



Landfill site in Chennai, TN, India

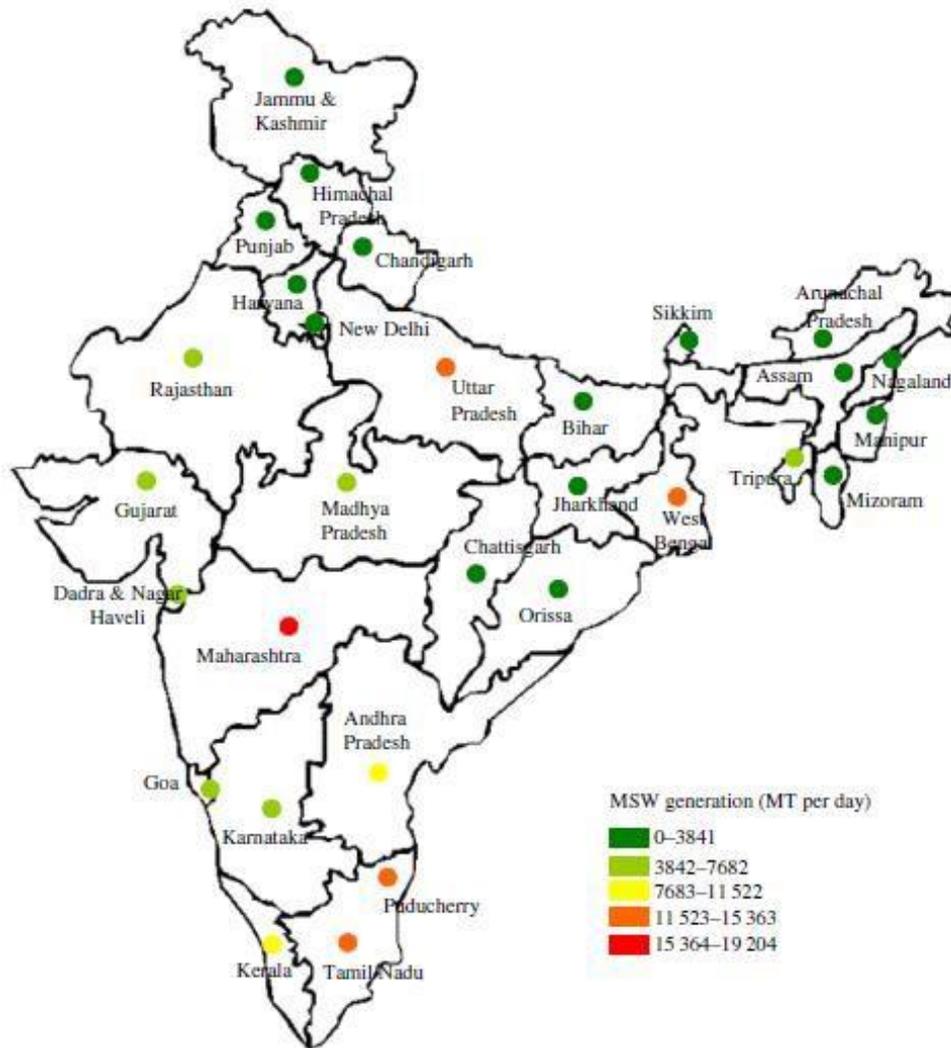
## At source waste segregation

Rupali Kadam | [kadamrupali1812@gmail.com](mailto:kadamrupali1812@gmail.com)

Rajkhush Kumar | [rajkhush.ecell@gmail.com](mailto:rajkhush.ecell@gmail.com)

Solid waste management (SWM) is a major problem for many urban local bodies (ULBs) in India, where urbanization, industrialization, and economic growth have resulted in increased municipal solid waste (MSW) generation per person [1]. Effective SWM is a major challenge in cities with high population density. Achieving sustainable development within a country experiencing rapid population growth and improvements in living standards is made more difficult in India because it is a diverse country with many different religious groups, cultures, and traditions. Despite significant development in social, economic, and environmental areas, SWM systems in India have remained relatively unchanged. The informal sector has a key role in extracting value from waste, with approximately 90% of residual waste currently dumped rather than properly landfilled [2].

There is an urgent need to move to a more sustainable SWM, and this requires new management systems and waste management facilities. Current SWM systems are inefficient, with waste having a negative impact on public health, the environment, and the economy [3]. The waste management and Handling Rules in India were introduced by the Ministry of Environment and Forests (MoEF) [4], although compliance is variable and limited.



**Figure.1 State-level statistics of MSW generation in India (2009–2012). Source: Central Pollution Control Board, Govt. of India, 2012. [5]**

Waste generation rate depends on factors such as population density, economic status, level of commercial activity, culture, and city/region. Figure 1 provides data on MSW generation in different states, indicating high waste generation in Maharashtra (115364–19204 tonnes per day), Uttar Pradesh, Tamil Nadu, West Bengal (11523–15363 tonnes per day), Andhra Pradesh, Kerala (7683–11522 tonnes per day) and Madhya Pradesh, Rajasthan, Gujarat, Karnataka, and Mizoram (3842–7662 tonnes per day). Lower waste generation occurs in Jammu and Kashmir, Bihar, Jharkhand, Chhattisgarh, Orissa, Goa, Assam, Arunachal Pradesh, Meghalaya, Tripura, Nagaland, and Manipur (less than 3841 tonnes per day).

census year	population $\times 10^6$	decadal growth $\times 10^6$	average annual exponential growth rate (%)	progressive growth rate compared with 1911 (%)
1911	252.0	13.7	0.56	5.75
1921	251.3	-0.8	-0.03	5.42
1931	278.9	27.6	1.04	17.02
1941	318.6	39.7	1.33	33.67
1951	361.1	42.4	1.25	51.47
1961	439.2	78.1	1.96	84.25
1971	548.1	108.9	2.20	129.94
1981	683.3	135.1	2.22	186.64
1991	846.4	163.1	2.16	255.05
2001	1028.7	182.3	1.97	331.52
2011	1210.2	181.4	1.64	407.64

**Table1. Population growth in India between 1911 and 2011. Source: Provisional Population Totals-India, 2011. [5]**

city	*population (2011) $\times 10^6$	#total waste generated in tonnes per day	waste generation (kg per capita per day)
Ahmedabad	6.3	2300	0.36
Hyderabad	7.7	4200	0.54
Bangalore	8.4	3700	0.44
Chennai	8.6	4500	0.52
Kolkata	14.1	3670	0.26
Delhi	16.3	5800	0.41
Mumbai	18.4	6500	0.35

**Table2. Major cities in India and per capita waste generation data (2010–2011). Source: \*Census of India 2011, #CPCB Report 2011. [5]**

## 2. Current waste management in India

### 2.1 Key waste management legislations in India

The MoEF issued MSW (Management and Handling) Rules 2000 to ensure proper waste management in India and newly updated draft rules have recently been published [4]. Municipal authorities are responsible for implementing these rules and developing infrastructure for collection, storage, segregation, transportation, processing, and disposal of MSW. Chandigarh is the first city to develop SWM in a planned way and has improved waste management compared with other Indian cities [10].

#### **Various Rules in India**

1. Environment Protection Act –1986
2. Hazardous Waste Management and Handling Rules –1989
3. Manufacturing, Storage and Transportation of Hazardous Waste Rules –1989
4. Bio-Medical Waste Management and Handling Rules –1998

5. Municipal Solid Waste Management and Handling Rules –2000
6. Plastic Waste (Management and Handling) Rules –2011
7. E-Waste (Management and Handling) Rules –2011

## **2.2 Role of the informal sector in waste materials reuse and recycling**

The informal sector has a very important role in India and this must be integrated into formal SWM systems [7, 9]. The informal sector is characterized by small-scale, labor-intensive, largely unregulated, and unregistered low-technology manufacturing or provision of materials and services [11]. Waste pickers collect household or commercial/industrial waste and many hundreds of thousands of waste pickers in India depend on waste for an income, despite the associated health and social issues. Pickers extract potential value from waste bins, trucks, streets, waterways, and dumpsites. Some work in recycling plants owned by cooperatives or waste picker associations. Waste picking is often the only source of income for families, providing a livelihood for significant numbers of urban poor and usable materials to other enterprises. Waste pickers in Pune collect organic waste for composting and biogas generation. Waste pickers also make a significant contribution by keeping cities clean. A recent study of six Indian cities found that waste pickers recovered approximately 20% of waste, with 80 000 people involved in recycling approximately three million tonnes. It is estimated that every tonne of recyclable material collected saved the ULB approximately INR 24500 per annum and avoided the emission of 721 kg CO<sub>2</sub> per annum [9].

## **2.3. Waste collection, transport, and waste disposal**

Waste collection, storage, and transport are essential elements of any SWM system and can be major challenges in cities. Waste collection is the responsibility of the municipal corporations in India, and bins are normally provided for biodegradable and inert waste [12–14]. Mixed biodegradable and inert waste is often dumped, with open burning a common practice. Improvements to waste collection and transport infrastructure in India will create jobs, improve public health and increase tourism [15]. Local bodies spend around Rs. 500–1000 per tonne on SWM with 70% of this amount spent on collection and 20% spent on transport.

SWM disposal is at a critical stage of development in India. There is a need to develop facilities to treat and dispose of increasing amounts of MSW [16]. More than 90% of waste in India is believed to be dumped in an unsatisfactory manner. It is estimated that approximately 1400km<sup>2</sup> was occupied by waste dumps in 1997 and this is expected to increase in the future [17, 18]. Properly engineered waste disposal protects public health and preserves key environmental resources such as groundwater, surface water, soil fertility, and air quality. Indian cities with containment landfill sites include Mumbai, Kolkata, Chennai, Nashik, Vadodara, Jamshedpur, Allahabad, Amritsar, Rajkot, Shimla, Thiruvananthapuram, and Dehradun [6]. Table 3 shows treatment facilities available in different states in India and table 7 has information on landfills associated with different cities.



**Figure 2. Waste collected in an open-body truck**



Figure 3. Waste pickers sorting through waste in a landfill

state	composting	vermicomposting	biomethanation	pelletization	waste to energy
Andaman and Nicobar	1	nil	nil	nil	nil
Andhra Pradesh	24	nil	nil	11	2
Assam	1	nil	nil	nil	nil
Chandigarh	Nil	nil	nil	1	nil
Chattisgarh	6	nil	nil	nil	nil
Delhi	3	nil	nil	nil	3
Goa	14	nil	nil	nil	nil
Gujarat	3	93	nil	6	nil
Himachal Pradesh	10	nil	nil	nil	nil
Jammu and Kashmir	1	nil	nil	nil	nil
Jharkhand	4	nil	nil	nil	nil
Kerala	21	7	10	1	1
Madhya Pradesh	7	nil	nil	2	nil
Maharashtra	6	2	5	5	2
Meghalaya	1	1	nil	nil	nil
Nagaland	1	1	nil	nil	nil
Orissa	1	nil	nil	nil	nil
Punjab	1	3	nil	nil	nil
Sikkim	1	nil	nil	nil	nil
Tamil Nadu	162	24	nil	3	nil
Tripura	1	nil	nil	nil	nil
West Bengal	13	7	nil	nil	nil
total	279	138	172	29	8

<sup>3</sup>All other states and UTs currently have no processing facilities.

Table3. State-wise status of MSW processing facilities in India in 2011. Source: Planning Commission 2014 [8].



**Figure 4. Roadside & community waste collection**

#### **2.4 The Informal Sector**

Other than the municipality, the informal sector provides an invaluable service when it comes to the MSWM system (Chintan, 2007). The informal sector is made up of urban poor (immigrants and marginalised people) in cities who do waste picking activities because it is the only earning opportunity available to many low skilled inhabitants. An estimate of two million waste-pickers exist in India today (Chaturvedi & Gidwani, 2010).

Waste picking is done for recycling of materials. Waste pickers collect and sort through various materials that have recyclable value and can be sold. Some collect mixed waste from resident's homes and sort the recyclables, others go through streets and dustbins, while some even collect recyclables from landfills and open dumps. This makes them highly vulnerable to health damages due to their shabby working conditions. At the end of the day the waste-pickers sort the recyclables into different categories and sell them to small dealers. From there, the waste is transported to bigger dealers who are specialised in recycling one type of recyclable material and they sell it to the recycling industry (Agarwal, Singhmar, Kulshrestha, & Mittal, 2005). The informal sector collection avoids environmental costs and reduces capacity problems at dumpsites (Sharholly, Ahmad, Mahmood, & Trivedi, 2005)



**Figure 5. Waste pickers separating waste into different categories**

## 2.5 Landfilling

A landfill is an area of land onto or into which waste is deposited. The aim is to avoid any contact between the waste and the surrounding environment, particularly the groundwater. Landfills can be classified into three categories, which are:

- i. Open dumps or open landfills, which are the most common in all developing countries, involve the refuse simply being dumped haphazardly into low-lying areas of open land.
- ii. Semi-controlled or operated landfills are designated sites where the dumped refuse is compacted and a topsoil cover is provided daily to prevent nuisances. All kinds of municipal, industrial, and clinical/hospital wastes are dumped without segregation. This type of landfill is not engineered to manage the leachate discharge or emissions of landfill gases.
- iii. Sanitary landfills are used in developed countries and have facilities for interception and treatment of the leachate using a series of ponds. This type of landfill also has arrangements for the control of gases from waste decomposition [19].

**3. Case study:** Encouraging urban households to segregate the waste they generate: Insights from a field experiment in Delhi, India.

*Paper: Encouraging urban households to segregate the waste they generate: Insights from a field experiment in Delhi, India*

*Journal: Resources, Conservation & Recycling*

*Volume\_ Publication year\_ pages: 134 (2018) 239–247*

### 3.1 Introduction:

At present, rag pickers are part of the informal sector foraging the Dhalaos (garbage collection points) to collect recyclables, but in the process coming in contact with animal excreta, sputum, dead animals, and at times, medical waste and thus susceptible to a lot of diseases (Sarkar, 2003). The rag pickers face challenges such as deplorable work conditions, low social status in their daily life, and yet the role they perform can be considered as a positive externality (Campos, 2014).

The study used field experiments in housing localities of Delhi with the following objectives:

- To investigate the determinants of waste segregation behavior at the household level;
- To understand the effect of interventions- information, norms, and incentives, to ensure compliance with SWM Rules, 2016;
- To understand how the interventions differ in their influence across the socio-economic categories of the society;

### 3.2 Data & methods:

Delhi has five municipal corporations— New Delhi Municipal Council (NDMC), Delhi Cantonment Board (DCB), East Municipal Corporation of Delhi (MCD), North MCD, and South MCD. The three MCDs manage 96% of the area and population of Delhi<sup>8</sup> Thus, in order for the study to be policy-relevant to Delhi; Study conducted it in the areas falling under the three MCDs. MCD property taxes were used to stratify the wards on the basis of income. We clubbed A, B, and C categories of the property taxes (category 1) and D, E, and F categories (category 2) to stratify the colonies for the purpose of the study. Category 1 is a relatively higher income group as compared to category 2. From each of the three corporations, one ward was chosen for the study. The sample for the study is drawn from group housing societies/ apartment colonies in

the selected wards. Group housing societies/ apartment colonies were chosen in order to maintain consistency in the waste collection services availed by the residents.

#### Adoption by different types of interventions.

Type of Intervention	Time Period		
	Baseline	Monitoring 1	Monitoring 2
Control	1.35%	2.54%	2.78%
Information	5.29%	54% (- 11.28)***	38.8% (- 8.46)***
Information + Norms	2.1%	47.4% (- 10.34)***	37.9% (- 8.4)***
Information + Monetary Incentive	3.76%	61.6% (- 12.22)***	54.9% (- 10.71)***

Values in parenthesis are the z statistic for the proportion difference between the control and each type of intervention given to the households at each round of monitoring.  
Note: \*\*\* significance at 1% level.

### 3.4 Discussion:

The purpose of the study was to investigate the determinants of household waste segregation behaviour. Emphasis has been put on information, norms, and economic motivations. The results confirm that even low-cost interventions such as the provision of information influence the waste disposal behaviour of households, though monetary incentives had the largest impact. This section discusses the results in two sub-sections—at the household level and at the society level.

## 4. Dustbins promoting waste segregation

- **Automatic waste segregating bins**

1) This Dustbin has an aluminium strip with a broken layer in between and when the wet waste falls upon its surface the circuit is completed and with the help of a motor, it drops the waste in the wet section.

1.1 This dustbin is inefficient to detect packaged and several other wet wastes.

1.2 High Cost of production and Low productivity of Dustbin.

Fig.6 represents automatic dry and wet waste segregation

Reference Link: <https://youtu.be/F6XndxIJr9A>

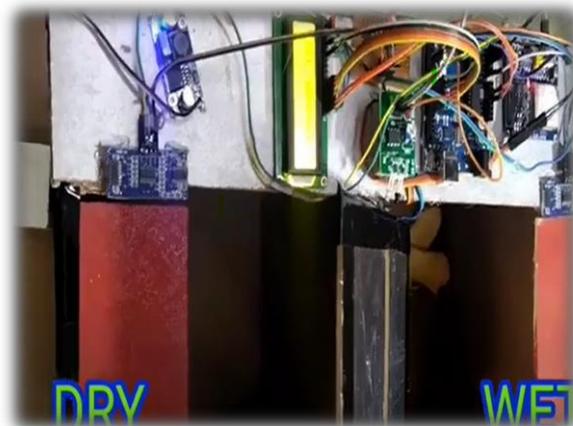


Figure 6

2) These dustbins are specially designed for High rise apartments, a garbage duct is attached through the height of the building and the duct has openings on every floor. Residents can simply drop their garbage from each floor by selecting the type of waste on the floor section.

2.1 Garbage Duct Used in High Rise Buildings.

2.2 All types of waste packed in polythene and then thrown.

2.3 Very High cost but fairly Good Productivity. People still wrap the whole garbage in one polythene and then throw it in the duct, and don't press the button on the type of waste and hence the problem is still unsolved even with such complicated and advanced technology.



Fig. 7 represents the Garbage chute system for high-rise apartments.

Reference Link: <https://youtu.be/--rE3DUrokY>

3) This dustbin uses IoT technology, it takes a picture of the waste and uploads it on the cloud-based server to predict what kind of waste it is and then opens the door of a particular dustbin suitable for the waste.

3.1 Extremely high cost, unaffordable for Indian households.

3.2 2 Very High Manufacturing, Maintenance, and IT cost Involved.

People placing wet waste wrapped in a polythene bag will again lead to the failure of this model as well.

Fig. 8 Represents IoT-based smart waste segregator and monitoring machine.

Reference Link: <https://youtu.be/5yIXHv4eXIE>



- **Non- technical dustbin designs**



Figure 9. Represents non-dustbins with waste separation compartments

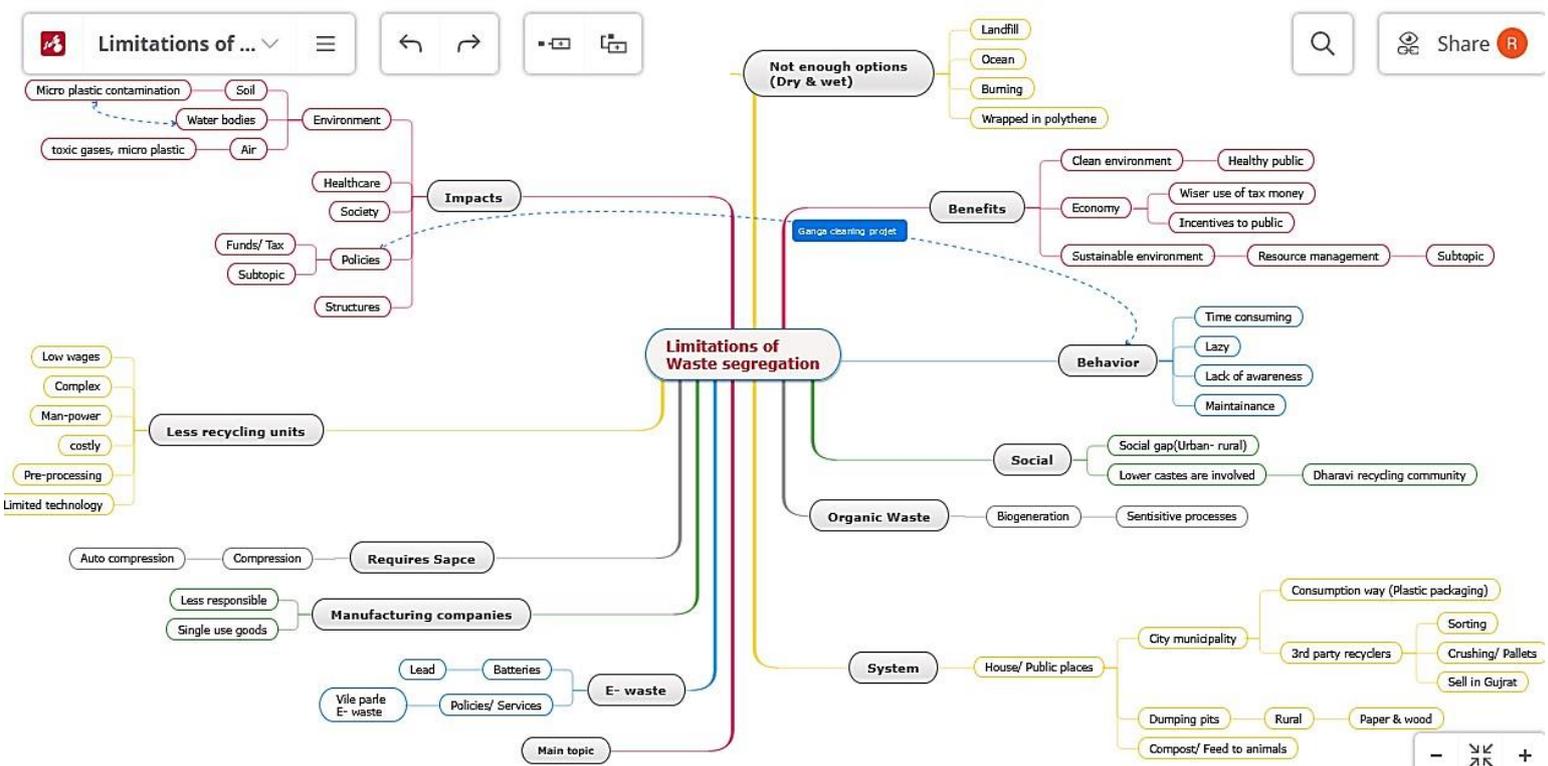
- 1) Simple, Reliable, DIY friendly, Less Expenditure, Dustbins made from Local Raw Material.
- 2) People can easily customize their existing dustbins hence cost of buying can be reduced.
- 3) Highly Efficient if people are willing to segregate.
- 4) Very Low Cost and High Productivity.

## Analysis

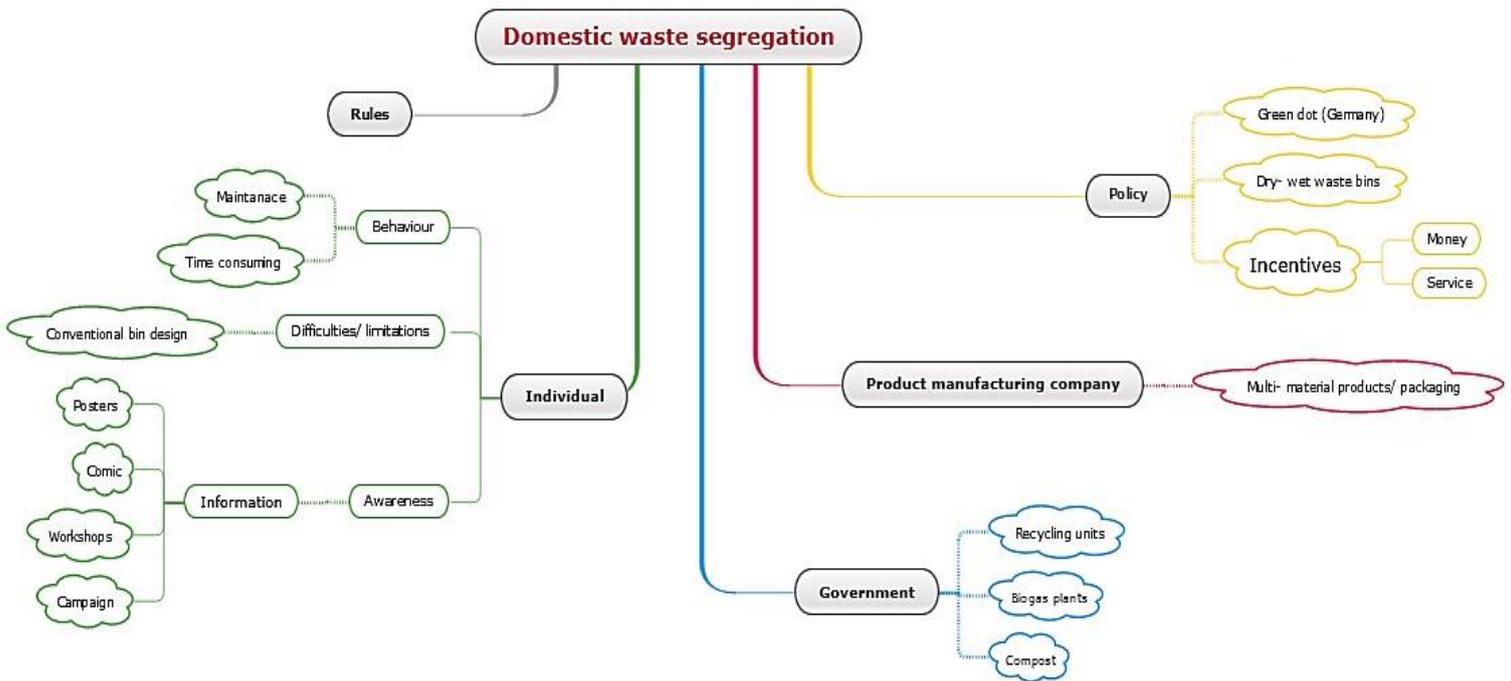
1. When dry and wet wastes are mixed, it requires money, labour and recycling plants to segregate them.
2. Waste segregation is essential and first step to avoid landfill and burning of waste.
3. A percentage of profit from recycling of waste can be utilised to incentives people as a reward for segregating their own waste.
4. Introducing a lot of technology, electronics or IoT into the dustbin itself is not a very good solution as people still don't mind following the instructions and simply put their whole waste into a polythene bag and throw, also these electronic dustbins are costly and Indian people according to our survey buy dustbins in range of 150-300Rs. only. Hence although a smart dustbin may add value to the waste segregation without proper awareness initiatives and behavioural changes, this can lead to failure.
5. A major problem is created by the polythene bags, as people place a polythene bag on the dustbin to avoid dirt sticking on the dustbin and finally wrap the whole waste altogether and then throw it wrapped. Hence in manual dustbins, we need to tackle this behavioural problem especially.
6. In Spite of two to three different dustbins for segregation, a dustbin with inbuilt compartments is easier to implement and handle for the user.

## Mind mapping

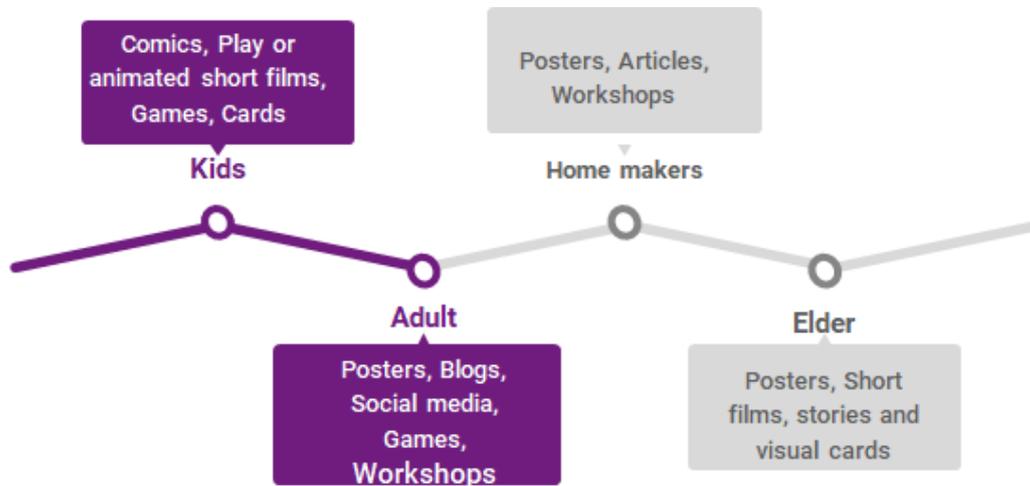
### 1. Limitations for waste segregation



## 2. Domestic waste segregation



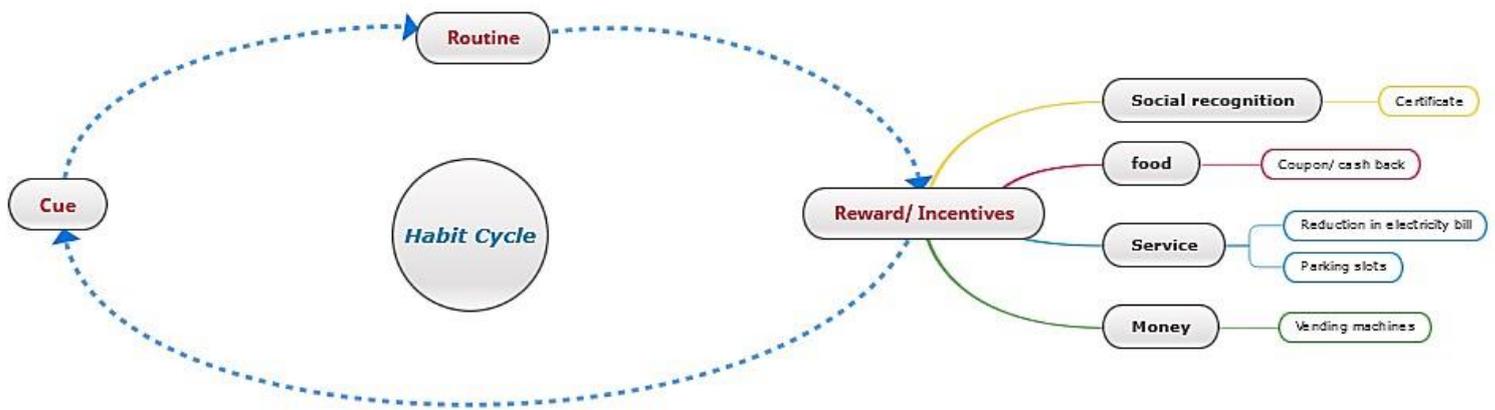
### Proposed solution- Awareness campaign



National Mission for Sustainable Habitat subcommittee report emphasized the need for community participation in waste management activities by the ULBs along with segregated storage at source for effective recycling (MoUD, 2014). The Clean India Mission, 2014 (Swachh Bharat Mission) guidelines advise ULBs to distribute two dustbins to promote segregation at source.

We can target large public areas for awareness campaigns. First we will provide enough information regarding waste classification, various resources of waste generation and its impact on environment and public health. We can use different mediums to provide information as provided in the above figure. We can introduce public about various rules & acts for waste management provided by MoEF.

After providing enough information we can give them tasks as discussed in our case study. The task of segregating their own waste. This task can be of 3 or 7 days which will act as routine. After successful segregation in row we will provide different types of incentives or rewards.



Rewards need not to be only in the form of money but it can be form of service, food or coupons. In return these rewards will complete habit cycle. Habit cycle is useful for any adaptive changes.

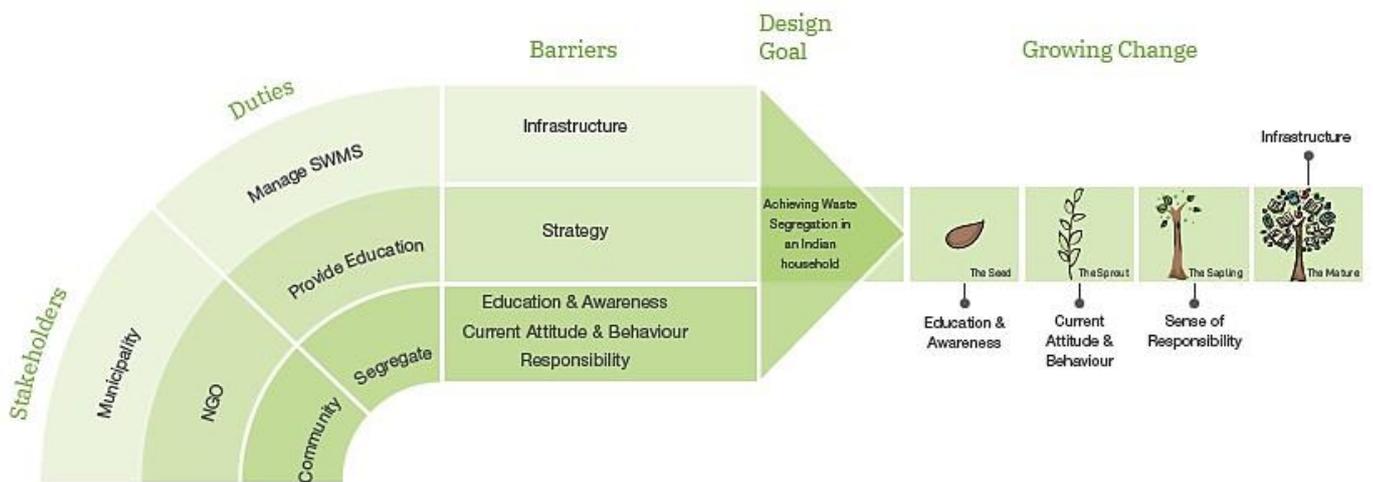


Figure 10. The phase of growing change, Ref. [20]

# LET'S PUNCH-IN

A Pilot Program that uses behavioural psychology to encourage people to segregate.



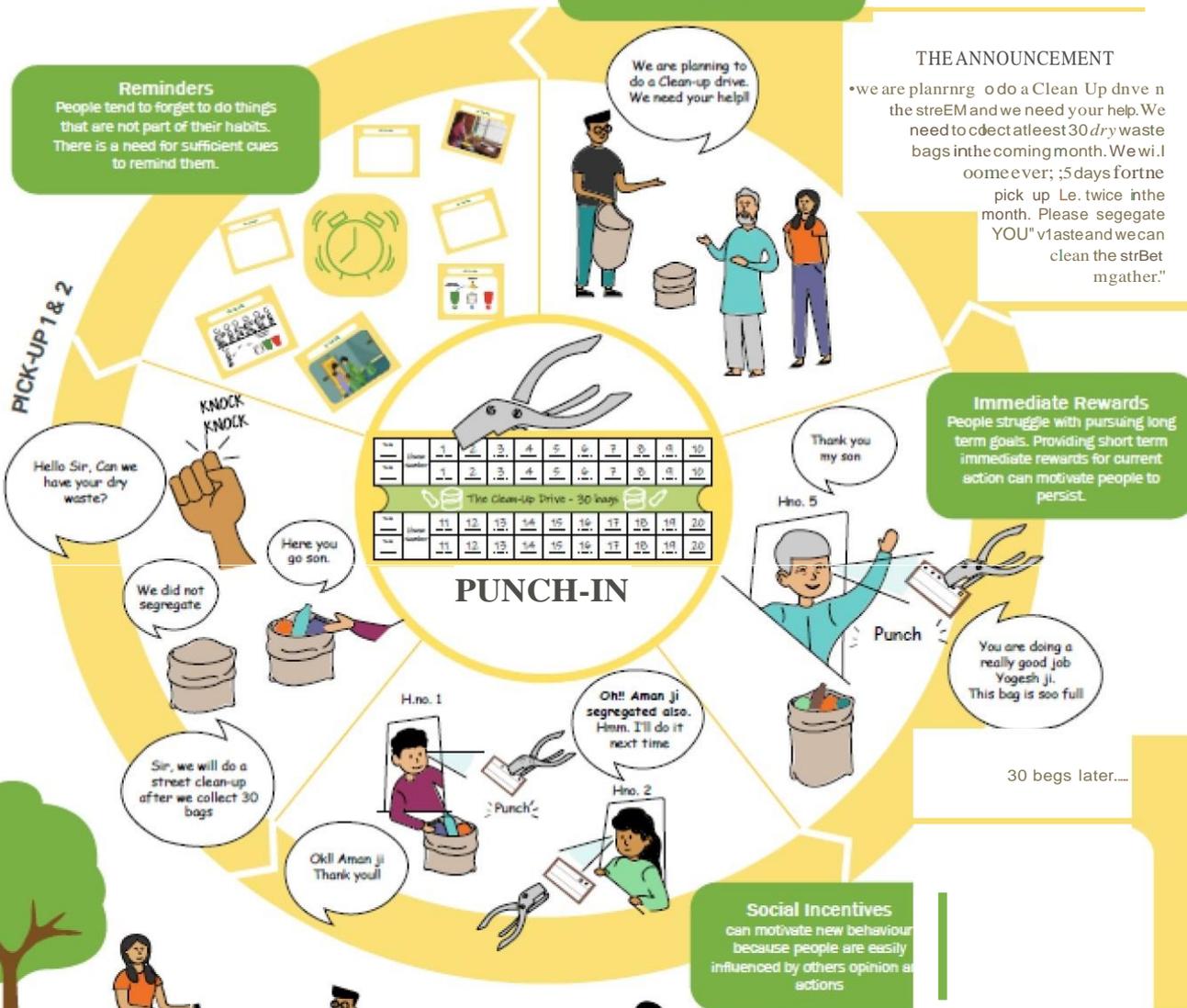
**Extrinsic Incentives** are physical or emotional rewards that motivate a person to do an activity because they see a benefit for themselves.

**Reminders**  
People tend to forget to do things that are not part of their habits. There is a need for sufficient cues to remind them.

**THE ANNOUNCEMENT**  
We are planning to do a Clean Up drive in the street and we need your help. We need to collect at least 30 dry waste bags in the coming month. We will come every 5 days for the pick up. Please segregate YOUR waste and we can clean the street together."

**Immediate Rewards**  
People struggle with pursuing long term goals. Providing short term immediate rewards for current action can motivate people to persist.

**Social Incentives** can motivate new behaviour because people are easily influenced by others' opinions and actions.



LEAN-UP DAY

## Conclusion

Waste is increasing as population is increasing and it will keep increasing in the future as well. Waste segregation is vital step to avoid various global issues like water and soil contamination, global warming due to release of methane through waste, toxic gases released by burning hazardous waste. And not utilising resources completely after manufacturing.

At the very beginning we analysed that people have lack of resources to segregate the waste like only two types of bins in few urban parts of India. Due to which people are not motivated to segregate the waste. In majority of the places all type of waste is dumped together in one bin from municipal corporations. Through literature review and the survey results in the Delhi we observed that majority of the public is not aware of different classes of waste, its resources and its impact on the environment. Which in result, people are not self-motivated to segregate their own waste. Many people are unaware about MoEF or CPCB which are government bodies for managing waste. There are specific rules or punishment for not segregating the waste

Through market analysis we are convinced that there are a lot of dustbins available in the market that use electronics, IoT, etc to segregate dry and wet waste. Through our analysis, we observed that in spite of multiple options available still segregation is not achieved.

We have arrived at the conclusion that human behavioural attitude towards waste management need to be changed to achieve success. This can be achieved through educating public and giving them tasks to segregate waste under observation and providing incentives or rewards to complete the habit cycle.

## Acknowledgement

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