Assessment of Municipal Solid Waste Management of Pune City using Geospatial Tools

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ABSTRACT
Solid waste management is among the basic essential services provided by municipal authorities in the country to keep cities clean. Due to industrialization, rural to urban migration and high growth rate of population have induced rapid urbanisation in developing countries and obviously in India also. The haphazard urbanisation created acute problem of solid waste management. The per capita waste generation rate in India has increased from 0.44 kg per day in 2001 to 0.5 kg per day in 2011; such a steep increase in waste generation within a decade has severed the stress on all infrastructural, natural and budgetary resources. Pune is one of the fastest developing city, it generates total quantity of waste is about 1300 to 1400 metric tons per day. So, there is need of the proper waste collection, transportation route for prevention of environment form the hazardous waste disposal. The proposed work emphasizes on the assessment of detail process of solid waste management such as collection, storage, segregation, transportation, treatment and disposal by using Geospatial tools like RS, GIS and GPS. It may help in sustainable urban environment of Pune city.

Keywords:
GIS, GPS, Remote Sensing, Municipal Solid Waste Management, Sustainable Urban Environment

1. INTRODUCTION
Solid waste comprises unwanted and discarded materials from houses, street sweeping, and commercial and industrial operations. Increase in urban population and changing life styles lead to the generation of solid waste. Generally, solid waste is heterogeneous in nature such as mixture of vegetables, food items, paper, plastics, rags, glass etc. If solid waste is disposed off on land in open areas, then it causes a negative impact on the environment, ground water and on health.

The most common problems associated with improper management of solid waste include diseases, odor nuisance, fire hazards, atmospheric and water pollution, aesthetic nuisance and economic losses (Jilani, 2002). There has been a significant increase in solid waste generation in India over the years from 100 gm per person per day in small towns to 500 grams per persons per day in large towns. Currently most of the municipal waste in India is being disposed unscientifically (Akolkar, 2005). Generally municipal solid waste is collected and deposited in landfill such unscientific disposal attract birds, rodents and fleas to the waste site and create unhygienic conditions (Suchitra, et al. 2007). The degradation of the solid waste results in the emission of carbon dioxide (CO2), methane (CH4) and other trace gases. The unscientific landfill site may reduce the quality of the drinking water and causes the disease like nausea, jaundice, asthma etc (Bean, et al. 1995).

In Pune city primary sources of solid waste are local households, commercial establishments, hospitals, hotels, restaurants, and markets. The total quantity of waste generated per day is about 1300 to 1400 metric tons (approximate generation per capita per day is 500 grams). Pune Municipal Corporation (PMC) is responsible for collection, storage, segregation, transportation and disposal of all solid waste generated in the city. In the present research work describes an attempt to assess the collection, segregation, transportation, treatment and disposal of PMC land fill site using geospatial tools like Remote Sensing (RS), Geographical Information System (GIS) and Global Position System (GPS).

2. SIGNIFICANCE OF STUDY
Pune city generates large amount of solid waste. This large amount of waste poorly disposed and untreated. The city does not have an engineered or scientific landfill site and the capacity of existing dump site cannot cater the future demand of the waste generated. So, there is an immediate need for designed scientific integrated solid waste management system using Geospatial tools like Remote Sensing, GIS and GPS to minimize adverse effects on environment, social and economic of solid waste management. Therefore the present research work focuses on understating effective waste management practices in study area.

3. OBJECTIVES
The main objective of this present research work is to assess the Municipal Solid Waste Management system like collection, storage, segregation, transportation, processing and disposal of Pune city using Geospatial tools. It may aid in quick and useful decisions for the purpose of administration and planning for a sustainable urban environment.

4. STUDY AREA
Pune is the second largest fast developing urban agglomerations in Maharashtra and ranks eight at national level. It is now rapidly changing its character from an education-administrative center to an important industrial hub and the IT center. Pune is a plateau city situated near the western margin of the Deccan Plateau. It is situated at an altitude of 560 m above the mean sea level. PMC lies between latitudes 18° 25'N and 18° 37'N and longitudes between73° 44'E and 73° 57'E and the geographical area is around 243.84 Sq.Km with a population of 3.1 million composed of 76 general electoral wards(according to 2011, Census of India). These wards were converted in 14 administrative wards by Pune Municipal Corporation (Figure 1). The density of the

city was 12,777 persons/ Sq.Km. The area in the central part of the PMC is densely populated than the marginal regions.

5. DATABASE & METHODOLOGY

The data collection involved collection of topographical maps, ward maps, satellite data and demographic details. The environment of these data and their source are shown in Table 1. The Survey of India topographical maps scale 1:25,000 was used for the current study of the following features: drainage, water bodies, contours, roads and rail network and administrative boundaries. Other data sources are satellite images of Pune city, various maps collected from published materials and from related web sites.

Table 1: Primary and secondary data details

Segment : Pune City	Sources
Toposheets No. 47F/14/1 to 47F/14/6, F/15/NE, F/15/NW and 47F/15/SE	Survey of India, scale 1:25000
Google Image	Internet
Geological Map	Geological Survey of India, Pune
Satellite Imagery – Landsat 5 TM (February, 2011)	Global Land Cover Facility (GLCF) earthexplorer.usgs.gov web site
Demographic details from Primary Census abstracts for, 2001 and 2011	Directorate of census operations, Census of India
All Secondary data related Solid Waste Management, Land use/ Land cover etc.	Pune Municipal Corporation (PMC)
Ward maps and Administrative Boundary	Pune Municipal Corporation (PMC)

The brief information about steps involved in implementation methodology for the present research work.

a. Procurement of Satellite data and related attribute data
b. Geo-correction of remote sensing data and topographical maps.
c. Application of standard image processing techniques to identify the existing solid waste system of study area.
d. Creation of GIS layers: digitization of contour lines, drainage, roads, railways, land use/ land cover area, location of smaller ramps, bio-gas plant and administrative boundary of study area from the topographical maps and Google images using GIS software's.
e. Fieldwork would be carried out to survey by using GPS.
f. Generation of base map and related database from topographical maps of Survey of India and satellite data.

Since the main objective of this research is to understand and assess the existing solid waste system of Pune city using Geospatial tools. The flowchart of methodology is given in Figure 2.

6. COMPOSITION OF MSW

Materials in MSW can be broadly categorized into three groups, Compostables, Recyclables and Inerts. Compostables or organic fractions consist of market wastes and food waste. Recyclables are included paper, plastic, glass and metal. The fraction of MSW which can neither be composted nor recycled into secondary raw materials is called Inert. Inert material includes stones, ash and silt which enter the collection system due to littering on streets and at public places.

7. MSW GENERATION

Generation of MSW has an obvious relation to the population of the city, caused by bigger cities generate more waste. Kolkata metropolitan area generates the largest amount of MSW (11,520 TPD or 4.2 million TPY) among Indian cities.

Municipal Waste is generated as Dry Waste and Wet Waste. It is observed that the previous literature tropical countries show the higher percentage of wet waste than dry. Pune city generates dry and wet waste approximately in equal proportion (i.e. 50%-50%). The garbage generated is dependent on the activity prevalent in the area where as wet waste generation is more in residential and commercial area such as hotels or food industry.

About 40 per cent of the waste is generated from households (domestic waste), followed by hotels, restaurants and other commercial establishments which together account for over 50 per cent of the waste generated (Figure 3).

Table 2: Source of MSW Generated in PMC

Sr. No.	Source	Quantity of Waste Generated per day- tons	Composition in %
1	Domestic (Households)	400	40
2	Commercials	250	25
3	Market Areas	50	5
4	Hotels and Restaurants	250	25
5	Vegetable waste (19 Markets)	50	5
	Total	**1000**	**100**

Source: Revised City Development Plan for Pune - 2041, Maharashtra, Under JNNURM

The total waste generated is in the range of 1300 to 1400 metric tonnes (MT) per day (per capita of 500 grams per day). The waste generated was collected, transported and disposed at land fill site which is about 20 km away from Pune at Uruli Devachi from the 1st of June 2010. PMC has stopped open dumping and total waste generated is processed scientifically.

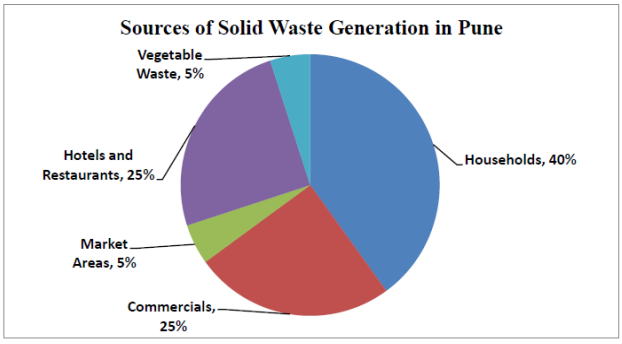

Figure 3: Sources of MSW Generation in PMC

Figure 4 represent the ward-wise solid waste generated in MTD. It can be seen that the major contributing wards for Pune city are Mahatma Phule Smarak (Bhavani Path), Kasba Peth. This is due to higher population density in the old city areas and commercial activities.

8. RESULTS AND DISCUSSION

The main components of waste management are collection, segregation, storage, transportation, treatment and disposal. Currently, most of the cities MSWM system includes above mention all components of waste management.

8.1 Waste Segregation

Segregation at source is the most important step in waste management and is done in two major categories: wet waste and dry waste. Wet waste is the bio degradable solid waste includes residential waste of all kinds and waste from markets and slaughterhouse. Dry waste is the recyclable solid waste that includes paper and plastic of all kinds excluding hazardous waste material.

Waste segregation was made mandatory by Hon. Supreme court and Govt. of India Gazette dated 3rd October 2001 and Municipal solid waste management and handling rules 2000. PMC has implemented solid waste segregation system for dry and wet waste in the city. 1st July 2005 was the last date for the residents for the non segregation waste collection. The corporation has started collection of only segregated waste from households which have forced the residents to segregate the waste. PMC has adopted decentralized pattern of solid waste segregation and disposal at its source through vermicomposting. From the total waste generated about 500 Metric Tons dry waste is separated and removed by various agencies like rag pickers, crap material vendors and other NGOs. These rag pickers are segregating waste at various sources like from door step collection, ghantagadi, municipal containers and at the dumping site. There are more than 5000 registered rag pickers involved in this waste segregation process. PMC has done ground truthing in 14 administrative wards regarding solid waste segregation practice in six categorized places namely Wards, Properties, Societies, Bungalows, Slums & Chawls and Hotels & Restaurants (Table 3). Among these except hotels industry, other categories have poor performance in segregation of waste at source.

Table 3: Segregation of MSW at source

Total Waste Segregated	**48 % to 50 %**
Wards	20 % to 65 %
Properties	42%
Societies	30%
Bungalows	47%
Slums & Chawls	32%
Hotels & Restaurants	85%

Source: Pune City Sanitation Plan, 2011

Figure 5 shows ward-wise solid waste segregation in percentage, where Vanaj Company and Vedbhavan (Kothrud) ward shows maximum segregation of waste are more than 60 per cent. Rajbhavan, Deccan Collage, Kalas Vishrantwadi, Ramwadi, Mohammad Wadi and Padmavati – Araneshwar wards, there is less segregation (0 to 20%) of waste.

8.2 Waste Collection

Waste collection is the removal of waste from houses and all commercial places to collection site from where it will go for further treatment or disposal. The Corporation organizes the collection and transportation through a team of its own conservancy workers and a fleet of vehicles and dumper-placers. The waste is also collected with the help of rag pickers by carrying out door-to-door collection in certain areas; these rag-pickers are not the employees of PMC, but they make their livelihood by salvaging recyclable waste from collection points and dump yards and they are also paid Rs. 10 per month by each household.

The waste collection efficiency of Pune municipality is 100 per cent, which is collected from door to door for 52 per cent of households and rest of the waste is collected from the community bins and containers.

8.2.1 Ghanta Trucks, Containers and Compactor Buckets

113 Ghanta trucks are deployed for door to door collection of waste. The Ghanta trucks collect about 95,000 Kg of wet waste every day. Containers are placed at certain locations in the city, which is used to dispose garbage by people, who are not covered under the door to door collection. There are a total of 936 containers and 412 compactor buckets placed in various parts of the city (Table 4).

Table 4: Ward-wise solid waste collection vehicles

Sr. No.	**Name of Ward office**	**Ghanta truck**	**Containers**	**Compactor Buckets**
1	Aundh	6	66	31
2	Ghole Road	11	120	21
3	Nagar Road	10	25	0
4	Dholepatil Road	8	62	18
5	Warje Karvenagar	14	115	46
6	Kothrud	13	42	12
7	Sangamwadi	12	33	0
8	Sahakar Nagar	5	39	18
9	Dhankawadi	4	74	20
10	Bibwewadi	5	81	135
11	Tilak Road	9	55	6
12	Bhavani Peth	6	59	37
13	Kasba Vishram	6	104	33
14	Hadapsar	4	61	35
	Total	**113**	**936**	**412**

Source: Pune City Sanitation Plan, 2011

8.2.2 Solid Waste collected through rag pickers

SWaCH, a PMC initiative is a registered society of waste pickers which has a total strength of 5500 members. Out of these, 1963 members are involved in door to door collection of solid waste. The data collected at sub ward level represents Household level solid waste collection (Figure 6) is more than 99 % in Vanaj Company Kothrud) ward and lowest (0 to 25%) at Ramtekdi, Mohammad Wadi, Hadapsar, Parwati Gaon. The sub wards of Aundh Gaon, Phulnagar(Yerwada), Model Colony, Vedbhavan, Rambaug Colony, NIBM, Katraj Gaon area have medium (50 to 75%) proportion

8.2.3 Private door to door collection efforts

Some societies and residential complexes have hired services of sweepers to collect door to door waste, which is segregated either at source or by the sweeper. The waste is then collected by Ghanta Trucks.

8.2.4 Solid Waste collected through Hotel trucks:

PMC has deployed 23 separate trucks for collection of hotel waste (Table 5), which is segregated at source.

Table 5: Waste collected by Hotel Trucks

Sr. No.	**Name of Ward office**	**Trucks**	**Hotels**	**Weight of Wet Waste (In kg)**
1	Aundh	2	72	9700
2	Ghole Road	3	215	22200
3	Nagar Road	2	116	9700
4	Dholepatil Road	3	171	18400
5	Warje Karvenagar	1	84	7200
6	Kothrud	2	110	11200
7	Sangamwadi	1	20	7200

8	Sahakar Nagar	2	94	5200
9	Dhankawadi	1	90	4000
10	Bibwewadi	1	45	3700
11	Tilak Road	1	42	6130
12	Bhavani Peth	2	108	5840
13	Kasba Vishram	1	130	6400
14	Hadapsar	1	52	7500
	Total	**23**	**1349**	**1,24,370**

Source: Pune City Sanitation Plan, 2011

8.3 Transportation of Solid Waste

The transportation of waste is done through Ghanta Trucks, Compactors, Hotel Trucks and Tractor, Dumper placer and Bulk Refuse Carrier (B.R.C). Dumper placers, hotel trucks and Ghanta trucks are deployed in all the 14 wards in addition to BRC and compactors in some of the wards. There are 7 different ramps of the transfer stations like Aundh, Kothrud, Katraj, Ghole Road, Koregaon Park and Yerwada and Hadapsar (Figure 7). The solid waste from each collection point is brought to these ramps of transfer stations by dumper placer or other transportation equipments. Before sending the waste to the disposal site at Urali Devachi, the entire waste is send to transfer stations for weighing and the same computerized record is maintained by authority.

Table 6: Use of Vehicles for Waste Transportation

Sr. No.	Type of Vehicle	Nos.
1	Ghanta Truck	113
2	Compactor	17
3	Mini Compactor	10
4	Hotel Truck	23
5	Dumper Placer	83
6	Bulk Refuse Carrier(B.R.C.)	60
7	Tractor	5
8	JCB	22
9	Loaders	2
10	Bulldozers	2

Source: Pune City Sanitation Plan, 2011

8.4 Processing and Scientific Disposal of Waste

The existing disposal site is located at Urali Devachi (165 acres), which is about 20 km away. Earlier, PMC was converting biodegradable organic waste into compost by the aerobic process at the landfill sites. But from 2002 onwards, PMC has shifted to Effective Micro Organism (EM), a Japanese technology. The EM technology eliminates harmful gases like ammonia and Hydrogen Sulphide, thus reducing the polluted smell; the microbes digest the organic matter and this produces high quality compost.

Presently, about 1000 tonnes of waste is composted using the EM technology; the compost is then supplied to farmers free of cost. Pune is the first city in India to implement this technology. PMC has adopted a decentralized system for waste disposal, at the local or ward level. Wet waste is disposed by vermiculture, biogas plant and waste to energy program. PMC is promoting this technology through public participation and by creating public awareness.

About 1370 MT/day of solid waste generated is scientifically treated in various ways (Table 7) like landfilling, organic compost, bio-gas and mechanical compost:

8.4.1 Hanjer Biotech Projects I & II

M/s Hanjer Biotech at Urali Devachi plant is capable to handle the mixed garbage with a full capacity of 1000 TPD. This project has constructed a scientific landfill to dispose the inert waste which is approximately 20 per cent of the total waste processing.

8.4.2 Organic Wastes Composting

Three organic wastes composting plant working in PMC. The capacity each plant is 100 TPD, out of which two processing plants have been specially made and the work of 3rd plant is in progress (Figure 8).

8.4.3 Bio Gas & Mechanical Compost Plants

Total 70 TPD of organic waste is being treated in 12 Biogas plants of 5 Tonnes capacity each, one biogas plant of 3 Tonnes capacity. Two Mechanical compost plants of 5 TPD in Ramtekadi and 2 TPD in Aundh is also functional (Figure 9).

Table 7: Solid Waste Management Project on PMC

Sr. No.	Name of the Project & place	Method	Capacity (TPD)
1	Hanjer Biotech projects - Urali Devachi	Composting, RDF, Pallets and Bio-fuel	1000
2	Disha Waste Management-Ramtekdi Industrial Estate	Vermi-composting	100
3	Ajinkya Biofert - Hadapsar	Vermi-composting	200
4	Bio-Gas and Mechanical Compost (15 Decentralized Plant)	Electricity and Compost	70

Source: Revised City Development Plan for Pune - 2041, Maharashtra, Under JNNURM

8.5 Ongoing Projects

Taking into consideration emergency breakdown, weekly offs and working efficiency of above plants and to cater to future requirement, there is a need for an additional plant to process waste. Hence construction of 700 TPD capacity waste to energy plant is in progress, the plant will work based on the technology of gasification/pyrolysis. It is expected that the plant will generate a total of 10 MW per hour of electricity.

8.6 Best Practice Models for SWM in Pune City

PMC has undertaken some innovative projects on pilot basis to manage solid waste generated in the city. Two such successful projects are:

1. 'Garbage Free Katraj' Model

2. 'Electricity Generation' through wet waste generated in hotels in Kothrud area.

Successful implementation of these projects at ward level has proved it to be a replicable model, which can be initiated phase wise in other wards of the city. These models are cost effective and demonstrate that people's participation in such programs help in implementing it successfully.

8.7 Future Generation of MSW

Presently PMC generated 1300 to 1400 tons of waste per day. Per capita per day waste generation is 500 gram. Future solid waste generation for Pune city is projected on the basis of existing per capita generation. Year wise generation of Municipal solid waste in Pune Municipal Corporation will be as follows:

Table 8: Future Generation of Solid Waste

Year	Projected Population of PMC	Waste Generation in TPD
2011	3115431	1558
2021	4487573	2244
2031	6211404	3106
2041	8597417	4299

8.8 Forthcoming Projects

1. Setting up biogas/ waste-to-energy (WtE) plant on a build-operate-transfer (BOT) basis, which will be taking care of nearly 50 MTD of wet waste in decentralized manner. This project is in pipeline and will be set up near Mundhwa.

2. Project coming up at landfill site which is completely funded by central Government consists of 150 MTD of vermiculture and nearly 500 MTD of mechanical composting.

3. Also in vessel compost plant near Kalyani Nagar on 1 acre land so that waste collected from house to house will be composted in this plant.

9. CONCLUSION

The study demonstrated the capacity to use GIS, GPS and remote sensing technology for the effective assessment of solid waste management system will minimize the environmental risk and human health problems.

The rapid increase in the quantities of MSW and the inability to provide day-to-day solid waste collection services may cause an irritation and health hazard. Segregation of waste is essential component of solid waste management which is comparatively very poor. Solid waste can be minimizing at sources using Geospatial tools. Open dumping of solid waste affect the surrounding area of the dumping site, produces very bad odor at the time of decomposition. In PMC area such situation rarely arises because of efficient and scientific MSW practices designed by using modern technology. The decentralized biogas plants based on solid waste will be the ideal solution. It will also to generate the electricity, which will be the additional advantage.

The study is useful in planning for the city in future. It emphasizes on the importance of the requirement of solid waste system. With the given time and limited knowledge with the primary and secondary data constraint this was an attempt to obtain the sustainable MSWM for urban environment.

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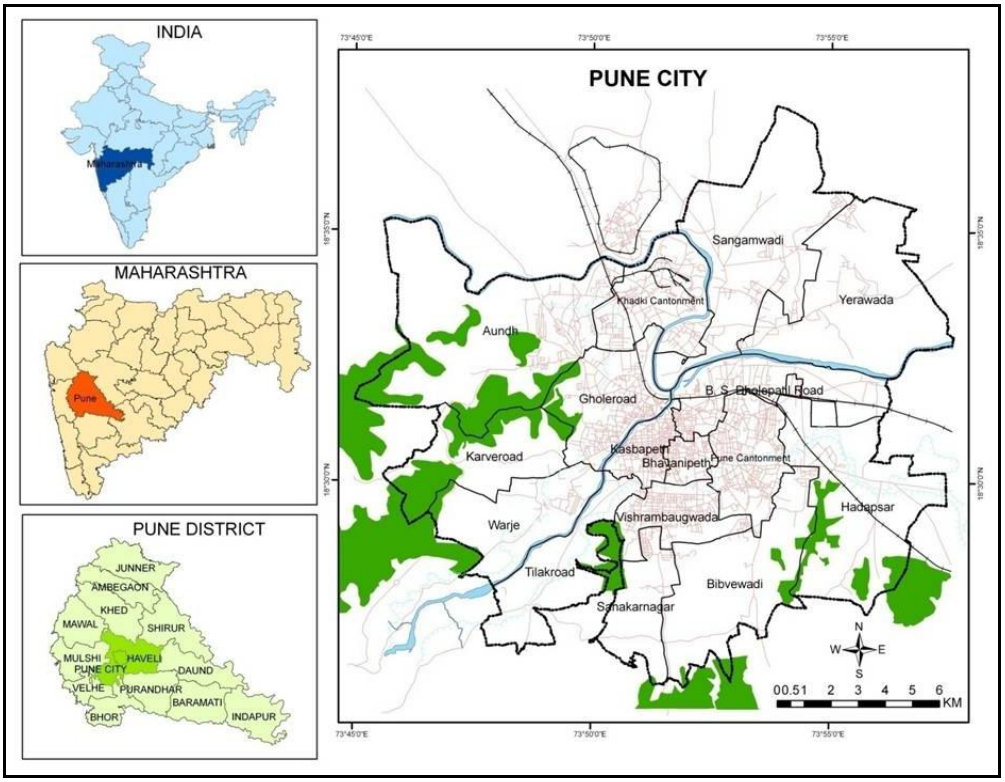

Figure 1: Location map of study area

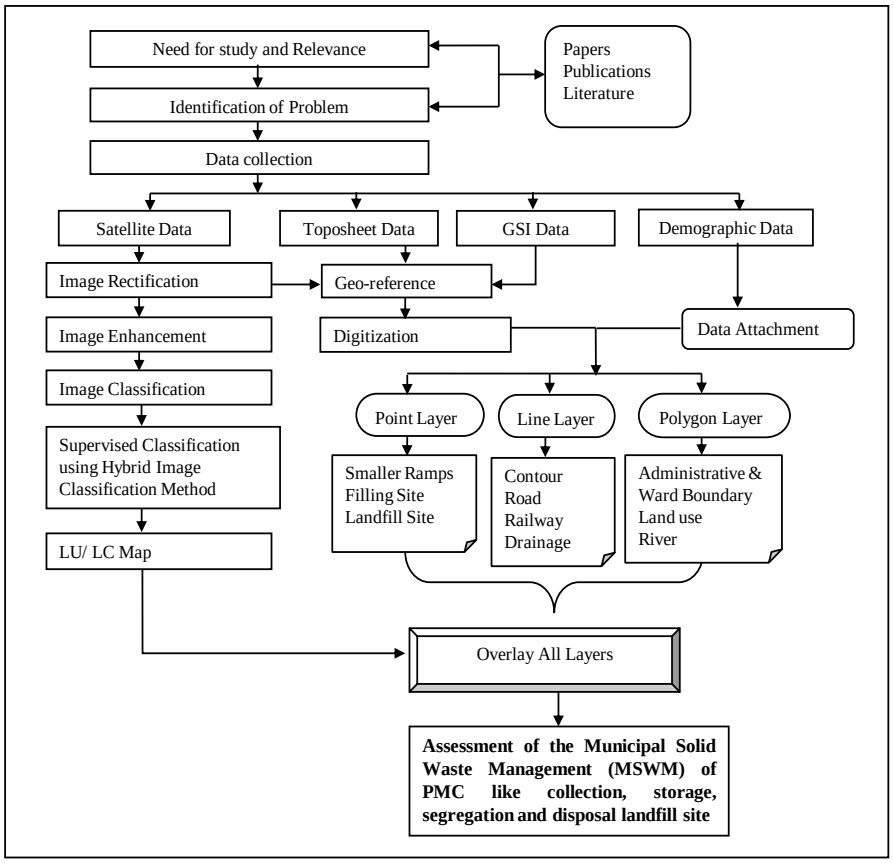

Figure 2: Flowchart of Methodology

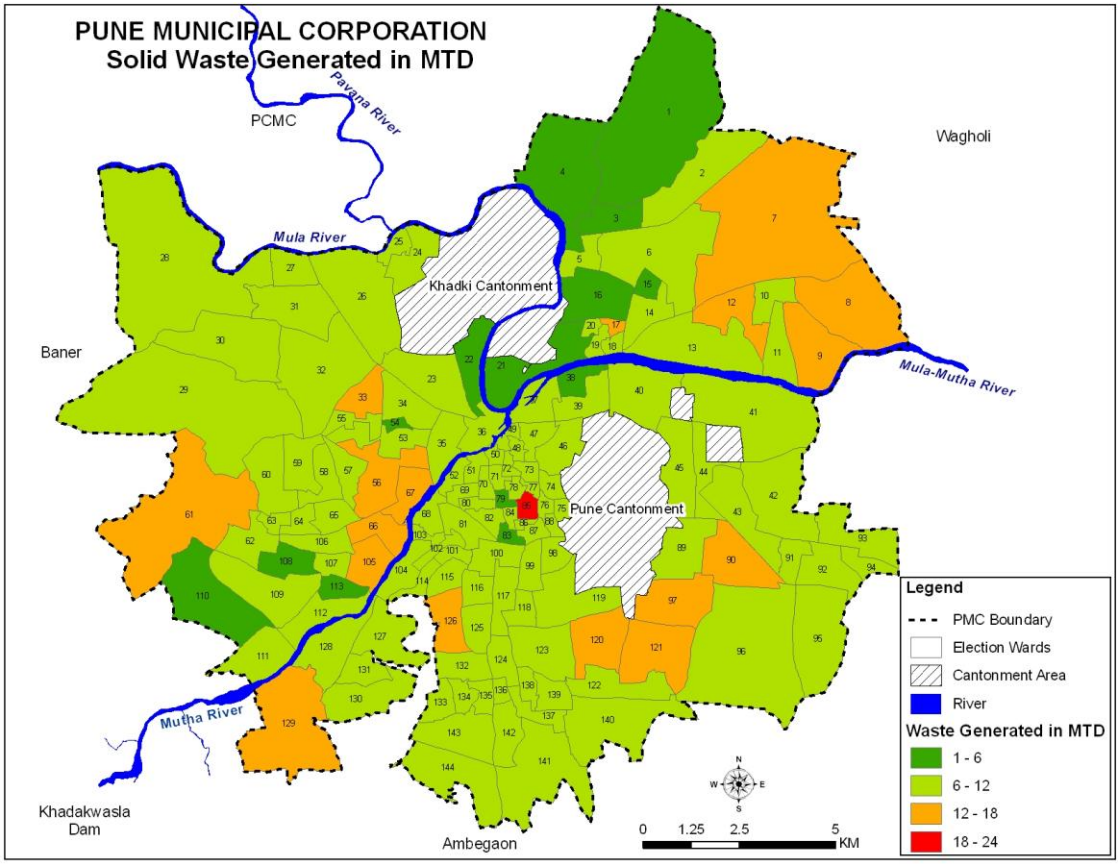

Figure 4: Ward-wise Solid Waste Generated in MTD

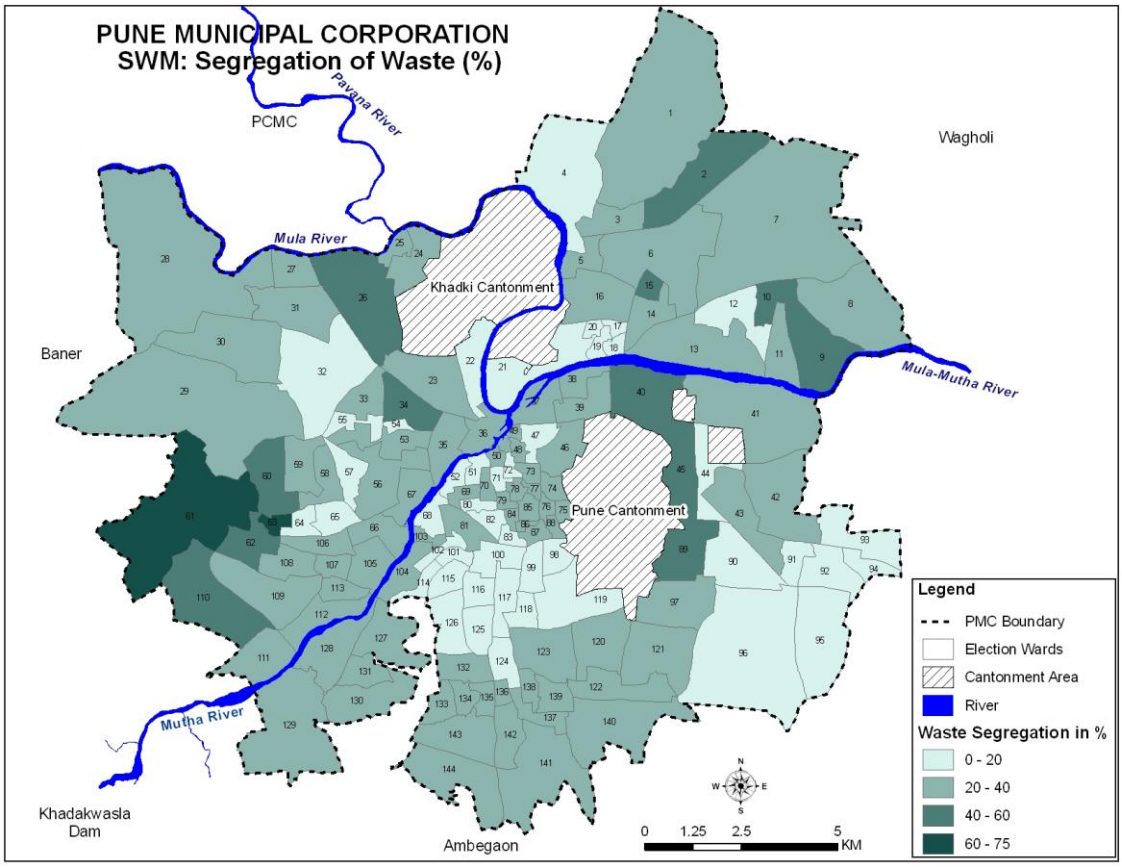

Figure 5: Ward-wise Segregation of Waste

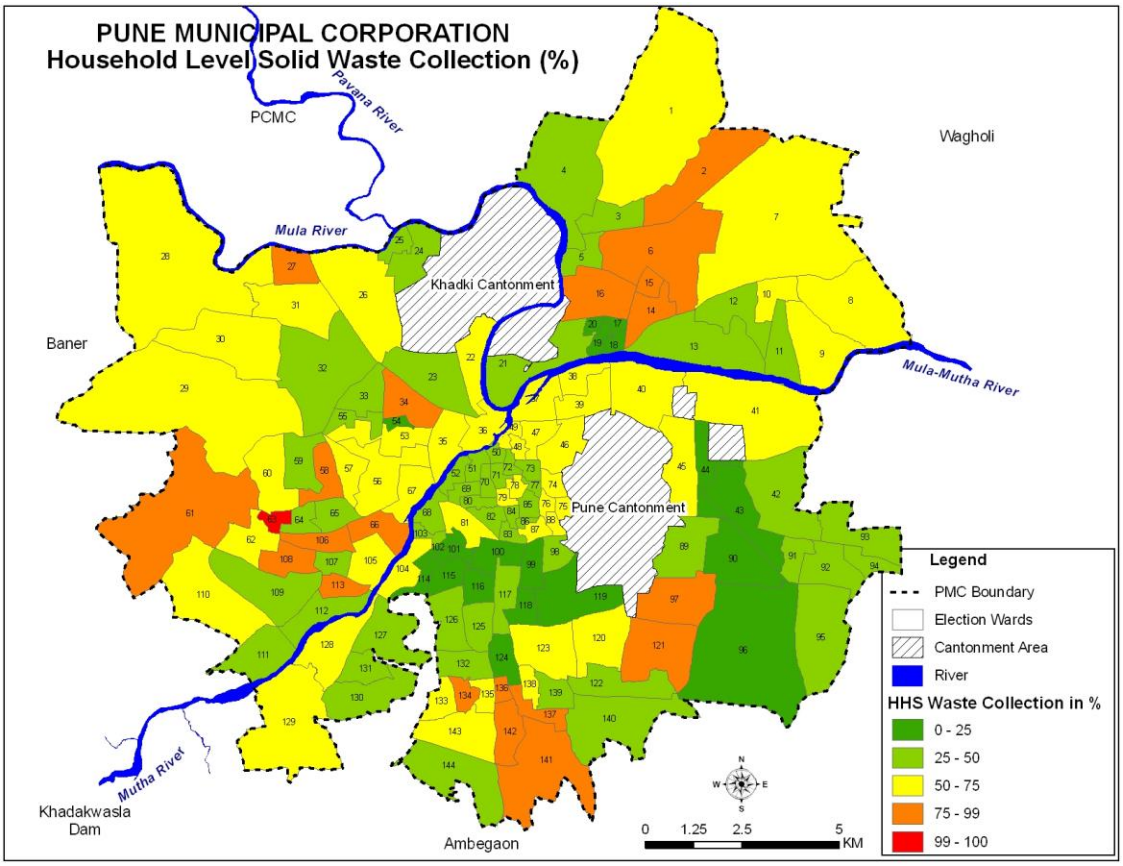

Figure 6: Ward-wise Collection of Waste

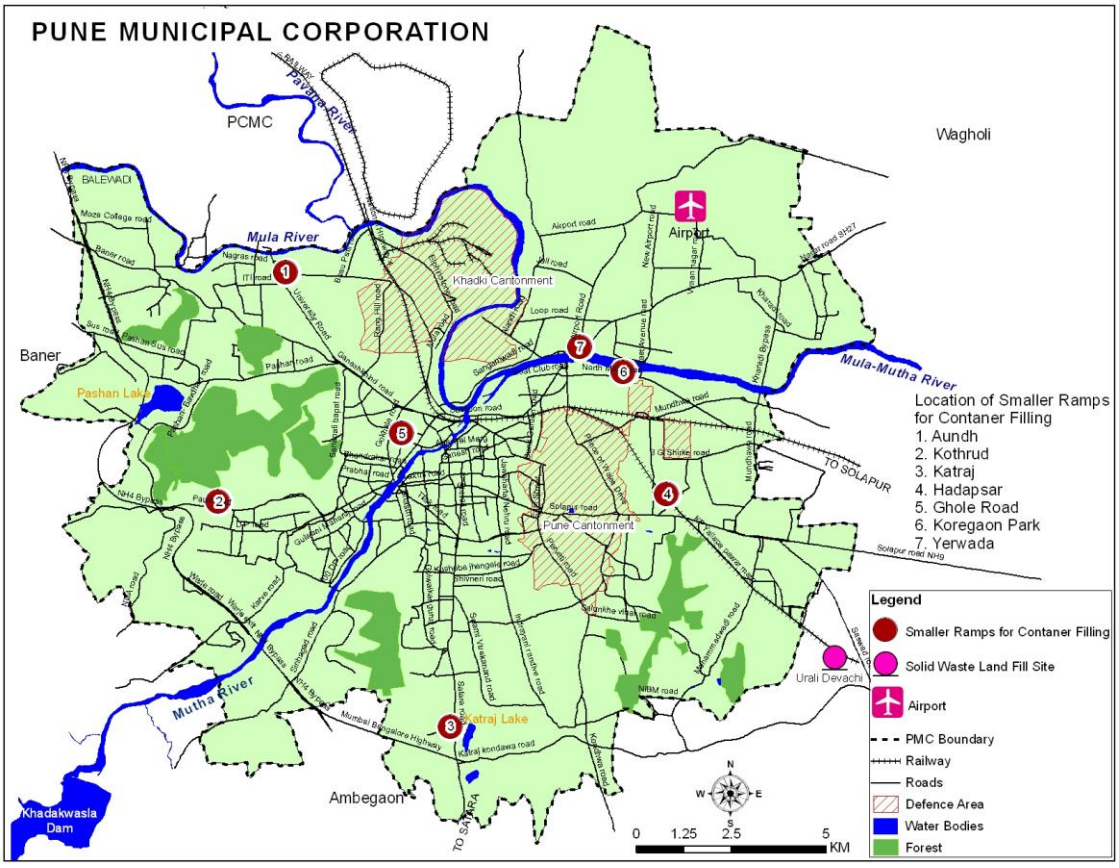

Figure 7: Solid Waste Transportation System of PMC

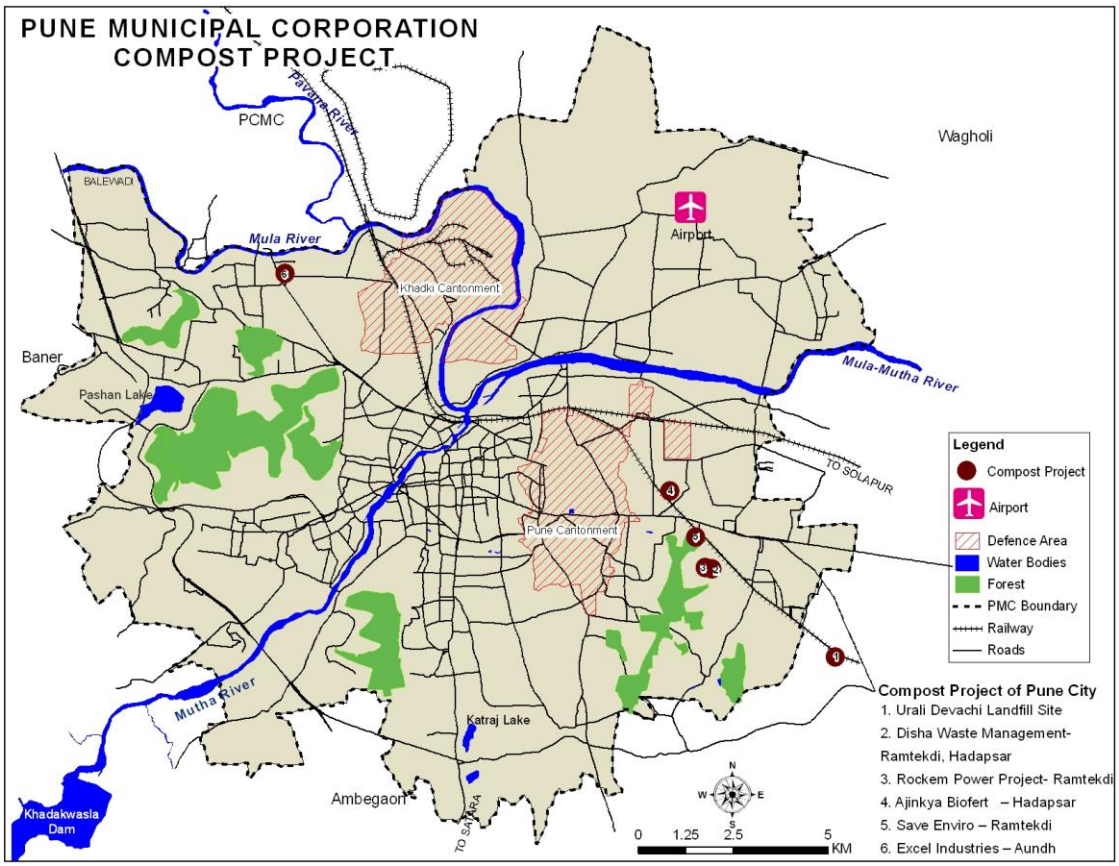

Figure 8: Compost Plant of PMC

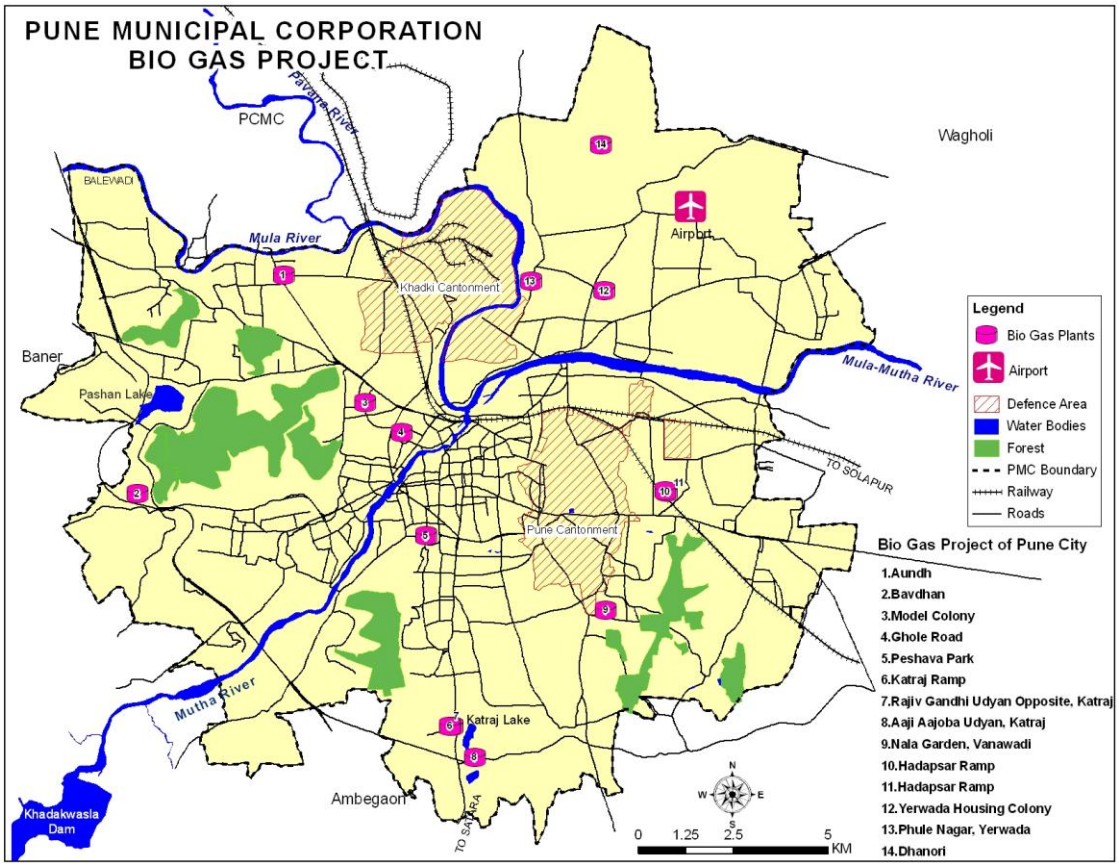

Figure 9: Bio Gas Project of PMC