DESIGN OF MUNICIPAL SOLID WASTE PLANT AND
SOLID WASTE MANAGEMENT FOR MAPUSA
GOA, INDIA
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ABSTRACT

The ever increasing urban population has put tremendous pressure on Solid Waste Management and is one of the essential obligatory functions of the Local Bodies. This paper provides an insight into how we can tackle the giant problem of solid waste disposal and also how to minimise the waste pollution rapidly, to avoid overuse of non biodegradable materials resulting in grave problems of health, sanitation and environmental degradation. Most urban areas in the country are plagued by acute problems related to solid waste. Due to lack of serious efforts by town/city authorities, garbage and its management has become a tenacious problem and this notwithstanding the fact that the largest part of municipal expenditure is allotted to it. Barring a few progressive municipal corporations in the country, most local bodies suffer due to non-availability of adequate expertise and experience, thereby not handling the solid waste properly, resulting a hazardous environment.

The Ministry of Non-conventional Energy Sources studied and tested the main processes such as incineration and bio-methanation as the options for waste processing without any success. As such the method of composting is becoming important, fast and dependable method of dealing with Municipal Solid Waste. Composting is a biological process, in which the organic matter is biodegraded by microorganisms under controlled conditions of temperature, moisture content, oxygen, pH and the retention time that can be initiated by mixing biodegradable organic matter with bulking agents to enhance the porosity of the mixture. In this study, a composting plant is considered that uses organic waste which is treated by the windrow composting method. This method has a lot of qualitative benefits such as reducing the amount of municipal solid waste, transportation cost of carrying municipal solid waste to land fill, emissions and leachate of landfill, increasing life span of landfill and reducing land use.

Key Words : Solid Waste, Pollution, Composting, Microorganisms, Windrow

INTRODUCTION

The Indian Constitution in its 12th schedule has laid down the functions envisaged to be performed by the municipal authorities; one amongst those is solid waste management. 4378 cities and towns of India generate waste in the range of 0.2 kg to 0.6 kg / capita / day amounting to 115000 MTs of waste per day. The Energy Research Institute has estimated that the waste generation will exceed 260 million tonnes by 2047 which speaks volumes of the problems that urban areas are going to face in coming decades in managing their waste.\textsuperscript{1-3} It is an obligatory duty of municipal authorities in the country to keep cities/towns clean and provide a good quality life to the citizens. However, the services provided by the municipal authorities are outdated and very inefficient. Domestic, commercial, biomedical and variety of toxic and domestic hazardous wastes are generally disposed of by the citizens on the streets, drains, open spaces, water bodies, etc., causing serious problems of health and environment. Problems of solid waste management are growing with rapid urbanization and change in the lifestyle of the people. The situation is becoming critical with the passage of time. The urban population in India has gone up five times in the last six decades.

Analysis of physical composition indicates total compostable matter in the waste is in the range of 40-60 percent while recyclable fraction was observed between 10 and 25 percent. The moisture content in the MSW was observed to
METHODOLOGY

Located 13 km away from the capital city of Panaji, Mapusa is a town in North Goa. The city is at 15.60°N 73.82°E and has elevation of 15 metres. Mapusa has a tropical climate with temperatures ranging from 37 °C in summer with high levels of humidity to 21 °C in winters. The city has experienced rapid growth in the last decade with emerging urban issues such as management of municipal solid waste (MSW). The Mapusa Municipal Council (MMC) is a statutory body responsible for MSW management in Mapusa, Goa, India. The current solid waste management system does not include segregation or recycling and scientific processing of waste. The waste is being disposed off through an open dumping resulting in non-compliance of environmental regulations.5,7

There are several MSW processing technologies, which are being followed in various parts of the world. Besides source reduction, reuse and recycling, broad categories of available technologies for processing MSW are (i) Physical Processing Technologies (ii) Thermal Processing Technologies and (iii) Biological Processing Technologies. Suitable processing technology to be adopted depends on parameters like Indian experience, Quantity of waste, Quality of waste, Capital investments required, Recurring expenditure, Economy of operation, Manpower Requirement, Level of skill required etc.9

Composting

Composting is one of the most suitable processing methods for bio-degradable waste for countries like India, which has predominantly warm climate and where the scope of capital investment is limited for such projects. Composting as an organized activity, with revenue returns on the organic manure produced, appears to be one of the best options. The establishment of a successful composting facility depends on making correct choices between the environmental and economic aspects. However it should always be kept in consideration that Aerobic composting is a natural process, which is subjected to certain uncertainties of biological activity. Added to this is the heterogeneity and uncertainty of quality of municipal garbage so that the final product’s quality and quantity, both may vary from time to time depending on the factors like Physical and chemical composition of raw waste input, Seasonal variations and Yard management and monitoring efficiencies. All activities associated with composting operations need careful selection of design and control to minimize adverse environmental impacts. The elements of composting facility at present include: (i) Material Intake System (ii) Yard Management System (iii) Coarse Segregation System (iv) Curing System (v) Refinement System (vi) Packing and Storage System (vi) Leachate, Litter and Odour Management System (vii) Process Monitoring and Control Systems (viii) Removal of Rejects.10

Sanitary landfill

Currently, the total waste generated by the Mapusa city is 22TPD. The waste disposal facility is planned for the safe disposal of processing rejects and non-biodegradable components of solid waste and it is envisaged that common sanitary landfill site would accommodate about 35% of processing rejects per day from the total MSW processed at composting plant.11-13

Deposition of waste in conical heaps over the landfill site and spreading these heaps using a tracked bulldozer is a low cost and easy option. However this practice will lead to highly unacceptable environmental conditions. The lower levels of waste are permanently saturated and free flow of water in and out of the dumped waste will lead to the migration of leachate into the surrounding surface and sub-surface water and thereby contaminating the ground water aquifers. The other major issue of simple deposition waste will be the formation of anaerobic conditions at the site as the waste deposition thickness increases, giving rise to the generation of landfill gas and thereby creating serious safety concerns in the immediate project influence area.14

RESULTS AND DISCUSSION

Considering these aspects, the landfill development strategy for Mapusa is formulated, to satisfy the regulatory requirements of MoEF and the guidelines of CPHEEO with various objectives. The principle means of achieving
Protection of surrounding environment of landfill site is by the provision of sealing layers at the base, side walls and top of the landfill. Appropriate and secure operational management of the site will minimise the following aspects:  
1. Water ingress into the landfill  
2. Leachate generation and uncontrolled dispersion  
3. Accumulation and uncontrolled release of landfill gas into the surrounding atmosphere  
The use of single or multiple synthetic liners, in combination with an in situ mineral liner or improved in situ soil will provide high levels of site containment. Considering the capital cost and containment levels required it is recommended to have:  
1. A single mineral liner formed in situ and re-compact clay on the base of the landfill  
2. A capping layer of re-compact clay above the final lift of solid waste  
3. A core clay in peripheral phase to form lateral containment and  
4. A maximum permeability of sealing layers will no greater than 1x 10⁻⁹ m/sec  
While the above measures are expected to provide desired levels of containment and environmental safety, it is to be noted that no industrial or biomedical wastes are allowed to mix with the solid waste being disposed off at the site. The mix of any of these wastes will render the waste hazardous there by requiring the use of highly expensive synthetic liners for containment.

**Leachate generation and treatment**

Water that percolates through the placed solid waste is known as leachate. During its progress through the waste, the water entrains suspended solids, extracts soluble constituents of the waste and soluble products of the waste degradation process. The composition of leachate depends up on the stage of waste degradation and the types of waste within the landfill.  
The quantity of leachate generated will depend on the annual precipitation rates and active area of the landfill. This requires preparation of complete water balance of the landfill site, in accordance with the development phases of the project. It is now too early to anticipate a detailed phasing of the landfill site and hence it is assumed that an area equivalent to the total waste generated in a year would be the active area for the landfill site in the particular year. However it is to be noted that the leachate generation trends vary drastically depending up on the quantity of waste deposited every day and the actual quantity shall be estimated by considering the cumulative quantity of waste deposited in the landfill. The quantity estimated here will just give an idea for the area requirements of leachate treatment.

**Landfill gas generation, control and management**

The landfill gas is generated due to the degradation of the organic matter in the wastes. Since the landfill material will be basically inerts, the landfill gas generation will be minimal.

**Specifications of landfill development:**

Development of landfill site should be subjected to rigorous planning. Key elements in developing a scientific landfill site will comprise:  
1. Organizing the waste/ processing rejects and inert transportation practices  
2. Detailed plans outlining the site development activities and  
3. Detailed designs of all the engineering works

**Buffer zones**

A vegetative cover will have to be provided as buffer zone between landfill site and the nearby localities. In addition to the buffer zone a compound wall all round the landfill site to a height of 3m or as suitable, shall also to be constructed, to totally seclude the site from outside activities.  
The proposed vegetative cover shall comprise trees and shrubs that improve the visual and aesthetic appearance of the site. In addition the waste reception area, administrative area and segregation areas shall also be provided with vegetative cover to the extent possible.  
The Design Construction and Operation of Compost Plant is planned, keeping in view the present compliance and quality and expectations of the market. A whole new line of processing has been planned from the entry gate to the product storage area.

The proposed plan for Design Construction and Operation of Compost Plant has four stages (1) pre-processing and (2) windrow composting of the municipal solid waste and (3) processing and (4) refinement of the stabilized material. The compost process and the material balance are worked out for 50 TPD of incoming municipal solid waste every day.
Design considerations of compost plant

The basic design of the compost plant is based on open windrow aerobic composting of organic component of solid waste, utilising the usable facilities in the existing compost plant. The basic parameters considered for design include: Best utilization of the land available, Smooth flow of material, Elimination of multiple handling of material, Elimination of manual processes to the extent possible and Ensure the output standards to meet the MSW Rules, 2000 (MoEF, GoI).

Some of important aspects that are being considered for the successful operation management are:

1. Quality of Feed
2. Availability of sufficient space
3. Processing Technology
4. Plant Efficiency
5. Compost Marketing

Assessment of windrow sizes

The compost plant would receive 50 tons of municipal solid waste every day. This waste would be placed in the first windrow of size 15m (L) X 4 m (W) X 2.5 m (H) and left for aerobic decomposition. After one week the waste would be turned and transferred from the first windrow to the second windrow and again left for decomposition. Again after one week the waste from the 2nd windrow would be turned and transferred to the 3rd windrow left for decomposition for one week. After three weeks of aerobic decomposition of waste on the compost pad, it would be transferred to the coarse segregation section.

Layout of compost plant

The layout of the compost plant is prepared by keeping maximum utilization of existing space in mind. The Plant will include Inspection section which will have Visual Inspection, Weighing and Final Inspection sections. After Inspection the garbage will be sent to Pre-processing Section where there will be sorting Station and Cage Drum Section. Appropriate yard management is the first important step towards successful operation of compost plant. The Yard management section is basically a main section where the garbage is treated. Further to that will be Curing Section, Refinement Section, Packing and Storage and Laboratory.

Civil infrastructure for the plant include Curing Section, Storage area, Office and Laboratory, Staff Quarter, Leachate Drains and Tank, Internal Roads, Boundary Wall and Green Belt.

Design:

Design data

1. Population: 70, 835 (2031) forecasted by Arithmetic progression
2. Study of site conditions:
   (i) Planning and designing considerations: Factors to be considered in planning and designing plant facilities include:
      (a) Topography
      (b) Local social conditions
      (c) Local environmental conditions
      (d) Climate
   (ii) Surveys: The surveys like Topographic, Land Use, Climatic and Environmental were carried out to obtain information like Available land area, boundary lines, Contour, Catchment area, Location of existing access road, Rainfall data etc.
   (iii) Properties of MSW: The MSW was tested in the laboratory for different parameters so as to judge what type of treatment to be given to the wastes. The Waste was tested for parameters like Oxygen concentration, Free air space, Particle size, C:N ratio etc.
   (iv) Garbage collection data: The data regarding the generation of MSW was carried out for all the seven days of the week so that exact design can be carried out.

Design of components

A) Composting Pad Details
   (i) Volume of waste generated on daily basis = 50 tonnes/day
   (ii) Compost pad volume = 100 cu. M
   (iii) Windrow pile calculations =

   Daily volume = \( \frac{\text{Mass}}{\text{Density}} = \frac{50}{0.5} = 100 \text{ cu. M} \)

   Area = \( \frac{2}{3} \times \text{base} \times \text{height} = \frac{2}{3} \times 4 \times 2.5 = 6.67 \text{ sq. m} \)

   Length required = \( \frac{\text{Daily Volume}}{\text{Area}} = \frac{100}{6.67} = 15 \text{ mts} \)

   Assuming 5 weeks of windrow process for removal of moisture from stacked piles.

   Spacing of windrows: Provide a gap of 5mts for turning the equipment.
(iv) Pad width, length and area
Provided nos. of windrows: 5 nos. (horizontal direction) and 7 nos. (vertical direction)

Total area of composting pads = $(5 \times (4 + 5)) \times (7 \times (15 + 3)) = 5670$ sq.m

B) Plant Details

Table 1: Plant details

<table>
<thead>
<tr>
<th>Windrow composting area requirement</th>
<th>Additional space requirement</th>
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<tbody>
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<td>Type</td>
<td>Area (m$^2$)</td>
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<tr>
<td>Tipping floor area</td>
<td>77</td>
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<tr>
<td>Storage of rejects</td>
<td>77</td>
</tr>
<tr>
<td>Storage of recyclables</td>
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<tr>
<td>Composting pad</td>
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<tr>
<td>Maturation area</td>
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<tr>
<td>Compost storage area</td>
<td>200</td>
</tr>
<tr>
<td>Total composting area</td>
<td>6120</td>
</tr>
</tbody>
</table>

C) Design of landfill

**Basic data**

Current waste generation = 22 tons /day

Design life of landfill = 20 years

Waste after 20 years = 50T

Average total precipitation: 3153.3 mm per year

Landfill capacity, height and area

(i) Total waste generation in ‘n’ years (T) = $0.2628 \times 10^6$ T

(ii) Total waste volume ($V_w$) = $0.5256 \times 10^6$ cu.m

Out of total waste generated, 35% constitutes non-biodegradable waste = $0.184 \times 10^6$ cu.m

(iii) Volume of daily cover ($V_{dc}$) = $0.0184 \times 10^6$ cu.m

(iv) Volume of liner and cover systems ($V_c$) = $0.023 \times 10^6$ cu.m

(v) Volume likely to become available due to settlement/biodegradation of waste ($V_s$) = $0.0184 \times 10^6$ cu.m

(vi) First estimate of landfill capacity ($C_i$) = $0.207 \times 10^6$ cu.m

Taking rectangular shape of landfill with $L: B = 2:1$ with maximum landfill height of 10m

Area Required = $20.70 \times 10^3$ sq. m

D) Landfill section and plan

Landfill section and plan evaluated on the basis of 2:1 side slope for the below-ground portion of the landfill. Length = 210m , Width = 105m , Height = 10m

E) Leachate collection system

The liner system will comprise of the following layers below the waste:

(i) 0.30 m thick drainage layer comprising of coarse sand or gravel

(ii) 0.2m thick protective layer of sandy silt

(iii) 1.50mm thick HDPE geomembrane

(iv) 1.0 m thick clay layer

**Leachate evaluation**

Total avg. precipitation = 3153.3 mm/year

Only one phase is operative every year

Plan area of operating phase = $22 \times 44 = 968$ sq.m

Leachate quantity = 25.17 cu.m per day

**Leachate collection pipe**

Assume diameter of pipe = 15 cm

Volume of leachate = 25.17 cu.m per day

Total Area of pipe required = $0.39$ sq.m

Therefore number of pipes required = 22 nos.

Spacing of pipe = 7.7 m

**Leachate holding tank**

Taking into consideration storage for 1 week

Size of tank required = $180$ cu.m

F) Design and construction of landfill liners

The liner system at the base and sides of a landfill is a critical component of the landfill which prevents ground water contamination. The selection of material to be used a soil barrier layer will usually be governed by the availability of materials, either at site or locally in nearby areas.

**Processing**

Deposition of waste in conical heaps over the landfill site and spreading these heaps although is a low cost and easy option, leads to highly unacceptable environmental conditions and inorder to avoid this, the landfill development strategy for Mapusa is formulated which satisfy the regulatory requirements of MoEF.
The Municipal Solid Waste Plant and Solid Waste Management for Mapusa, Goa is designed by keeping the population forecasted for 2031. Study of the site conditions and different surveys carried out help in designing an economical and efficient plant. Furthermore the Properties of MSW tested in the laboratory also help in deciding if any special treatment is required beforehand so as to achieve the desired properties required for the treatment of the waste. The data regarding the generation of MSW was carried out for all the seven days of the week so that exact design can be carried out.

While designing the landfill a care has been taken to provide single or multiple synthetic liners, in combination with an in situ mineral liner or improved in situ soil so as to provide high levels of site containment.

Although It is too early to anticipate a detailed phasing of the landfill site, for better planning it is assumed that an area equivalent to the total waste generated in a year would be the active area for the landfill site in the particular year.

The landfill gas generated due to the degradation of the organic matter in the wastes will be minimal since the landfill material will be inert.

A vegetative cover comprising of trees and shrubs provided will not only improve the visual and aesthetic appearance of the site but will also act as buffer zone between landfill site and the nearby localities.

The Design Construction and Operation of Compost Plant is planned, keeping in view the present compliance and quality and expectations of the market. A whole new line of processing has been planned from the entry gate to the product storage area.

**CONCLUSION**

Design of Municipal Solid Waste Plant and Solid Waste Management for Mapusa, Goa, India will provide good solution to tackle giant problem of solid waste disposal and also how to minimise the waste pollution rapidly, to avoid overuse of non biodegradable materials resulting in grave problems of health, sanitation and environmental degradation. Most urban areas in the country are plagued by acute problems related to solid waste.

The plant is aimed at producing the compost of satisfactory standards. The efficient and sophisticated air handling systems will safeguard against odour emission and odour control. In composting system more emphasis is laid on management of non-degradable material before they go through screening system. Facility should focus on plastic bags, glass, textiles metal, cans etc. which can be sorted out by segregation at household level and by door to door collection system.

A quality air floor with regular and automated turning, Good air flow and ability to add moisture allow to attain goals like high loss of mass, more complete degradation, odour reduction etc.

If properly managed, the designed plant will not only solve the problem of waste produced in the area but will also generate income to the Municipal Council.

**REFERENCES**


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