

# International Journal of Innovative Research in Science, Engineering and Technology

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## A Project Report on Modified Landfill Design for Sustainable Waste Management

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**Abstract:** Characterization of municipal solid waste (MSW) is important for adequate decision making in the management strategy of urban MSW of a city. The objective of this study was to characterize the MSW at a landfill of Pune city, India and suggest appropriate MSW management methods. The investigations showed that biological treatment of MSW will be feasible as it contains high organic matter and moisture content. This would help to divert 70% of the total waste, if solid waste treatment facilities were provided at source, which would lead to enormous cost savings of waste collection, transport and disposal. Energy generation through incineration of MSW was not feasible. The changing pattern of characterization of MSW in relation to socio-economic changes has been discussed. Though the study was focused on Pune city, investigations will help solid waste management planners, materials recovery facility designers and for estimation of landfill gas emission in developing metropolitan cities.

**KEYWORDS:** landfill design municipal solid waste (MSW); municipal solid waste (MSW); energy generation; GHG.

### I. INTRODUCTION

Waste management is an important element of environment protection. Proper characterization of municipal solid waste (MSW) is the fundamental basis for planning of municipal waste management services. The knowledge of solid waste sources and types of waste in a given service area is required in order to design and operate appropriate solid waste management systems. This information is necessary in order to identify the waste components to target for source reduction and recycling, and design of material recovery facilities and waste-to-energy projects. Waste composition indicates the components of the waste stream in percentage of the mass or volume. The composition and characteristics of MSW change with time all over the world. Even in the same country, waste composition depends on a number of factors such as social customs, standard of living, and geographical location, and climate, season and so on. MSW is heterogeneous in nature and consists of a number of different materials which are derived from various types of activities. National policy decisions that influence the components of MSW systems are not possible until data of composition and quantity of solid waste are available. More than 90% of MSW generated in India is directly disposed on land in an unsatisfactory manner. The diverse nature of data about the composition of MSW necessitates a rigorous study in any given locale.

#### 1.1 Study area

The city of Pune, located at 18°31' N latitude and 73°51' E longitudes, is situated in the western region of the Deccan Plateau at the confluence of the Mula and Mutha rivers in the state of Maharashtra in India (Figure 1). Pune is one of the fastest developing urban areas in Asia and ranks eighth at national level. The present growth is attributable to various factors such as industrialization, expanding educational institutes and information technology (IT) companies and establishments of various government organizations. One of the negative impacts of the city's rapid development is the increase in MSW generation, resulting in environmental degradation. Many factors, such as spiraling urban population.

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Vol. 8, Issue 5, May 2019



Figure 1: Location map of Pune. Source: [www.mapsofindia.com](http://www.mapsofindia.com)

Economic development, consumption patterns, climate and institutional framework, contribute to MSW generation and the composition of the waste. Among them, urban population growth and economic development are vital because they not only accelerate consumption but also increase the generation of waste in developing countries. Pune, with a population approaching 3 400 000, is estimated to generate about 1200 metric tons of MSW daily. The per capita generation of MSW varies from 0.30 to 0.40 kg per day per person depending on the economic status of the community involved. MSW in Pune city has been predicted to increase from 1100 t per day in 2007 to 1800 t per day in 2011 and 2600 t per day in 2025. The annual rate of increase in solid waste generation has been forecasted to be 1.29% through 2025 (PMC, 2008).

## 1.2 Landfill site

The earlier landfill site of Pune city was at Kothrud, which closed in 1982. The present landfill site is at UruliDevachi on Pune–Saswad road, which is about 15 to 18 km from Pune and lies at 18828016.1300N and 73856057.6200 E. It covers an area of 64 ha (6.40\_105m<sup>2</sup>) of which 15 ha were permanently sealed off as it was already landfilled. The original site was a partial stone quarry and had deep excavated areas. Landfill had been operational since 1983 and it mainly contains residential waste, market waste, institutional waste and waste from slaughterhouses and information technology (IT) industries. The waste is transported to the landfill site from four transfer stations. At present the total amount of landfill waste is about 0.438 million t per annum. Although the segregation of waste was undertaken at source, such as household level, hotels and restaurants for dry and wet waste, waste received at the landfill site was mostly of a mixed nature. A significant amount of recyclable materials was being recycled by the informal sector through scavengers on the landfill site and supplied to appropriate processing factories as raw material. Since there was a lack of awareness in the past about solid waste disposal, people used to dump unsegregated waste and also Pune

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Vol. 8, Issue 5, May 2019

Municipal Corporation (PMC) used to dispose the unsegregated waste on the dumping site without any soil cover or leachate management. This gave rise to problems such as landfill fires, smoke, bad odor, leachate and so on. The height of waste dumped was 18 m. Recently PMC has agreed to allot 20 000m<sup>2</sup> of land for an integrated solid waste management plant.



The present practice of solid waste disposal consists of biological decomposition of waste and landfilling. An effective microorganism solution has been applied over solid waste to decompose the organic matter (PMC, 2010). Complete decomposition is not possible because of the unsegregated waste. It was understood from the official sources that only small quantities (150 t/day) of decomposed organic matter were segregated. These were then collected by local farmers and used as manure while the remaining solid waste was left and used for landfilling. The average annual emission of suspended particulate matter (SPM), sulfur dioxide (SO<sub>2</sub>) and nitrogen oxide (NO<sub>x</sub>) at the disposal site was 1708.3 mgm<sub>-3</sub>, 285.33 mgm<sub>-3</sub> and 234.07 mgm<sub>-3</sub> respectively. The SPM, sulfur dioxide and nitrogen oxide concentrations are more than those stipulated by Indian MSW standard limit (CPHEEO, 2000; Dhare Amar et al., 2008). The burning of solid waste creates heavy smoke and dust pollution and dousing the waste with water to prevent fires, which also results in production of leachate (Purandare, 2003). The landfill does not have leachate and gas collection systems. The leachate produced from the landfill has changed the characteristics of the ground aquifer within the vicinity of the landfill site (NissarShazia et al., 2008). The solid waste disposal and management practice of PMC have caused a lot of environmental problems such as groundwater contamination, frequent landfill fires, and a bad odour problem in UraliDevachi village, all of which require immediate attention (Khare and Mali, 2007).

### 1.3 Objectives

1. The objectives of the present study are the development of modified design methodology for landfill system with gas recovery option and estimation of energy generation value for the case of Pune MSW.
2. To characterization of MSW delivered to Pune city's landfill,
3. To studying the changing trends of waste characterization in the past 10 years and
4. To suggest the appropriate MSW treatment plan.

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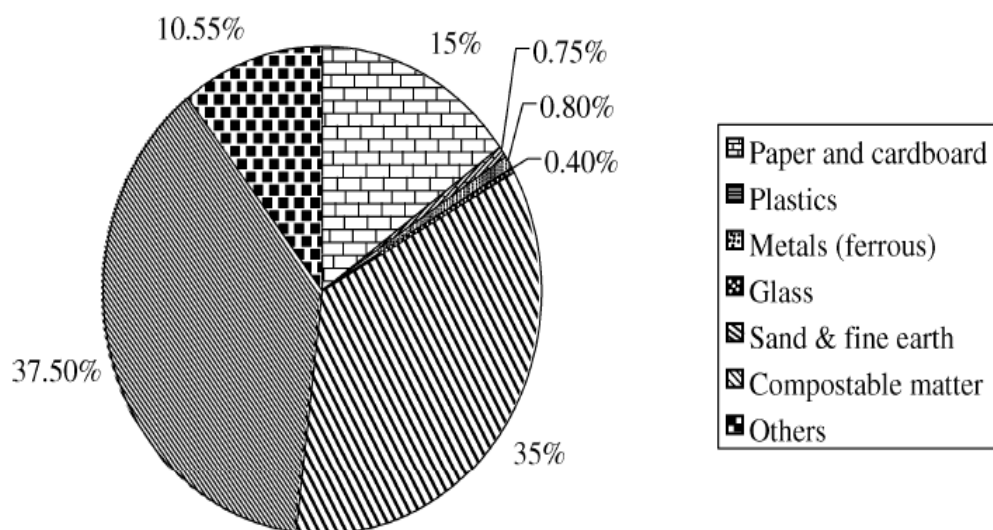
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Vol. 8, Issue 5, May 2019

### 1.4 Present scenario of waste management in Pune–

MSW of Pune presents a case, which is very close to the national waste scenario. MSW characteristics are presented. In general MSW management is a four-step process. These are collection, transportation, processing and disposal. As is the case in many developing country cities, Pune solid waste management system fails at the collection stage. Unsegregated waste creates unhygienic conditions at collection centers and also makes the retrieval of reusable material very difficult. This further result in more land requirement for the final disposal of waste. This even brings down the efficiency of various disposal processes such as aerobic composting, vermi-composting and incineration. it shows the schematic representation of MSW management in Pune.



**Figure 2: Characteristics of Pune municipal solid waste.**

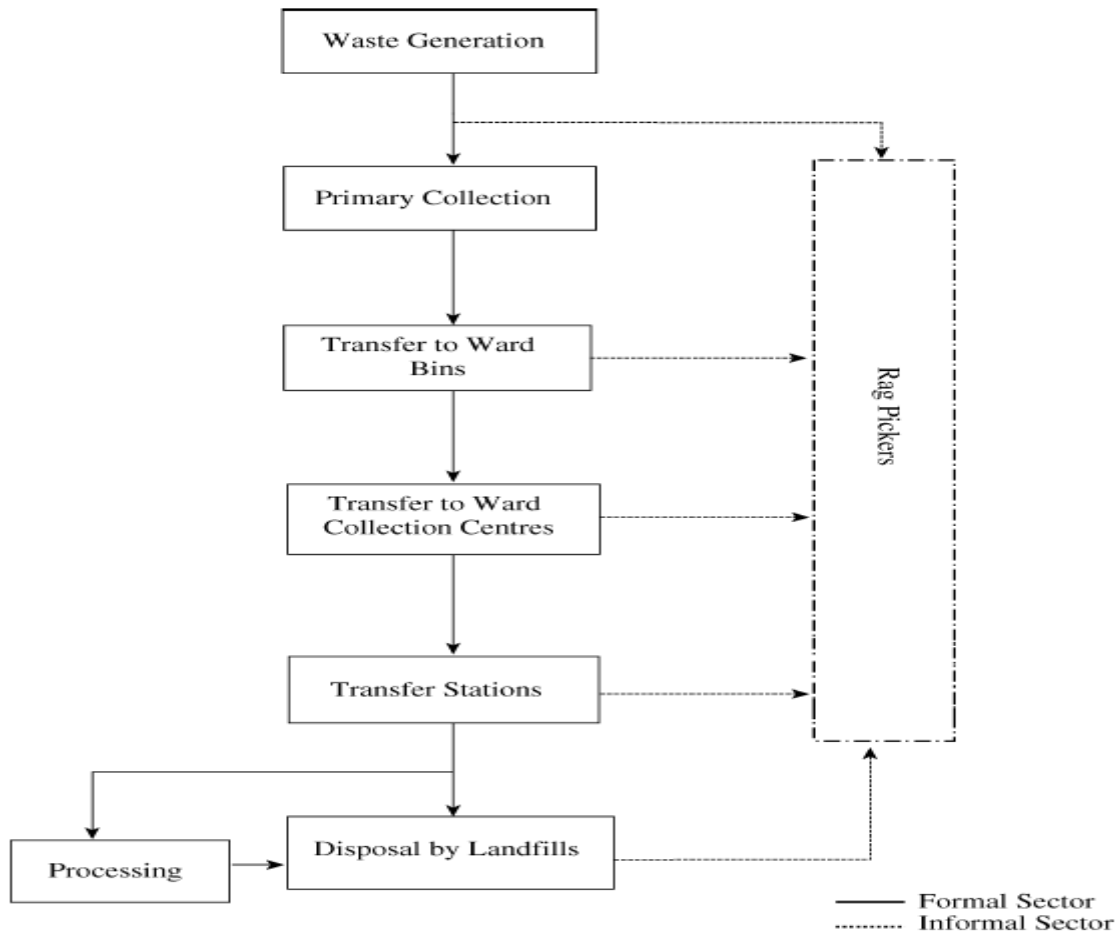
Pune presents a classical example of fast growing urban waste management problem. With a population of more than 15 million, Pune has been experiencing tremendous growth in all spheres: population, urbanization, traffic, industries, trade and so on. The Municipal Corporation of Greater Pune (MCGP) is the body responsible for the management of MSW in Pune. Present per capita waste generation rate was recorded at 0.5 kg with a collection efficiency of around 80.90% (CPCB, 1995; 1997). The total waste generated every day is as high as 6500 tons (2.37 million tons/yr). Pune has a unique geographic location, with 169 sq. km of area with very high population density. The formal sector, which has a total of 39,845 (approx.) employees and informal sector of approximately 100,000 rag pickers, collect the MSW generated. MCGP spends around Rs. 4000 million every year to manage MSW with a large fleet of vehicles and machinery. Pune, unlike cities in the other developing countries, could achieve a higher percentage of waste collection due to its innovative practices such as .night clearing. And .two shift system of collection. Despite all these efforts, MSW management is continuing to be in bad shape leaving a wide scope for severe public criticism. Many reasons are there for this failure with the most prominent being the unsegregated collection of waste and poor public awareness and participation. Unsegregated collection of waste shows a cumulative effect throughout the flow line, and, starting from poor collection from ward bins to fall in recovery of reusable material. Poor public awareness and participation adds to it. The unsegregated waste thus collected passes through the flow line showed in Figure 2. No formal resource recovery exists in the MCGP plan. However, it was found that rag pickers collect reusable material at various levels, which accounts for Rs 900 million every year.

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Vol. 8, Issue 5, May 2019



**Figure 3: Schematic diagram of present municipal solid waste management in Pune**

In general, waste is transported to land disposal sites directly. Four major landfill sites exist in Pune, which are shown in Table 1. These four sites are close to their full capacity, making the MSW take recourse to other derelict sites, which are not at all suitable for waste disposal.

### 1.5 Historical development of landfill technology

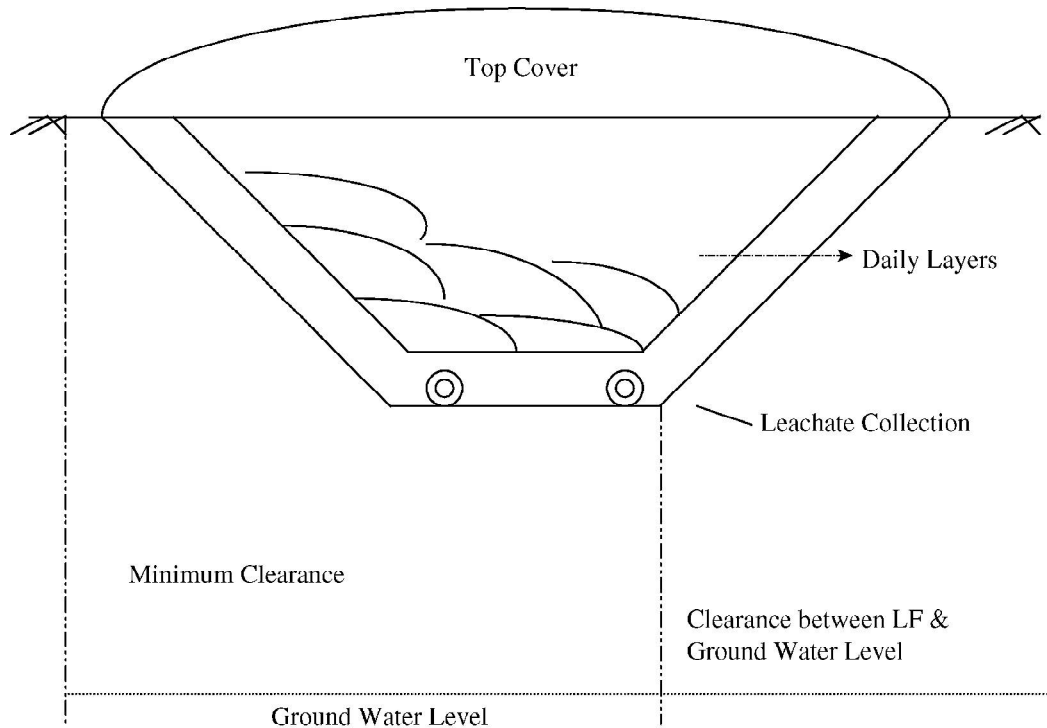
Until recently, the concept of land filling was used to dump waste material for disposal. Therefore, not much care was taken about their construction. Placing the waste in the Earth upper crust was considered as the safest practice of waste disposal. But with rapid industrialization and urbanization, land filling has metamorphosed. As uncontrolled landfills have shown potential of polluting various parts of the environment and many accidents have also happened, regulations have been imposed on landfill location, site design and their preparation and maintenance. A certain degree of engineering was made mandatory for landfills. Figure 3 shows the schematic representation of landfills. Landfill location was based on many factors and an Environmental Impact Assessment (EIA) is mandatory for the siting of landfills. Land availability for longer dumping periods and availability of cover material are some of the important guiding parameters in LF site selection.

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Vol. 8, Issue 5, May 2019



**Figure 4: Schematic representation of a landfill**

Due to these engineering inputs, landfills have been tightened up leaving much better environment in the cells. For better waste decomposition. As a result of careful sealing of cells with daily cover, public nuisance could be reduced along with improved anaerobic conditions within the cell and the life of the landfill could be reduced. This would lead to increased emission of LFG and its escape into the atmosphere is a potential threat to the global environment, which leads to global warming. On the other hand, LFG has considerable energy value and it depends on the composition of waste and also other conditions. Typically, the LFG collected is used for electricity generation and boiler heating in various industries.

## II. LITERATURE SURVEY

### Electronic Waste Management System at Pune

A comprehensive study conducted by author on the existing E-waste management system in Pune. The study gives idea about the present E-waste practices of the various stakeholders in the system. Figure 1 illustrates the existing E-waste management system in Pune and the following paragraphs discuss the same.

#### Informal Sector:

The waste collectors or rag pickers are the most important link in electronic waste flow and they are collecting most of electronic waste in Pune city from household users as well as from manufacturers. There is another set of operators, waste traders with better financial capacity, who bid for larger volumes of waste being discarded by companies and organization through auctions. The waste then flows down to scrap dealers; first they are dismantling Waste into different components, collect useful components and then shift the other waste to plastic recyclers or thrown on open land. The E-wastes produced in small and medium sectors mainly end up with the informal recyclers where recycling is done in hazardous manner causing danger to not only to the environment but also to the people involved in the recycling

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Vol. 8, Issue 5, May 2019

activity. However E-waste has been kept away from the dump sites so far. But, its activity still generates a high environmental and social impact (use of toxic chemicals, poor working conditions, child labor, etc.). Rag-picker picks discarded waste from local garbage dumps or open fields. In the existing system the E-wastes collected by the Rag picker end up in the hands of informal recyclers through Local Waste Marts and the Mumbai Market. Thus, it is necessary to develop new path and to modify the existing system to ensure that E-wastes end up with authorized recyclers.

### Formal Sector:

In contrast to the threat presented by informal sector, the opportunities presented by the Organized Sector are immense. The formal recycling needs the joint efforts of all the stakeholders including WEEE producers, Domestic users, and other consumers so that an eco-friendly management and recycling should be carried out. By use of proper tools, machinery, equipment's without damaging health of labor which is finally resulting in efficient management of E waste. Life cycle of the electronic and electrical equipment's starting from the birth at manufacturing sector reaches the consumers and after their consumption at user end, these equipment's enter the chain of recycling at the collection centers designated by companies and thus reaching authorized recyclers and dismantler's .To replace informal sector by formal one for recycling, government of India enacted rules . Various recycling companies have evolved out in India which has been granted authorization by concerned pollution control boards and they maintain all standards as prescribed by the central pollution control board.

Very few formal E-waste collecting and dismantling centers are running successfully in Pune city. According to Maharashtra Pollution Control Board (MPCB), Pune officials there are three E-waste recyclers. Approximately 1000 Tons of E-waste was processed and recycled in these recycling units. The registered recycle centers of E-waste, in and around Pune are:

1. Hi-Tech recycling India (P) Ltd. Bhugaon, Pune.
2. Eco-credible Enviro Solutions Pvt. Ltd, Pune.
3. Green IT- Recycling Centre (P) Ltd, Ranajangaon, Pune.

These three E-waste recycling centers are working as per MPCB guidelines. While the MPCB has permitted Eco credible to recycle 2000 Tons per year, the company has been able to recycle only 150 Tons wastes this year, because of E-waste availability is insufficient manner. Since most electronic and electrical products have a value at the end of their useful life, the informal sector is able to pay the consumer to acquire this waste. The formal sector, because of its larger infrastructure and operational costs, finds it hard to compete with the informal sector.



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Vol. 8, Issue 5, May 2019

## Household Users:

Approximately 500 Tons to 1000 Tons E-waste generated in Pune city is of domestic nature, maximum 300 Tons is being collected. Rest of all E-waste is added to the municipal solid waste. According to the study of some households in Pune using random sampling most of citizens of Pune are not aware about E-waste and its hazards. The focus of the study was to know the disposal techniques of the electronic waste products and to assess the E-waste awareness among the domestic users. The different families in Pune according to living standard were considered for the study. The study gave valuable inputs regarding awareness of the toxic substances present in the E-waste and knowledge of the hazards to human health and the environment and the people's expected value from the products that were disposed and/or recycled. The analysis shows that most of the people are not aware of the hazardous materials present in the electronics products but only a few actually knew the practices adopted to recycle this waste. In Household disposal of E-waste in Pune most of waste is disposed with household waste as well as sold to kabadiwalas.

## Government:

The government of Maharashtra has taken various initiatives for E-waste management under MPCB with municipal corporations of major cities in Maharashtra. But the major problems in E-waste management are lack of awareness, high rate of generation of E-waste, lack of infrastructure in E-waste management. Government has passed a law for E waste management and handling in 2018, but lack political wills it would not get implemented properly. While the E waste rules were implemented in 2018, even after three years the problem of domestic E-waste disposal and recycling remains. Pune city's solid waste management system has to bear an extra 30 per cent load of electronic waste (E-waste) not being separated, collected or recycled by government institutions. As the MPCB did not carry any studies of E-waste since 2018, the officials could not give any accurate figures and estimated that the E-waste generation has increased from 1950 Tons in 2018 to 4500 Tons in year 2018. Thus, it is the responsibility of government as well as citizens to do the systematic E-waste management and disposal.

## III. 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.

## IV. MATERIALS AND METHODS

### 4.1 Sample collection and segregation

Sampling for the present work was done monthly from January 2008 to November 2008 to account for seasonal variations and representative characteristics of MSW. The sampling locations were identified in consultation with municipal authorities responsible for the operation of the site to obtain a representative sample. A total of 25 samples were characterized for physical and chemical analysis of MSW. The samples were collected from three to four locations as unloading of waste was done at different places. Special care was taken at time of sampling to obtain a representative sample. A typical load of the solid waste in a vehicle weighs between 4500 and 9000 kg. It was not practically possible to separate the entire load or a load from an even larger vehicle. The solid waste unloaded from the vehicle created a small heap of waste. It was spread horizontally by an earth mover and approximately four quarters were made, one of which was selected for sampling. The volume of each sample was about 100 kg for physical analysis of MSW. Using clean polyethylene airtight bags, 5 kg of mixed sample were collected and labeled for each location and subjected to chemical analysis. Initially it was analyzed only for moisture content and later on for other parameters by proper storing.



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Vol. 8, Issue 5, May 2019

## 4.2 Sorting and processing of samples

Waste samples were manually sorted with the help of landfill workers into seven categories, namely plastic, paper, cloth (rubber, leather and synthetics), metals, stone, glass and organic matter. Sorting was based on visual inspections, and small particles, which would not be visually identified, were classified as stone. Each category of waste was weighed separately by an electronic weighing balance (Saco Electronic weighing balance). Standard personal safety procedures were followed during the sorting process such as wearing gloves, goggles, apron and shoes. For analytical purposes the samples were cut and shredded, except for bulky materials (e.g. metals, glass and stones). The size of particle for the processed fraction was less than 4mm for volatile solids, ash, organic matter and pH, thus excluding the bulky material for the analysis. This meant that compared with the actual landfill conditions some of the variables in the samples had higher observed concentrations relative to their in situ condition.

## 4.3 Laboratory sample analysis

(a) Ph. The dried MSW waste was analyzed for ph. The pH was analyzed by shaking 50 g of waste material in 250 ml of distilled water for 24 h and analyzing by pH meter (Elico India, LI, 127) (USEPA, 2001).

**Table 1: Waste composition category**

Series No.	Waste composition category	Waste components
1	Plastic	Plastic bags, packaging material, plastic bottles
2	Paper	Packaging paper, cardboard wrapper, newsprint, magazines, office paper
3	Cloth	Rubber, clothes, synthetic, cables, leather
4	Metal	Ferrous, non-ferrous, tin cans, metal foils
5	Stone	Stone, construction material brickbats, sand, aggregate, ceramics, crockery
6	Glass	Clear, brown, green, other
7	Compostable	Food, vegetable, yard trimmings, wood, leaves, grass

(b) Organic matter. Some 25 g of dry waste were ignited at 360°C for 24 h to evaluate the organic matter (USEPA, 2001).

(c) Moisture content. Moisture content was determined gravimetrically. Samples in airtight bags were used to determine the moisture content. Mixed samples of 100 g were taken and dried in the oven at 105°C for 24 h, cooled in a desiccator and the difference in weight recorded (Vesilind et al., 2003). Moisture content is per cent sample weight lost on drying.

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Vol. 8, Issue 5, May 2019

(d) Total solids, volatile solids, fixed solids. Some 50 g of wet sample were dried at 103–105°C for the total solids. Then total solids were ignited in a muffle furnace at 550 – 508°C for 1 h. The fraction during ignition was termed ‘volatile solids’ and the fraction of solids remaining after ignition were called ‘fixed solids’.

(e) Density by core cutter method. A core cutter consisting of hollow steel cylinder with 10 cm internal diameter and about 13 cm high and a 2.5 cm high dolly is driven in the landfill with the help of a suitable rammer. The cutter containing the MSW was dug out of the landfill, the dolly was removed and excess MSW was trimmed off. Density was determined by the mass of MSW in the cutter divided by the volume of core cutter and expressed in terms of kg mm<sup>-3</sup>.

(f) Organic carbon (C). The solid waste was pulverized after air drying it to pass a 0.42mm sieve. The method was used to determine the organic carbon (C) content of the waste sample which is similar to the procedure used to measure soil organic C content.

(g) Total Kjeldhal nitrogen (N). TKN was analyzed according to the application note supplied by Teactor.

### V. CONCEPTUAL BACKGROUND

#### 5.1 COMPOSITION OF MSW

Materials in MSW can be broadly categorized into three groups, Compostable, Recyclables and Inserts. Compostable 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.

#### 5.2 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
<b>Total</b>		<b>1000</b>	<b>100</b>

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 UruliDevachi from the 1st of June 2018. PMC has stopped open dumping and total waste generated is processed scientifically

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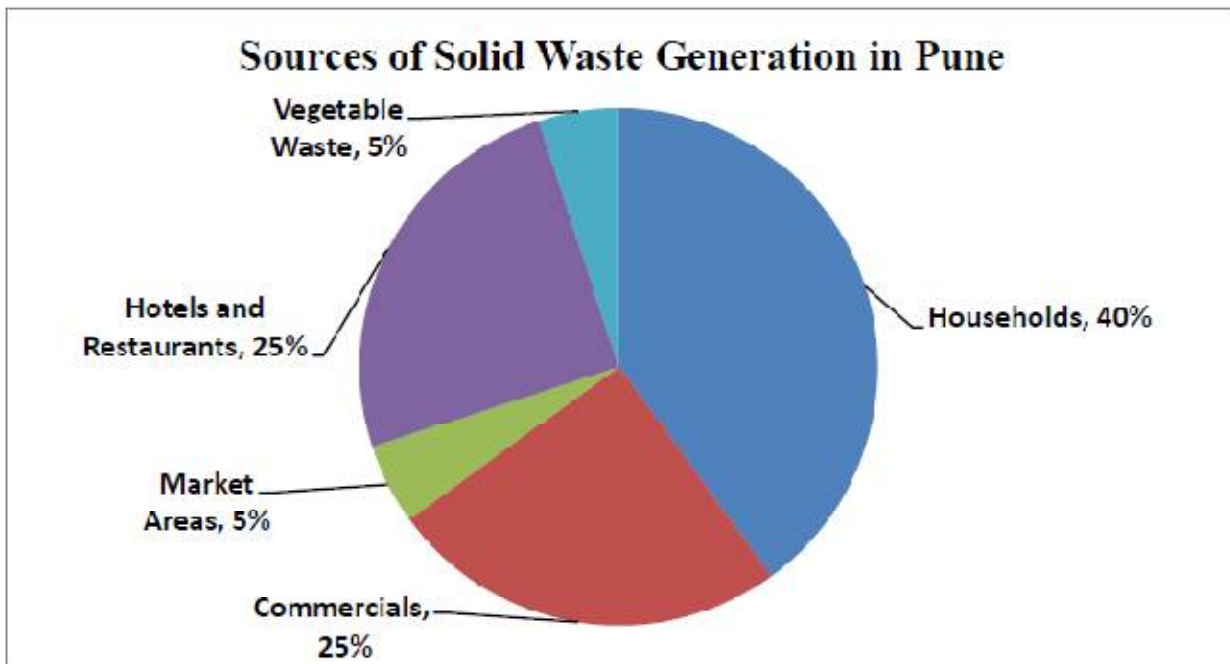


Figure 5: Sources of MSW Generation in PMC

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

### 5.3 Proposed methodology for modified design of landfills

Given the poor situation of waste management and landfills as also the failure of existing landfills to attract private participation, the following new methodology of landfill design is proposed and developed to attract private participation in waste management by providing economic gains. The proposed design is based on an integrated approach to waste disposal and energy generation. This approach can be applied only to the proposed new landfills. It may not be applied to the existing landfills.

The following assumptions are made:

- Waste is segregated at source and should contain very little fraction of recyclable material when it reaches the landfill site.
- Direct shipment of waste is considered in most of the cases as the proposed landfills with modified designs could be located in different parts of the mainland leaving a wider scope for minimization of transportation cost and efficient waste collection.

In this modified design approach, in contrast to the conventional approach, land requirement is determined for the waste generation level and for a given life of landfill, the required number of cells is decided upon.

Let

Density of waste in landfill =  $\rho_w$ . If t/m<sup>3</sup>

Total waste generated per day (tons) =  $Wd$

Annual waste generation (tons) =  $Wa$

Compostable fraction of MSW =  $fcf$

Non-organic/reusable fraction of MSW =  $fn$

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Vol. 8, Issue 5, May 2019

Collection efficiency =  $e_{coll}$

Fraction to be landfilled =  $f_{if}$

Landfilling efficiency =  $e_{if}$

Depth of fill (m) =  $d_{if}$

Let  $f_{cs}$  be the ratio of volume of cover soil to the volume of waste

Volume of waste after landfilling including daily cover (daily), m<sup>3</sup>

$$= \frac{W_d \times f_{if} \times e_{coll}(1 + f_{cs})}{\rho_{w-if} \times e_{if}}$$

Let the volume of each cell be

$$(L \times 2B \times d_{if}) - 0.5 d_{if}^2 (2L + B - 5d_{if})$$

Where,

L = base length of landfill (with one end open)

B = breadth of the base (wall to wall)

And 1:1 slope is assumed on all sides of the landfill.

For a .cell. To cater for a one year of waste, the designed volume should be equal to the Volume of waste in place per year

$$\Rightarrow (L \times 2B \times d_{if}) - 0.5 d_{if}^2 (2L + B - 5d_{if}) = \frac{W_d \times f_{if} \times e_{coll}(1 + f_{cs}) \times 365 \text{ days}}{\rho_{w-if} \times e_{if}}$$

$$\text{Area in metres (A}_{LF}\text{)} = \frac{W_a \times f_{if} \times e_{coll}(1 + f_{cs})}{\rho_{w-if} \times d_{if} \times e_{if}}$$

$$2LB - 0.5 d (2L + B - 5d) = \frac{W_a \times f_{if} \times e_{coll}(1 + f_{cs})}{\rho_{w-if} \times d_{if} \times e_{if}}$$

With 1:1 slope, the dimensions of each cell can be calculated by trial and error for any given set of waste generation data. Maturation period of three years is considered for this modified design of landfill. This has been assumed based on the anaerobic digester demonstrated for the digestion of market waste. It has been assumed that by the time the waste reaches the landfill the non-compostable fraction is negligible and proper shredding and damping are carried out, which shortens the maturation period of the waste in the semi-engineered. Landfill cell. This assumption is further supported by the pilot study carried out on landfills with gas recovery in Delhi and Nagpur. Each cell may be designed to cater to the waste generated for one year and the life of each cell should be three years for gas generation (effectively it gets four years as maturation).

## VI. RESEARCH 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.

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Vol. 8, Issue 5, May 2019

**Table3: 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, 2018)	Global Land Cover Facility (GLCF) earthexplorer.usgs.gov web site
Demographic details from Primary Census abstracts for, 2017 and 2018	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.

- Procurement of Satellite data and related attribute data
- Geo-correction of remote sensing data and topographical maps.
- Application of standard image processing techniques to identify the existing solid waste system of study area.
- 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.
- Fieldwork would be carried out to survey by using GPS.
- 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.

## VII. RESULTS AND DISCUSSIONS

### 7.1 Characterization of solid waste

Waste samples collected from UraliDevachi landfill site from different locations and for different months were characterized for physical and chemical parameters. All physical components of the bulk waste were segregated manually on site and the results are summarized. The total weight of each wet waste category was determined and expressed in percentage. Proximate analysis of all collected samples was done in the laboratory and the results are given. Mean values and standard deviations were calculated for different components of MSW. From a practical point of view, the empirical data obtained in the present study appear to be case dependent and can be used only to assist for planning of solid waste management of Pune landfill site. The physical survey of the landfill site shows that the organic fraction includes paper, cardboard, rubber/leather/synthetics and compostable matter. The inorganic fraction includes plastic, metals, earth ware, stone, brickbats, ceramics, and glass and so on. Tables 2 and 3 show the physical and chemical composition of the waste respectively based on weighing of wet samples. The degradable materials form a major fraction and metal was the smallest composition of MSW for various months. Organic matter varied from 46.0% to 85.4%. The coefficient of variation for compostable matter was 13.80%, which was less than the maximum variation coefficient observed; that is, 22%. The moisture content at the present landfill site varied from 38.91% to 58.91%. This indicates that waste contains sufficient moisture content to initiate the biodegradation. The increase in recyclables (plastic, paper, metal, etc.) has given rise to the phenomenon of scavenging activity (about 300 to 400 scavengers) where therecycling units have mushroomed near the landfill site, providing employment to unskilled labor. The average composition of MSW includes plastic 7.1% (\_4.1), paper 6.9% (\_4.5), cloth 7.8% (\_5.4), metal 0.7% (\_0.6), glass 1.2% (\_1.4), organic matter 69.3% (\_9.6) and stone 7% (\_5.2) (Figure 3) while density was found to be 854.96 (\_212.86) kgm<sub>-3</sub>. Figure 4 shows the monthly variation of MSW composition. The presence of carbon compounds in MSW

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 8, Issue 5, May 2019

varied from 4.05% to 19.28% with average 11.62%, which was essential for landfill gas formation. Nitrogen and phosphorus are also essential for the microbial activity in a landfill. The average nitrogen content was 0.64% on a wet weight basis. The average carbon to nitrogen (C/N) ratio was 20.09 \_ 4.38.

**Table 4: Physical analysis of MSW of UraliDevachi landfill**

Series No.	Sampling date	Sample No.	Plastic <sup>a</sup>	Paper <sup>b</sup>	Cloth <sup>c</sup>	Metal <sup>d</sup>	Stone <sup>e</sup>	Glass	Organic <sup>f</sup>	Total
1	26/1/2008	1	5.2	9.0	0.4	0.0	0.0	0.0	85.4	100.0
2		2	7.4	5.1	10.9	1.6	11.9	0.0	63.1	100.0
3		3	3.6	6.9	2.1	0.0	15.0	0.0	72.4	100.0
4	16/2/2008	1	9.0	9.6	2.6	1.1	4.3	1.0	72.4	100.0
5		2	8.6	9.8	7.7	0.4	3.5	1.4	68.8	100.0
6	30/3/2008	1	7.5	4.0	3.5	0.7	11.4	0.0	72.9	100.0
7		2	3.4	8.2	8.9	0.0	18.3	0.0	61.2	100.0
8		3	4.9	6.8	0.6	0.0	8.2	0.0	79.5	100.0
9	13/4/2008	1	7.5	9.0	5.9	1.5	14.3	2.4	59.4	100.0
10		2	5.7	4.5	4.0	0.5	12.2	5.2	67.9	100.0
11		3	9.8	5.8	4.0	0.9	13.3	0.7	65.5	100.0
12	29/5/2008	1	5.8	6.7	20.2	0.0	1.6	2.5	63.2	100.0
13		2	11.0	11.8	9.8	0.0	1.4	0.0	66.0	100.0
14		3	7.6	7.9	15.4	0.0	3.0	0.9	65.3	100.0
15	19/7/2008	1	2.4	4.1	5.2	1.3	1.8	0.3	84.9	100.0
16		2	5.3	4.6	8.2	1.2	2.0	0.6	78.1	100.0
17	19/8/2008	1	6.7	24.7	16.8	0.7	2.7	2.5	46.0	100.0
18		2	17.3	4.5	14.6	0.5	2.3	4.7	56.2	100.0
19		3	19.3	4.3	16.4	0.6	2.2	0.4	57.0	100.0
20	28/9/2008	1	4.8	2.3	4.9	0.7	5.5	0.9	80.9	100.0
21		2	9.0	1.2	2.8	0.6	5.7	1.3	79.4	100.0
22	19/10/2008	1	2.7	4.5	6.3	1.1	7.6	1.1	76.8	100.0
23		2	2.8	7.7	5.7	0.8	7.0	1.3	74.8	100.0
24	9/11/2008	1	3.4	3.6	8.8	1.8	11.3	1.4	69.8	100.0
25		2	5.8	5.4	11.2	1.0	8.6	1.2	66.8	100.0
		Mean ±	7.1	6.9	7.8	0.7	7.0	1.2	69.3	100.0
		std dev.	4.1	4.5	5.4	0.6	5.2	1.4	9.6	

## 7.2 Variation of MSW characteristics with time

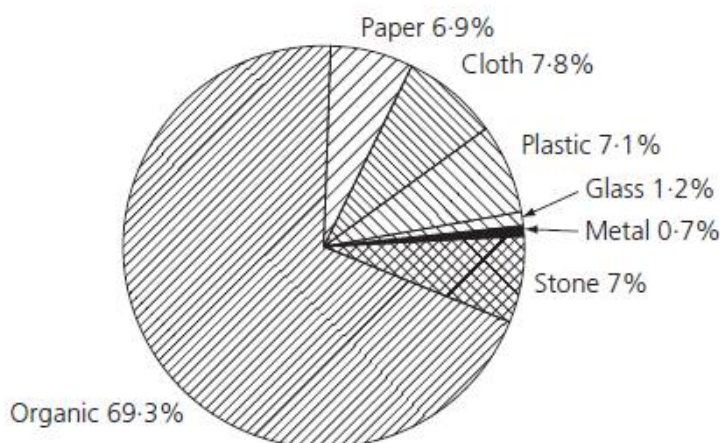
There has been a remarkable effect on the waste generation of the city from 2001 to 2008 which can be very well related to the overall economic development that has taken place. Organic matter had increased from 51.5% in 2001 to 69.3% in 2008. The municipal corporation had taken up the issue of awareness programmers since 1999. The corporation has offered a 5% rebate on property tax to those citizens who will provide appropriate MSW management facilities there was an increase in the number of city scavengers, collecting the recyclable materials, and the only waste left was organic matter and non-recyclable materials. The biodegradable fraction was quite high, essentially attributable to the habit of using fresh vegetables in India. The number of restaurants and hotels has increased, which was also contributing to the increase in organic matter. The high biodegradable fraction warrants frequent collection and removal of solid waste from the collection points. It has been observed that the percentage of recyclable material (paper, plastic, glass and metal) delivered to the landfill decreased from 20% in 1990 to 6.2% in 2001. There was an increase of recyclable material by 9.57% from 2001 to 2008, owing to changing lifestyle, increase in economic status, material consumption pattern, educational institutes, IT sector, and throwaway culture and so on.

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 5, May 2019



**Figure 6: Physical composition of MSW of Pune.**

This increase has given rise to the practice of scavenging, especially in the city and landfill area, providing employment to hundreds of unskilled workers. Inert matter has increased from 15% in 1999 to 40.60% in 2001 (an increase of 25%) as shown in Figure 5. This was attributed to the practice of inclusion of the street sweepings, drain silt and construction and demolition waste in MSW. High inert content increases the densities of MSW. Inert matter has decreased from 40% in 2001 to 7% in 2008 (a decrease of 33%) owing to improvements in the road surface and increase in concrete road.

**Table 5: Composition of municipal solid waste of Pune**

Parameter	a	b	c	d
Physical parameters				
1 Organic matter: %	55	51.5	70	69.3
2 Paper: %	5	1.9	8	6.9
3 Rubber, leather, synthetics: %	NA	0.4	NA	NA
4 Plastics: %	5	2.3	7	7.1
5 Clothes: %	NA	1.2	NA	7.8
6 Glass: %	10	1.1	6	1.2
7 Metal: %	NA	0.9	4	0.7
8 Inert matter: %	15	40.6	5	7
9 Density: kg m <sup>-3</sup>	NA	437.00	NA	854.96
10 Gross calorific value: kcal kg <sup>-1</sup>	NA	937.00	NA	NA

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 8, Issue 5, May 2019

Length and construction and demolition waste not being allowed in MSW. The reduction in inert matter caused an increase in the percentage of organic and recyclable matter. There was small variation in organic matter, paper and plastic between 2007 and 2008. The percentage of glass and metal has decreased from 6% to 1.2% and 4% to 0.7% respectively, from 2007 to 2008.

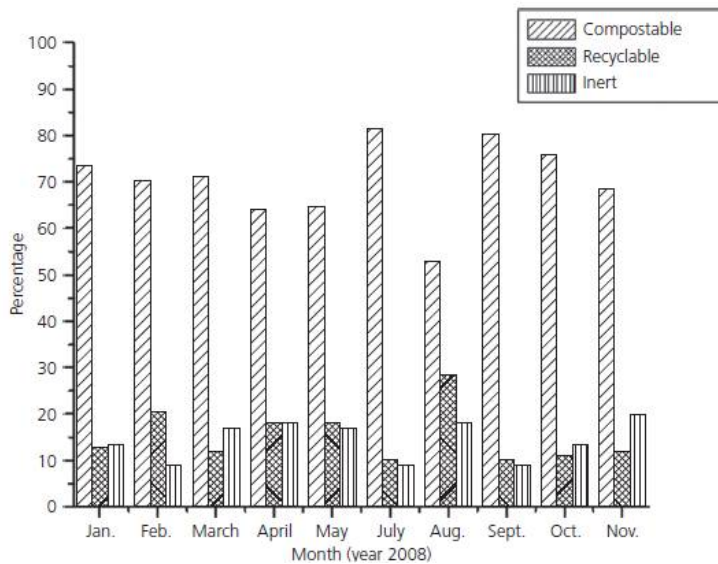


Figure 7: Variation of physical composition of MSW

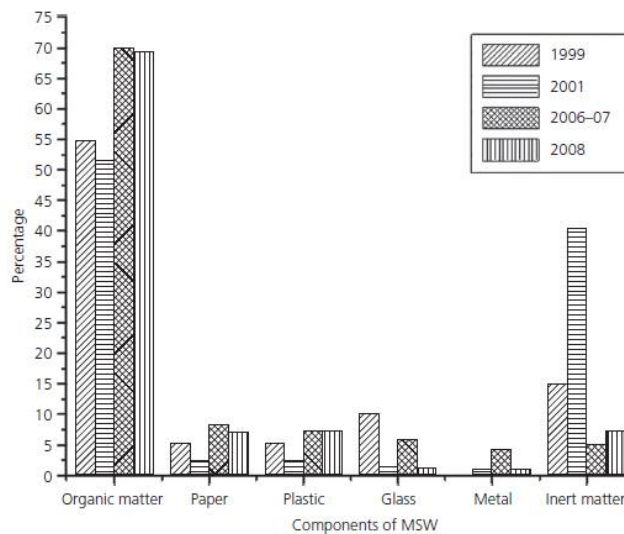


Figure 8: Variation of MSW composition with time



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(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 8, Issue 5, May 2019

## 7.3 Necessity of waste management

The results show that organic matter and moisture content in UraliDevachi landfill waste was significantly higher, which causes various environmental and social problems within the vicinity of the landfill. There are frequent landfill fires throughout the year, mostly in summer. Groundwater resources have been contaminated due to landfill leachate. The socio-economic development of villages/towns adjacent to landfill is affected. It is mandatory for all cities in India to have the solid waste management system as per MSW 2000 rules and regulations which specifies that only inorganic waste should be scientifically disposed. Therefore there is a need to take appropriate action to manage landfill waste.

## 7.4 Appropriate method of MSW management

Management of the MSW of a city depends on population density, peripheral development, socio-economic conditions, residents' solid waste management habitual culture and so on. Characterization of MSW of Pune landfill showed that biodegradable matter was 70% and the remaining 30% was recyclable and inert matter. Organic waste generation was about 831 t/day, recyclable 190 t/day and inert was about 179 t/day. The total area of Pune city was divided into three zones, zone one being central Pune, zone two the new developments and zone three included suburbs and areas of these zones, which were 42.64 km<sup>2</sup>, 103.28 km<sup>2</sup> and 98.04 km<sup>2</sup> respectively (PMC, 2010). PMC had made it mandatory for new constructions in zone two and zone three to have organic and recyclable waste management facilities on their premises. Organic matter of waste can be treated by composting (aerobic or anaerobic composting and vermicomposting) or by anaerobic digestion process. Composting of waste yields soil conditioner, which can be used for gardening purposes, and anaerobic digestion will yield gas which can be used as fuel or electricity generation, which will be useful for various purposes in housing complexes. The core area of the city (zone one), the slum area, vegetable markets, slaughterhouse, gardens and parks and so on do not have enough space to treat the solid waste. Instead of transporting the waste from those areas of city to the present landfill location, it is proposed to use the partial space from existing reserved space for parks, gardens, playgrounds and recreation for treating the compostable waste. The total reserved area is 127.68 ha at 106 places within the city (PMC, 2010). The end products of biological waste treatment (compost or gas) will satisfy some manure or electricity requirements of the reserved area. Solid waste treatment at source can help to divert 70% of the total waste and will lead to enormous savings in the cost of waste collection, transport and disposal. The recycling matter should go to the recycling industry. This will reduce the burden on landfill and environmental effects as landfill will also be minimized. Incineration for energy generation from MSW was not feasible as organic content was low and moisture content was high. The inorganic portion of waste sand, silt, clay, fine earth and ash can be disposed at engineered landfill as per MSW rules and regulations. The landfill site should be fenced to restrict unauthorized entry. The sanitary landfill site should have proper access roads for the container carriers. Landfill should be surrounded by open drains to collect surface runoff during monsoon. After the life of the sanitary landfill site is over the site should be used for gardening purposes only, after laying a top soil layer of 0.5m depth. The main components of waste management are collection, segregation, storage, transportation, treatment and disposal. Currently, most of the cities MSWM system includes above mentioned all components of waste management.

## 7.5 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 2017 and Municipal solid waste management and handling rules 2018. 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, scrap 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

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(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 8, Issue 5, May 2019

process. PMC has done ground trothing 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 6: 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%

### 7.6 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.

### 7.7 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 7: 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	WarjeKarvenagar	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	BhavaniPeth	6	59	37
13	KasbaVishram	6	104	33
14	Hadapsar	4	61	35
	<b>Total</b>	<b>113</b>	<b>936</b>	<b>412</b>

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 8, Issue 5, May 2019

### 7.8 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 is more than 99 % in Vanaj Company Kothrud) ward and lowest (0 to 25%) at Ramtekdi, Mohammad Wadi, Hadapsar, ParwatiGaon. The sub wards of AundhGaon, Phulnagar(Yerwada), Model Colony, Vedbhavan, Rambaug Colony, NIBM, KatrajGaon area have medium (50 to 75%) proportion.

### 7.9 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.

### 7.10 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 8: 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	WarjeKarvenagar	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	BhavaniPeth	2	108	5840
13	KasbaVishram	1	130	6400
14	Hadapsar	1	52	7500
	<b>Total</b>	<b>23</b>	<b>1349</b>	<b>1,24,370</b>

### 7.11Transportation 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. 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 UraliDevachi, the entire waste is send to transfer stations for weighing and the same computerized record is maintained by authority.

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 5, May 2019

**Table 9: 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

### 7.12 Processing and Scientific Disposal of Waste

The existing disposal site is located at UraliDevachi (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 2016 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 tons 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 like landfilling, organic compost, bio-gas and mechanical compost:

### VIII. CONCLUSION

(a) The first step in waste management is to gain an understanding of the waste types being generated in order to design appropriate collection and disposal strategies.

(b) Characterization of MSW of the landfill site of Pune city shows that it contains a high percentage of organic matter (69.3%) and organic content in MSW to the tune of 32.83%, and average moisture content 48.08%, which confirms the viability of biological treatment.

(c) Effective management of solid waste at the landfill site of Pune city will reduce the environmental effects of landfill.

(d) The investigations of the present study will be useful for Pune city as well as for developing metropolitan cities when making decisions regarding the integrated solid waste management strategy and for selection of treatment and disposal options.

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