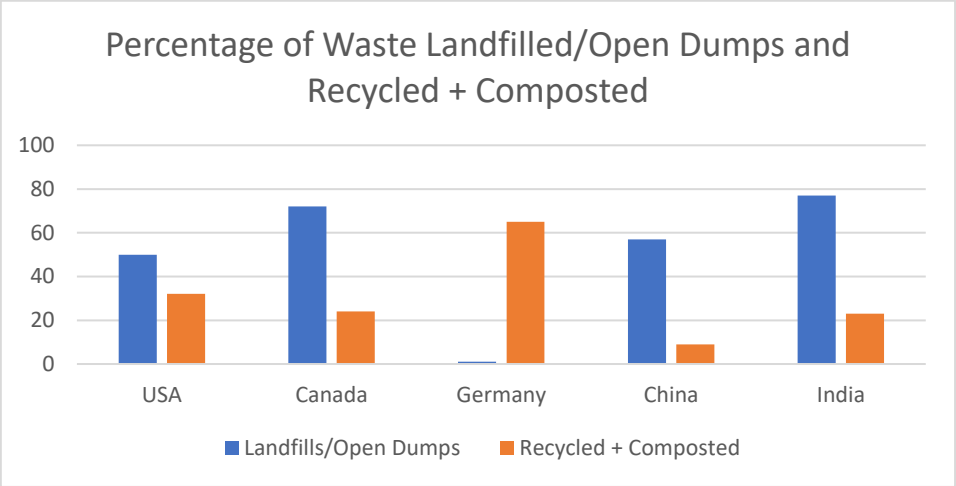


Figure 3. Percentage of Waste Landfilled/Open Dumps and Recycled + Composted (Adopted From (EPA, 2018), (ECCC, 2020), (BMU, 2018), (UBA, 2020), (Statusbericht, 2020), (Katz, 2019), (BBC, 2019), (TOI, 2020), (MoEF, 2021))

## 3. Highlights of Waste Management in India

Although India's per capita waste generation is well below the global average, the overall waste is high due to its population. So far, we have not been very successful in managing our waste appropriately or efficiently. In India, municipal solid waste is governed by the Solid Waste Management Rules, which saw significant amendments in 2016. One of the major highlights of the amendments was to make source segregation compulsory (Kaza et al., 2016). The SWM rules were first framed in the year 2000 in response to a PIL filed by Almitra Patel in 1996 against the open dumps and improper or non-existent waste management practices in India at that time (The Hindu, 2016). The introduction of Swachh Bharat Abhiyan in 2014 also significantly impacted and enhanced the awareness of the issue. Since then, a lot has been invested by states in waste management.

### 3.1 Budget Allocation

| **Budget Allocation for Swachh Bharat Mission** | |
|---|---|
| **Year** | **Investment Allotted** |
| 2021-2026 | 1,41,678 Crores (Approx. 28,335 Crores/Year) |
| 2020-2021 | 12,300 Crores |
| 2019-2020 | 12,644 Crores |
| 2018-2019 | 15,373 Crores |
| 2017-2018 | 16,248 Crores |
| 2016-2017 | 11,300 Crores |

Table 6. Budget allocation for the Swachh Bharat Mission by the Government of India (Adopted From MoF, 2021)

Since 2014, the GOI has invested vast amounts of money in Swachh Bharat Mission, as shown in Table 6. It had slightly reduced its budget allocation from 2018 – 2020 compared to its previous year, where the highest funding came in 2017. In the most recent budget, i.e., of 2021, there was a massive allocation of 1,41,678 Crores for five years, i.e. about 28,335 Crores per year, increasing 15,000 crores compared to 2020 (MoF, 2021). These funds need to be utilised with extreme caution by identifying and investing in the areas where India needs to improve and focus on. This can be done by analysing the present condition of each state and its cities in collaboration with various stakeholders such as ULB's, residents, NGO's, the informal sector, and the private sector. It is vital and challenging as India is one of the most diverse countries globally, and hence it is also important to consider everyone's interests.

### 3.2 State-wise performance

Ideally, the best practice to manage waste would be segregating the waste at its source and handing it over to the municipality to be recycled or treated appropriately. The Indian states and their respective governments, municipalities, and citizens play an important role in implementing such strategies and eradicating the waste problem.

As given in table 7, the rate of waste generation among urban areas is the highest in Maharashtra, followed by other economically developed and high-income states, such as Uttar Pradesh, Tamil Nadu, Delhi, Gujarat, Karnataka, Telangana, and West Bengal. These are the states that need the most attention as they contribute the most waste overall. The door-to-door waste collection in these states is good, although 100% has not been achieved. It is also crucial to monitor how often the waste is collected and if it is done efficiently.

Source segregation is still yet to be adopted by everyone as only half of the wards of the above nine states seem to be practising it currently. Nevertheless, it is critical for success as it reduces the work that needs to be done later by the municipality, which can usually get very complicated even with the help of machines.

In most of these states, more than half of the waste is processed. West Bengal, however, has only a 9% processing rate which is extremely low. Gujarat and Madhya Pradesh have an excellent processing rate of 87%. The overall processing rate of India's urban areas is just 60%. Nevertheless, this is a significant improvement compared to 18% at the beginning of 2016. Most of the waste is still dumped in open areas in India and is burnt periodically, causing massive environmental impacts. The total no. of waste processing facilities set up is 2028, but only 160 are functional as per the Annual report of the Ministry of Environment, Forest and Climate Change (MoEF). (MoEF, 2021)

| S.No. | State | Total Wards (Nos.) | Ward With 100% Door-to-Door collection (No's) | Ward With 100% Source Segregation (No's) | Total Waste Generated (Metric Ton Per Day) | Total Waste Processed (Metric Tone Per Day) | Total Waste Processing (%) |
|---|---|---|---|---|---|---|---|
| 1 | Andhra Pradesh | 3,409 | 3,409 | 3,300 | 6,141 | 3850 | 63% |
| 2 | Andaman and Nicobar | 24 | 24 | 23 | 90 | 86 | 95% |
| 3 | Arunachal Pradesh | 75 | 75 | 11 | 181 | 0 | 0% |
| 4 | Assam | 943 | 698 | 368 | 1,432 | 759 | 53% |
| 5 | Bihar | 3,377 | 3,276 | 1,107 | 2,272 | 1,159 | 51% |
| 6 | Chandigarh | 26 | 26 | 24 | 479 | 455 | 95% |
| 7 | Chhattisgarh | 3,217 | 3,217 | 3,217 | 1650 | 1,485 | 90% |
| 8 | Daman & Diu | 28 | 28 | 28 | 32 | 24 | 75% |
| 9 | Dadra & Nagar Haveli | 15 | 15 | 15 | 55 | 55 | 100% |
| 10 | Delhi | 294 | 294 | 59 | 10,500 | 5,775 | 55% |
| 11 | Goa | 217 | 217 | 173 | 250 | 175 | 70% |
| 12 | Gujarat | 1,427 | 1,427 | 1,187 | 10,274 | 8,938 | 87% |
| 13 | Haryana | 1,496 | 1,401 | 935 | 4,783 | 2,296 | 48% |
| 14 | Himachal Pradesh | 497 | 490 | 490 | 377 | 294 | 78% |
| 15 | Jammu and Kashmir (Including Leh & Ladakh) | 1,081 | 809 | 137 | 1,489 | 238 | 16% |
| 16 | Jharkhand | 932 | 897 | 752 | 2,135 | 1,281 | 60% |
| 17 | Karnataka | 6,464 | 6,464 | 3,694 | 10,000 | 5,400 | 54% |
| 18 | Kerala | 3,536 | 3,022 | 3,536 | 2,696 | 1,914 | 71% |
| 19 | Madhya Pradesh | 7,115 | 7,115 | 7,005 | 6,424 | 5,589 | 87% |
| 20 | Maharashtra | 7,322 | 6,590 | 6,346 | 22,080 | 12,806 | 58% |
| 21 | Manipur | 306 | 270 | 196 | 174 | 101 | 58% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **22** | **Meghalaya** | **114** | **27** | **27** | **268** | **10** | **4%** |
| **23** | **Mizoram** | **264** | **264** | **230** | **236** | **83** | **35%** |
| **24** | **Nagaland** | **234** | **148** | **30** | **461** | **277** | **6%** |
| **25** | **Odisha** | **2,024** | **2,009** | **1,402** | **2,721** | **1,306** | **48%** |
| **26** | **Puducherry** | **122** | **122** | **116** | **415** | **55** | **13%** |
| **27** | **Punjab** | **3,123** | **3,064** | **2,664** | **4,100** | **2,501** | **61%** |
| **28** | **Rajasthan** | **5,389** | **5,389** | **4,419** | **6,500** | **4,680** | **72%** |
| **29** | **Sikkim** | **53** | **53** | **50** | **89** | **62** | **70%** |
| **30** | **Tamil Nadu** | **12,814** | **12,429** | **10,891** | **15,437** | **10,497** | **68%** |
| **31** | **Telangana** | **2,112** | **2,020** | **1,008** | **8,634** | **6,735** | **78%** |
| **32** | **Tripura** | **310** | **277** | **243** | **450** | **239** | **53%** |
| **33** | **Uttar Pradesh** | **12,007** | **11,872** | **8,294** | **15,500** | **8,990** | **58%** |
| **34** | **Uttarakhand** | **1,170** | **1,170** | **669** | **1,589** | **731** | **46%** |
| **35** | **West Bengal** | **2,938** | **2,527** | **558** | **7,700** | **700** | **9%** |
| **Total/Average** | | **84,475** | **81,135** | **63,204** | **1,47,613** | **89,545** | **60%** |

Table 7. Statistics of waste generation, processing and door-to-door collection from wards in the Indian States (Adopted From MoEF, 2020)

Since 2016, the government has also been very proactive in rewarding the cities practising efficient waste management strategies by monitoring them with surveys and feedback of the citizens through Swachh Survekhsan (MoHU, 2021). In the latest report of 2020 (MoHU, 2020), Indore was declared the cleanest city of India for the fourth consecutive time. Among 25 states, Chattisgarh was the best-performing state with 3293.5 points out of 6000, followed by Maharashtra with 2995.3 points (See Figure 4). According to a recorded statement of the Minister of MoEF in 2015, India's waste generation is expected to grow to 165 Million Tonne by 2030 and 450 Million Tonne by 2050 (Indian Spend, 2017). Therefore, immediate measures need to be taken to flatten this curve.

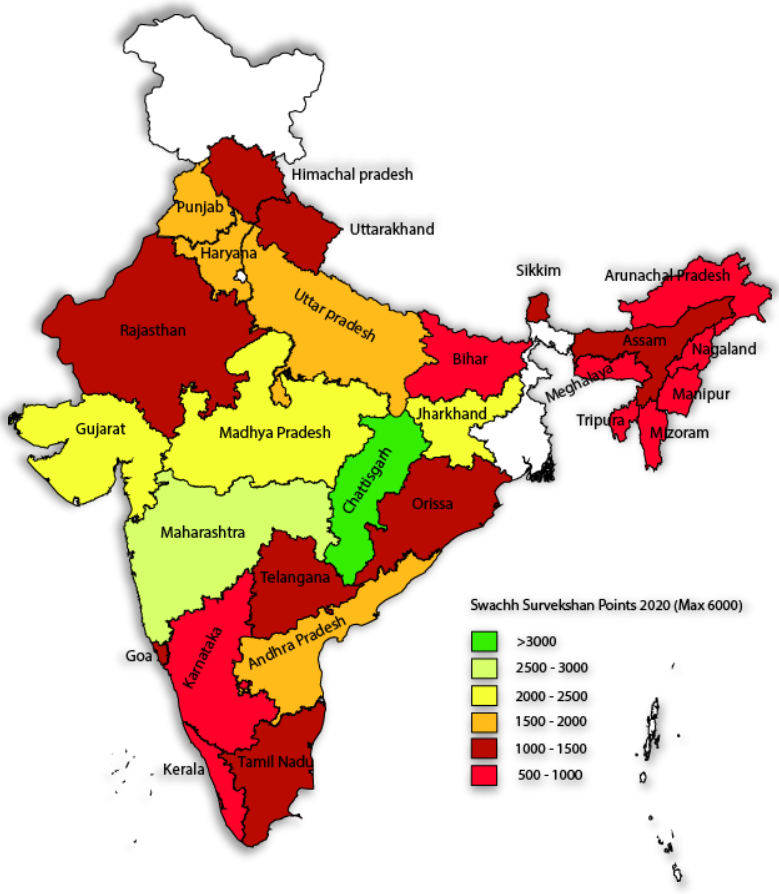


Figure 4. State Wise Swachh Survekshan Points for 2020. (Adopted From MoHU, 2020)

### 3.3 Waste Recycling Plants in India

Recycler plants play an essential role in managing waste as recycling materials will eliminate the need to exploit new materials, reduce pollution and energy consumption, minimise landfills and open dumps, and provide income options for various sectors.

Setting up a recycler plant to process around 300 MT of waste can cost around 30 crores but can vary from 1 crore to 150 crores or even more depending on the technology used and amount of waste processed. This also provides an opportunity to make money by recycling. (The Hindu, 2020)

As given in table 8, India has 312 dismantler/recycler plants with an overall capacity of 7,82,093 MT annually. Furthermore, most plants belong to Karnataka, Uttar Pradesh, Maharashtra, Rajasthan, Haryana, Gujarat, and Tamil Nadu, which also happen to be the highest waste generators. There needs to be better infrastructure and efficiency as India's recycling rate only stands at 5% despite generating 10%-20% recyclable waste. The rate of waste collection also needs to improve since it can directly impact the recycling rate.

| S.No. | State | Number of Authorised Dismantler/Recycler | State Wise Capacity (Million Tons Per Annum) |
|---|---|---|---|
| 1 | Andhra Pradesh | 1 | 480 |
| 2 | Chhattisgarh | 1 | 600 |
| 3 | Goa | 1 | 103 |
| 4 | Gujarat | 16 | 49053 |
| 5 | Haryana | 28 | 87378 |
| 6 | Himachal Pradesh | 1 | 1000 |
| 7 | Jammu and Kashmir (Including Leh & Ladakh) | 1 | 165 |
| 8 | Karnataka | 71 | 52722 |
| 9 | Madhya Pradesh | 2 | 9600 |
| 10 | Maharashtra | 75 | 78192 |
| 11 | Odisha | 3 | 3680 |
| 12 | Punjab | 3 | 4850 |
| 13 | Rajasthan | 26 | 90769 |
| 14 | Tamil Nadu | 24 | 97271 |
| 15 | Telangana | 11 | 41493 |
| 16 | Uttar Pradesh | 41 | 243627 |
| 17 | Uttarakhand | 4 | 19250 |
| 18 | West Bengal | 3 | 1860 |
| Total | | 312 | 7,82,093 |

Table 8. State-wise recycling capacity (Adopted From MoEF, 2020)

### 3.4 Open Dumps and Informal Sector

India is estimated to have about 2 - 4 million waste picker families (The News Minute, 2017). Moreover, since India has more than 70% of open dumps and much littering, the role of the rag pickers becomes crucial as they are estimated to collect about 56% of the recyclable materials (CPHEEO, 2016a). It also comes with significant health concerns as most of the waste is disposed of unsatisfactorily and can have dire impacts on the health of anyone who comes in contact. These dumps are located in the outskirts and within a city and almost in every locality. Dumps also take a lot of land area, which otherwise could have been used to

build other important structures. MoEF estimates that there are about 3159 dumpsites in the country, and these dumpsites are significant contributors to air pollution by releasing methane and contaminating groundwater (MoEF, 2021). Dumps become a bigger problem as only 74% of wards in India practice 100% source segregation, meaning that much of the mixed waste can be found in the open dumps. (MoEF, 2020)

The waste in the dumps can also potentially become food to animals and damage their health. When the dump area is overloaded, the waste is mainly burnt to make way for the new trash, and this has the potential to release very harmful chemicals such as carbon monoxide, nitrogen oxide, sulfur dioxide, which can harm the environment, animals, and the residents around. Several studies have been published analysing the health and environmental impacts of improper solid waste management, leading to skin, respiratory, gastrointestinal diseases, and more. (CPHEEO, 2016b)

## 4. Opportunities, Challenges and Threats

After thoroughly analysing the current systems in place, it is essential to review them frequently to improvise and implement the updated, curated solutions. This section lets us look at what opportunities we can create with waste and address their challenges and threats.

### 4.1 Waste-To-Energy Plants (WTE)

Waste-to-Energy plants generate energy such as electricity through various methods. India had 92 WTE plants as of 2019 (MoEF, 2020). More have been sanctioned to be built in multiple states. Although WTE has been very impactful in European countries, there are a few practical problems in implementing the technology in India. The composition of waste produced in India is different from that of the west, as seen earlier. India generates waste with more moisture content and low calorific value, which hurts the efficiency of electricity generation and makes the entire process a very costly and non-profitable affair.

Most of the waste sent to WTE plants in India is currently mostly unsegregated, and some materials are unsuitable to be burnt in these plants. Therefore, more energy is required to burn such materials. According to the Power and Renewable Energy Minister of India, only about 15% of the total MSW generated every year can be classified as non-biodegradable, non-recyclable, high-calorific-value waste. Furthermore, on average, 100 tonnes per day of municipal solid waste is required to generate 1 MW of power with present technology. All these factors and the costs involved in running these plants mean that the power generated is priced higher. WTE plants sell electricity at about Rs 7 per kWh or more, whereas coal and solar plants sell electricity at 3-4 per kWh. (Economic Times, 2019)

The government is also currently developing technologies related to Pyrolysis and Gasification (CPHEEO, 2016a). These WTE plants can cost around ten crores and go up exponentially depending on the processing capacity (Ankur, 2019). Besides generating electricity, waste can be used in biogas, bio-methanation, incineration plants, and Refused-derived fuel. In 2019, around 36 WTE plants were under construction (MoEF, 2020). While these are promising prospects, the utilisation compatibility seems to be low at present.

Besides, WTE plants have been met with a lot of criticism in the past as many argue that these plants are not environment friendly, primarily due to the air pollution they cause. The Okhla WTE plant in Delhi is one such plant fined and discontinued by the National Green Tribunal in 2016 for polluting the environment. (Economic Times, 2019). It may also be due to the low quality and unsuitable waste that is burnt in the plants. This can be countered provided there are excellent segregation strategies. However, the composition of our waste is something we cannot control due to our population. WTE plants in Germany are profitable because they receive segregated and high calorific value wastes. Along with electricity, they also supply hot water to the municipalities and earn extra revenue. Therefore, their WTE plants also do not seem to have harmful effects on the environment.

It remains to be seen how feasible WTE plants are in the long run and more research needs to be done to optimise the functioning of the plants.

### 4.2 Waste-to-Compost Plants

Since most of the waste produced in India is organic, this provides a huge opportunity to expand our compost rates which currently stands at 18% (TOI, 2020). Due to India's huge agriculture sector, more farmers can be partnered with to utilise this compost. Using compost from WTE plants may also reduce the need for chemical fertilisers, which improves the quality of the crops and soil. A report by Chintan notes that organic compost costs Rs 6,000/MT against chemical fertilisers that cost Rs 5000/MT along with subsidies provided by the government, which is why composting is not a preferred option currently for many. (Chintan, 2019)(Chintan, 2019)

Currently, lower than 5% of organic waste generated in urban areas is converted to compost (Down To Earth, 2019). In 2019, the Ministry of Housing and Urban Affairs (MoHU) reported that about 232 WTC plants were under construction (MoEF, 2020).

### 4.3 Landfills

Usually, landfills need to be avoided wherever possible, but with the current scenario in India, the immediate solution is to have engineered landfill sites as a temporary precaution. India mostly has open dumps instead of landfills which can be much more damaging. The waste in Landfills is treated over time and managed better compared to open dumps. Apart from releasing harmful gases, landfills can also cause leachates, which can contaminate soil and groundwater. Hence landfills need to be managed and engineered with extreme caution and be located in places far from residential areas. At present, India has only 22 active landfills (MoEF, 2021).

### 4.4 Behavioural Change and Attitude towards Waste

To influence behavioural change in Indian citizens and their attitude towards waste, we must focus on the benchmark integrated solid waste management (ISWM) hierarchy (CPHEEO, 2016a). This is an inverted pyramid that puts the prevention of producing waste at the top and as the best remedy in waste management. Then comes reuse, followed by recycling and energy recovery, whereas disposal needs to be the least preferred option (see Figure 5).

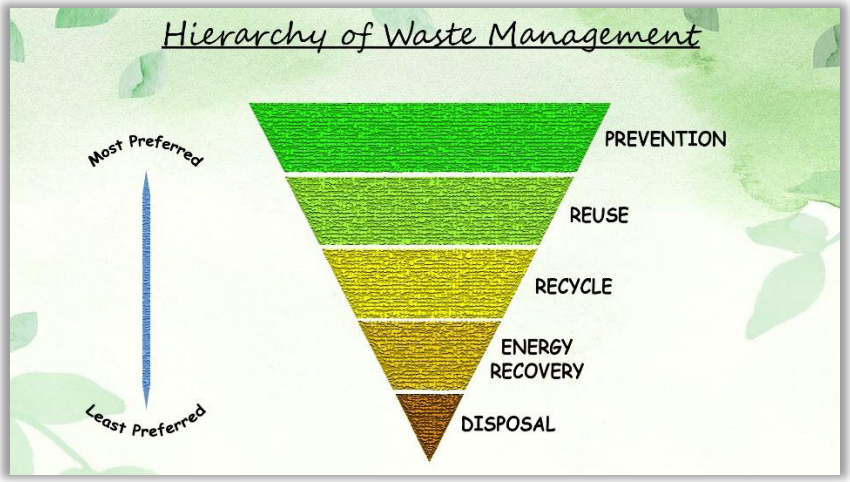


Figure 5. Waste Management Hierarchy. (Adopted from CPHEEO, 2016a)

People need to become conscious about the quantity and quality of their consumption and short-term and long-term impacts on the environment. They need to refuse or prevent waste wherever necessary and possible or buy reusable and recyclable products. Home compost practices should be promoted. Wherein people can grow various plants and vegetables made from the organic waste they produced.

Banning certain harmful products or materials produced due to their cost-effectiveness, like plastic, will also be necessary to keep the environmental impact in check. Source segregation needs to be practised very strictly as that can solve most of our complicated problems. The government is also currently focussing on promoting source segregation and minimising the use of single-use plastic. (MoF, 2021)

More awareness drives need to be done to educate citizens about their responsibilities, rights, impacts of their actions and provide updates about rule changes. It is also essential to eliminate the stigma surrounding waste that managing it is a dirty job and the "someone-else-will-do-it" attitude present in our societies. Once the government unequivocally describes the rules, heavy fines need to be imposed on anyone who does not adhere to the rules and does not follow the best sustainable practices.

### 4.5 Integrating Private & Informal Sector

The rag pickers belong to the informal sector, and they are crucial to the waste management ecosystem. According to the government report, it is estimated that the informal sector collects about 56% of recyclable material (CPHEEO, 2016a). They need to be hired and trained by the municipalities, be given social security and appropriate gear to perform the labour-intensive tasks. This will certainly optimise the entire process and make it organised while also providing livelihood to the people involved. Currently, it is estimated that a rag picker in India makes an inadequate amount of Rs 40 – 50 per day on average (Down To Earth, 2020).

The government can also partner with more small and medium private companies that offer specialised services through Private Public Partnership (PPP). Many companies have already come up utilising opportunities in WTE and the recycling industries. This has much potential as better results can be achieved when the government partners with its citizens and it can also improve the transparency and trust between them.

Some products, such as plastics, can be monitored throughout their life cycle until they are disposed of satisfactorily or recycled via barcodes or unique identification numbers. The product producer can do this, and it is already being tried worldwide in the form of EPR (Extended producer responsibility) (CPHEEO, 2016a). In the EPR strategy, the producer takes responsibility for reusing, recycling, or storing a product for treatment after the consumer has discarded it. Presently, this requires legislation, but the companies can also do this voluntarily as their social responsibility. This decentralisation of waste management systems will also boost the effectiveness of the measures that we take as it will reduce the burden on municipalities and help in efficient monitoring, storage, transport, and collection of waste as more and more private partnerships are made. Private companies can also hire rag pickers as permanent employees or on a legal contract basis.

### 4.6 Innovations and Infrastructure

The basic facilities such as disposal bins are very poorly maintained. This leads to people littering wherever they feel convenient, like and at the spot where they use or consume the product. This waste mostly becomes food to animals or is left without being collected, giving rise to open dumps. Disposal bins need to be made available in every street, especially the commercial places, and they need to be monitored and maintained regularly. Nonconformity should be dealt with by imposing heavy penalties.

Investments need to be made in specialised trucks that are designed to clean the roads and streets. Currently, this is done manually by municipal employees, which is not as effective. The

The use of trucks can quicken the process and can be done efficiently. Bengaluru is one such city that has deployed such vehicles (Devaiah, 2019).

In India, most vehicles that collect garbage are not covered from the top, and this allows the trash to drop from the vehicle when it is moving efficiently. The smell of the trash can be so intense that it can be smelt from two streets away. Hence, we also need better trash pick-up vehicles.

Currently, at source, Indians segregate their waste as dry-waste and wet-waste. However, we can also expand this category. There are four categories for source segregation in Germany: paper waste, organic waste, packaging & plastics, and residual waste, including waste that does not belong to the other three categories (UBA, 2014). This is not only very easy to implement but also helps ease the complexity involved in different processes.

We can also incentivise the waste disposal process. Germany's Pfand (deposit) system (Bouliane, 2021) is one such innovative idea where you pay extra while buying a particular

type of bottle, and when you return it through a machine, you get your money reimbursed. Similar machines have been installed in some cities of India too, which give out food coupons for every plastic bottle returned (Jain, 2018). It needs to be done at a larger scale for more products, raising awareness and interest of the people towards managing waste. This will also contribute to India's circular economy. The structure of the current waste management of India is shown in Figure 6.

To have some immediate positive impacts, we can also invest in Waste-Watchers, who can initially monitor public behaviour and impose fines as and when required. The municipalities or private stakeholders can also use drones to monitor and locate open dumps as well.

While it is essential to take immediate remedies, it is also crucial to invest in research and development and develop the latest technologies curated to our problems for a long-term impact. For this, private research institutions and international organisations can partner with the government.

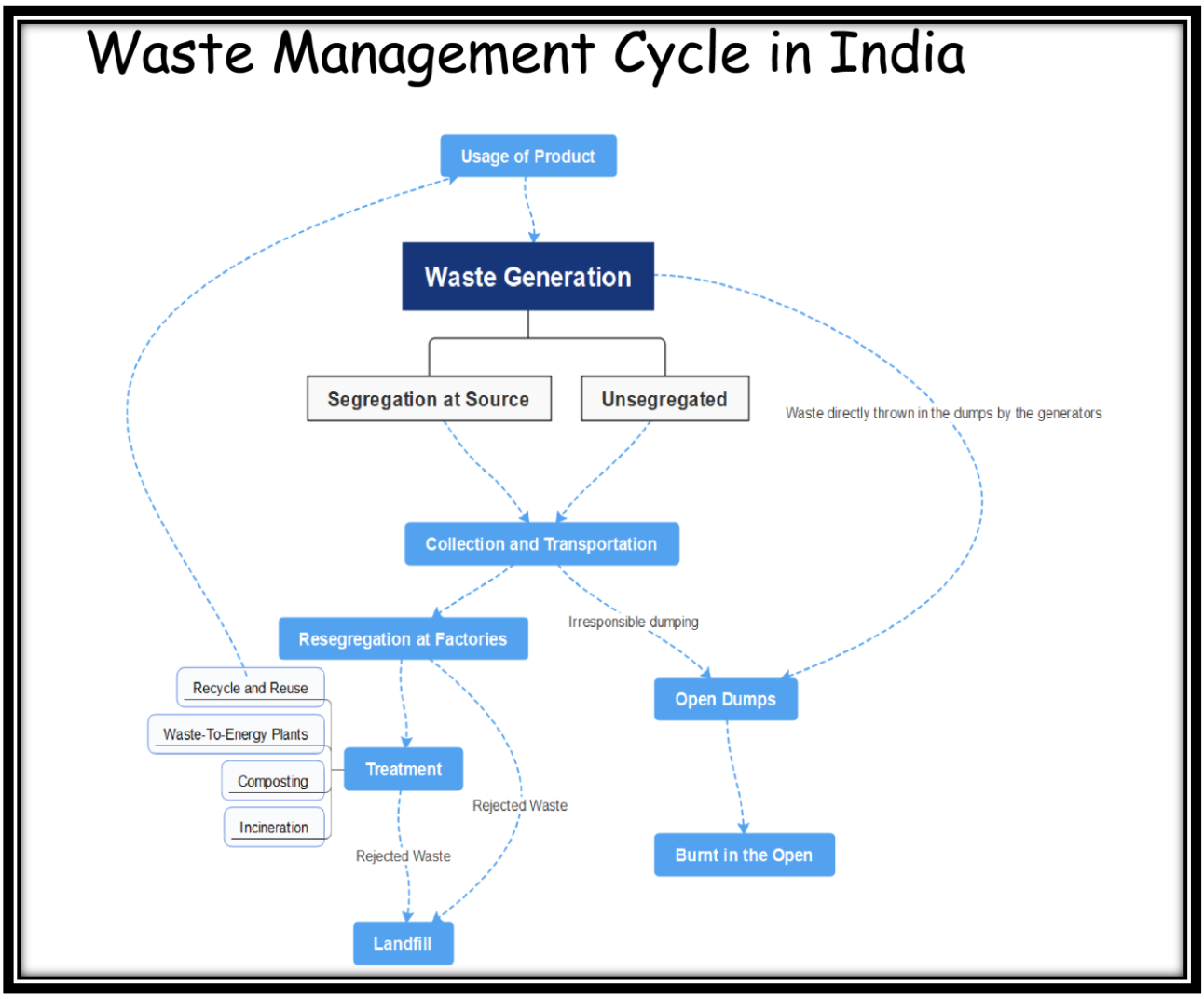


Figure 6 – Waste Management System of India

## 5. Conclusion

Waste management in India needs immediate attention. Most of our waste problems can be solved by following source segregation, social responsibility in abiding by the rules and eradicating open dumps. While there are also some positive signs for India in the form of government taking more interest and allocating more funds for waste management and citizens becoming more informed, Indians still need to work relentlessly, and some immediate precautionary measures need to be taken. Countries like Germany are achieving positive trends due to excellent cooperation between the government and the citizens and adopting sustainable practices curated for the type of waste they generate. India needs to innovate and invest in sustainable methods and adapt accordingly. Failure to do so will eventually make us meet the same fate as developed countries like the USA,

Canada, and China. Well-thought-out rules that can bring out a change in the behaviour of citizens should be implemented. India can also achieve outstanding results in the immediate future if the SWM rules presented by the GOI are followed religiously by adhering to the prevention, reduction, recycling, and reuse hierarchy. There is also considerable potential in WTE plants which will allow us to monetise and reuse waste. Therefore, the latest technologies need to be explored for efficiency and reliability. Attention also needs to be given to rag pickers to improve their health, livelihood and they need to be trained so that their contribution is channelled in an organised way. Following these essential solutions will allow us to move towards a circular economy seamlessly.

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