**A PROJECT REPORT ON**

# QUANTIFICATION, CHARACTERIZATION AND MANAGEMENT OF SOLID WASTE FROM MAHE, UNION TERRITORY OF PONDICHERRY

**Sponsored by Department of Science, Technology and Environment, Government of Pondicherry**

By

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GOVERNMENT OF PONDICHERRY
**MAHATMA GANDHI GOVT. ARTS COLLEGE**

**P. O. New Mahe - 673311**

**Dated……………………**

## FOREWORD

It is gratifying to note that the Plant Science Department of our College has undertaken a project on "Quantification, characterization and management of solid waste from Mahe, Union Territory of Pondicherry", under the sponsorship of the Department of Science, Technology and Environment, Government of Pondicherry.

The team of researchers headed by Dr. C.C. Harilal, the Principal Investigator and the Co-investigators Mr. C.P. Ravindran, HOD, Plant Science and Dr. G. Pradeep Kumar, Lecturer in Plant Science have not only surveyed and quantified the magnitude of the problem but also suggested ways to counter it. The problem, being perennially recurring in nature, needs eternal vigilance from all sections of our society.

This seems to me a modest contribution of this institution in this direction and is meant to supplement the efforts of the Mahe Administration and the civic authorities in tackling the issue of waste disposal at Mahe, Palloor and Pandakkal.

I congratulate the team of investigators on the successful completion of their project and thank the DSTE and DHTE, Government of Pondicherry for their support and encouragement to our team.

(Dr. ANTONY FERNANDEZ)
PRINCIPAL
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Mahe
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## CONTENTS

**DOCUMENTATION PAGE**

| | | |
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**Abstract:**

Solid waste menace is a serious concern all over the World. The effective disposal and management of solid wastes are hot topics of discussion today. In India, ample studies pertaining to solid waste disposal and management have been undertaken and quite a few are still going on. Since the magnitude of issues related to solid waste varies with location and time, area specific studies need to be carried out to derive management plans adequate to the region.

In the present study, an attempt has been made to assess the problems of solid waste accumulation and its impact on the environment of Mahe. Efforts were made to locate major sites of deposition, mode and magnitude of disposal together with their physical and chemical characterization. Secondary data was also procured from various sources to substantiate the findings. Based on the major findings, a number of management plans suitable to Mahe have been proposed.


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# EXECUTIVE SUMMARY

Solid waste menace is a serious concern all over the world and its effective disposal and management are hot topics of discussion today. Since the magnitude of issues related to solid waste varies with location and time, area specific studies need to be carried out to derive management plans adequate to the region.

In the present study, an attempt has been made to assess various issues associated with solid waste disposal in Mahe. Efforts were also carried out to formulate an ideal and sustainable management plan for solid waste disposal.

For detailed assessment, the entire area has been divided into three segments (Mahe town, Pandakkal and Palloor). Efforts were taken to locate major sites of deposition, mode and magnitude of disposal together with their physical and chemical characterization. The work has been scheduled in three phases, viz. survey, field work and laboratory investigation. Standard methods were employed for the collection, segregation, processing and analysis of samples for generating primary data pertaining to quantity and quality.

Survey results indicate that Mahe municipality does not have an effective and sustainable solid waste management system. The reasons can be attributed to lack of operational disposal sites, adequate technology and infrastructure.

Results on quantification indicate that Mahe municipality produces approximately 7.1 tones of solid waste per day, of which higher production is in Mahe town followed by Palloor and Pandakkal. Analytical results on segregation indicate more diverse components in samples collected from Mahe town followed by Pandakkal and Palloor. The case of non-degradable substances (plastic) was also the same (14.8% in Mahe town, 11.8% in Pandakkal and 9.5% in Palloor). Higher organic content was noticed in Palloor (90.4) followed by Pandakkal (87.7) and Mahe town (77.2%). Moisture percentage (Oven dry basis) reported higher in Pandakkal (59.23%), followed by Palloor (55.48%) and Mahe town (53.82%). Similar was the case of moisture percentage on air-dry basis, which was 46.29% in Pandakkal, followed by Palloor (41.89%) and Mahe town (40.72%).

Estimation of elements like cadmium, chromium, copper, iron and lead were also carried out and results revealed that concentration of most of the elements were higher in samples from Mahe town followed by Palloor and Pandakkal. Higher NPK content was noticed in samples collected from Pandakkal followed by Palloor and Mahe town.

Based on the findings, a number of management plans adequate to Mahe have been proposed. Accordingly an INCINERATOR based solid waste management system is ideal, taking into consideration low land availability, high population density and unfavourable climatological conditions for composting. Detailed long term management plans were also suggested, which upon implementation will ensure long term sustainability in the area of solid waste management.

## LIST OF TABLES



## LIST OF FIGURES

## LIST OF PLATES

# INTRODUCTION

Solid wastes include all solid materials that the processor no longer considers of any sufficient value to retain (Wilson, 1977 and Tchobanoglous *et. al*., 1993). They are generated by domestic, industrial, agricultural, commercial and healthcare activities and accumulates in streets and public places, creating much of environmental issues. The words “garbage”, “trash”, “refuse”, “rubbish” etc. are used to refer to some forms of them.

The modern world has changed to a throw away society. With population explosion, increasing urbanization coupled with changing lifestyles, more and more wastes of diverse nature are being generated in many cities and townships. In early days, the wastes did not create any problem to the community as quantity of wastes generated was within the assimilative capacity of nature. Today, the scenario is quite different and the urban environment, all over the world poses serious threat from excessive generation of solid wastes. Non - availability of land for management too accelerated the gravity of the issue. The major chunk of wastes generated in various cities and townships remains unattended to causing health hazards and / or nuisance to the inhabitants. The immediate requirement, no doubt, is to develop an ecologically sound, economically viable and healthy waste management strategy to every city and township. Apart from deriving sustainable solutions of solid waste management, a complete re-education of ‘how we live’ is also the need of the hour.

Based on differences in their sources and characteristics, the solid wastes can broadly be classified into Municipal (Urban) solid wastes, Industrial wastes and Hospital wastes. Waste generation, both municipal and industrial, continues to increase world wide in tandem with growth in consumption. In developed countries, per capita waste generation increased nearly three-fold over the last two decades, reaching a level five to six times higher than that in developing countries. With increase in population and living standards, waste generation in developing countries is also increasing rapidly, and may double in volume in the current decade. If current trends continue, the world may see a five-fold increase in waste generation by the year 2025. There is urgent need to develop an integrated approach where the public, private and community sectors work together to develop local solutions facilitating sustainable solid waste management.

Urban waste management is drawing increasing attention, as citizens observe that too much garbage is lying uncollected in the streets, causing inconvenience and environmental pollution, and being a risk for public health. Although government authorities apply all the means at their disposal, the piles of wastes only seem to grow from day to day. In an era of shrinking municipal budgets and a restriction of the scope of municipal government jurisdiction, the problem is likely to intensify unless alternate approaches can be developed.

**RISKS AND PROBLEMS ASSOCIATED WITH SOLID WASTES**

There are many negative impacts associated with improper solid waste management. Some of the most important are mentioned in the following list. The relative importance of each depends on the nature of the waste and local conditions.

- Unmanaged waste degrades the urban environment, discouraging efforts to keep streets and open spaces in a clean and attractive condition. Sustainable management of solid waste is a clear indicator of the effectiveness of a municipal administration - if the provision of this service is inadequate, it fetches in public protest and agitation.
- Waste, that is treated or disposed off in unsatisfactory way can cause severe aesthetic nuisance in terms of smell and appearance.
- Uncollected wastes often end up in drains, causing blockages, which result in flooding and in sanitary conditions.
- Polluted water flowing from waste dumps and disposal sites (leachates) can cause serious pollution of water supplies. Chemical wastes (especially persistent organics) may be fatal or have serious effects if ingested, inhaled or touched and can cause widespread pollution of water supplies.
- Flies breed in some constituents of solid wastes, and flies are very effective vectors that spread diseases.
- Mosquitoes breed in blocked drains and in rainwater that is retained in discarded cans, tyres and other objects. Mosquitoes spread disease, including malaria, chicken guinea and dengue.
- Plastic bags are a particular aesthetic nuisance and they cause the death of grazing animals, which eat them.
- Rats find shelter and food in waste dumps. Rats consume and spoil food, spread disease, damage electrical cables and other materials and inflict unpleasant bites.
- Dangerous items (such as broken glass, razor blades, hypodermic needles and other healthcare wastes, aerosol cans and potentially explosive containers and chemicals from industries) may pose risks of injury or poisoning, particularly to children and people who sort through the waste.

- Fires on disposal sites can cause major air pollution, causing illness and reducing visibility, making disposal sites dangerously unstable, causing explosions of cans, and possibly spreading to adjacent property.
- Methane (one of the main components of landfill gas) is much more effective than carbon dioxide as a greenhouse gas, leading to climate change.
- Gases, which are produced by the decomposition of wastes, can be explosive if it is allowed to accumulate in confined spaces (such as the cellars of buildings).
- Liquids and fumes, escaping from deposits of chemical wastes (perhaps formed as a result of chemical reactions between components in the wastes), can have fatal or other serious effects.
- Dumps of construction waste and abandoned vehicles block streets and other access ways.
- Waste items that are recycled without being cleaned effectively or sterilized can transmit infection to later users.
- Aerosols and dusts can spread fungi and pathogens from uncollected and decomposing wastes.
- The open burning of waste causes air pollution; the products of combustion include dioxins, which are particularly hazardous.

**SOLID WASTE AND ITS MANAGEMENT - INDIAN CONTEXT**

Consumption, linked to per capita income has a strong relationship with waste generation. In light of increase in per capita income, more savings are spent on goods and services, especially when the transition is from a low income to a middle-income level. Urbanization not only concentrates waste, but also raises generation rates since urban consumers consume more than rural ones.

Municipal solid wastes or urban solid wastes generally composed of a spectrum of refuse categories like food wastes, rubbish containing packing materials, demolition and construction wastes, street sweepings, garden wastes, abandoned parts of vehicles and appliances and residues from small scale industries.

The quantity and composition of municipal solid wastes vary greatly for different municipalities and time of the year. Numerous factors are influencing the characteristics of municipal solid wastes, the important among them being degree of urbanization and industrialization, social customs, per capita income and other factors like geology, geography, climate etc.

There is only few statistics available on the waste generation and characteristics of Indian cities and towns. Studies, which are limited, revealed that the moisture content of municipal solid wastes might vary from 15% to 50%, depending upon the composition of wastes as well as climatic conditions. The calorific value may vary from 800kcal/kg to 1010 kcal/kg and density from 330 kg/m$^3$ to 560 kg/m$^3$. It is also estimated that the daily per capita waste generation in India ranges from 100 gm in small towns to 500 gm in large towns (Saxena, 2001). India will probably see a rise in waste generation from less than 40,000 metric tones per year to over 1,25,000 metric tones by the year 2030 (Padmalal *et. al.,* 2002). Their composition will also vary widely, depending upon the geographical location and season. According to Bhide and Sundaresan (1983), the changes in relative shares of different constituents of wastes in the past several decades can largely be attributed to the changing lifestyles and increasing consumerism.

In India, Municipal solid waste management is one of the most neglected areas of urban development. The existing infrastructure is far short of the desired levels. This eventually led to disputes of various sorts. Numerous cases are pending before the Hon'ble Court as well as the concerned departments against improper waste management practices. Realizing various constraints in the area of waste management, the Burman Committee (1999), constituted as per directions of the Hon'ble Supreme Court, recommended that biological process (composting) should be carried out in each municipality. Composting of city wastes is now a legal requirement provided under the Municipal Solid Waste Management (MSW) Rules 2000, for all municipal bodies in the country. The MSW Rules 2000 requires that "biodegradable wastes shall be processed by composting, vermi-composting, anaerobic digestion or any other appropriate biological processing for their stabilisation". The specified deadline for setting up of waste processing and disposal facilities was 31 December 2003 or earlier. But neither the central nor the state governments have yet responded to show any kind of preparedness for it, nor have they been able to grasp it as an environmental and social good that requires official support, which can also generate employment.

The crude solid waste disposal practice of open dumping and burning is being widely practiced even today by most of the urban local bodies of India. Open dumping invites many environment issues like surface and ground water contamination, bird and rodent menaces, animal menaces, foul odor and release of poisonous gases etc.

Some of the other efforts include sanitary land filling and incineration. Eventhough sanitary land filling has proved to be an effective technology, availability of land, high initial costs for design and construction, public opposition during selection of sites and increasingly the concern for recovery of materials instead of disposal are acting as major objections to this technology.

Apart from these attempts, unfortunately, no serious and concerted efforts have so far been made for complete resource recovery and effective management of solid wastes. The research and development activities in regard to municipal solid wastes, particular to India are still in its infancy. No doubt, the existing unscientific practices of solid waste management can create environmental problems as well as health hazards to the local inhabitants in the long run. This warrants alternative technologies of solid waste management to make the cities and townships cleaner and greener.

## INTEGRATED SOLID WASTE MANAGEMENT SYSTEM (ISWMS)

Solid waste management includes all activities that seek to minimize the health, environmental and aesthetic impacts of solid wastes. Today the world is looking forward to integrate solid waste management systems for tacking the waste related issues of urban environments.

Integrated Solid Waste Management System (ISWMS) involves the selection and application of appropriate technologies, techniques, and management practices to design a program that achieves business goals and objectives, while minimizing operating costs and environmental harm (Tchobanoglous, Theisen, & Vigil, 1993). In most businesses, a single choice of method is frequently unsatisfactory, inadequate, and not economical. Use of an integrated approach to managing solid waste has evolved in response to the regulations developed to implement various approaches (Tchobanoglous *et al.*, 1993). There are a number of examples from all over India and around the world where communities have practiced managing their waste locally and set up successful community-based waste management models. ISWMS consists of reducing the amount and toxicity of wastes at the source, recycling, reusing or composting as much of the waste as is economically reasonable, burning the waste that cannot be economically recycled to generate heat in waste-to energy facilities and finally land filling the residue left out on an environmentally acceptable manner. The approach is not a hierarchical scheme, but is synergistic in nature. The elements most often associated with ISWMS include:

- Source reduction
- Reusing / Recycling
- Composting
- Land filling and
- Incineration

**SOURCE REDUCTION (WASTE PREVENTION)**

Source reduction "includes the design, manufacture, purchase or use of materials, such as products and packaging, to reduce their amount or toxicity before they enter the municipal solid waste management system”. Some of the strategies include:

- Designing products or packaging to reduce the quantity or the toxicity of the materials used, or to make them easy to reuse.
- Manufacturing of products that last as long as possible by the use of durable designs and materials and providing repair services and replacement parts. This facilitates consumers to repair, resell, exchange, or donate unwanted products as much as possible to avoid disposal. Sharing and rental of tools and equipments is also encouraged.
- Reusing existing products or packaging, for example, refillable bottles, reusable pallets and reconditioned barrels and drums.
- Phasing out of products or packaging those are unsafe in production, use, post-consumer use or that produce or release harmful products when disposed.
- Elimination of excess packaging and packaging that is difficult to recycle.
- Managing non-product organic wastes (e.g., food scraps and yard trimmings) through on-site composting or other waste management methods.
- Providing incentives to firms for decreased generation of wastes.

**REUSING / RECYCLING**

Recycling is defined as the collection materials like paper, cardboard, steel, glass, aluminum etc. and manufacturing them into a new product whereas reusing refers to repeated use of a commodity. Greatly increased recycling in this country could be achieved through several measures. Some analysts claim that 50% to 80% of the nation's natural resources could be recycled or reused by the year 2012.

Recycling and thereby waste reduction will play an important role in any future waste management strategy. It is not a complete process unless the legal and institutional framework can create markets for the recycled products that can beneficially utilize the materials picked up from the curb. The technical and engineering function of waste management cannot operate in vacuum, but must be aware of the political and social ramifications of its action. The waste management / disposal field is in a constant state of flux and appropriate solutions should be innovative, as well as technically and economically feasible.

Few measures of recycling to be effective include:

- Imparting awareness to discourage the "throwaway" mentality and impose ban on disposable items. Legislation should also require that recyclable materials will be recycled and should ban disposal of these materials by incineration and land filling.
- Governmental regulations and policies that encourage the use of virgin materials through taxes, incentives etc. should be revised to discourage the use of virgin materials and promote the use of recycled ones.
- The establishment of stable markets for recycled materials is essential. Legislation should promote procurement of products containing a high content of recycled and recyclable materials and government contracts should specify products with the highest practical percentage of recycled content.
- Products and packaging materials should be conspicuously labeled to indicate recycled content, including post-consumer content, recyclability, toxicity and appropriate disposal. Uniform governmentally approved standards should be applied to terms commonly used for product labeling and promotion, such as, "biodegradable," "recycled," "recyclable," "post-consumer waste," and others.
- Economic considerations of recycling should include avoided disposal fees, the avoidance of future clean-up costs, the costs of future land acquisition, transportation, and facility development. Disposal cost savings of recycling programs should be publicized. Disposal surcharges may be used as means of financing recycling programs.
- Land-use planning should provide for siting for recycling and other waste management facilities. Regulations should assure compatibility with surrounding land uses, minimal negative impacts on residential neighborhoods and construction to minimize litter.
- Household and small quantity commercial toxic and hazardous wastes should be segregated, labeled and collected separately in community-level programs that recycle, treat, or otherwise safely manage those wastes. Product and disposal charges should be considered as means of funding these programs.
- Convenient recycling opportunities and sufficient incentives to recycle should be provided to all residents. Collection routes, schedules and fees should be designed to promote efficient and economical collection of recyclable materials. Joint planning by labor / environmental groups to minimize contractual problems and other issues involving municipal personnel and to maximize environmental benefits is encouraged.

**COMPOSTING**

Composting involves the collection of organic residues / wastes, treatment of this organic material in such a way that it decomposes to humus and the utilization of the co-product as a soil amendment.

Anything that is naturally degradable can be thrown into a compost bin. These include food and organic waste created by food processing plants, kitchens, galleys, animal feedlots, yard work, municipal sewage treatment plants etc. Paper, leaves and grass clippings can also be decomposed in this process and the end product can be used as manure.

It has been estimated that up to 50% of all domestic solid waste is kitchen waste, which in principal could be used for the home manufacture of compost. It is therefore highly desirable that the public be encouraged, wherever possible, to set up their own compost heap at home. The use of kitchen waste in compost heaps will certainly have a positive impact on the quanta of solid waste, which though limited could well be significant.

Composting is thus an excellent method of recycling biodegradable waste from an ecological point of view. However, many large and small composting schemes have failed because composting is regarded as a disposal process and not a production process. It is essential - as in any production process - to pay careful attention to the marketing and the quality of the product.
Some of the strategies in this area include:

- Composting of kitchen and yard wastes at the household and community level should be encouraged through public education and dissemination of information on composting.
- Organic materials such as kitchen waste, yard waste and wet or soiled paper that cannot be recycled should be composted to produce a useful product. If source separation is not used, appropriate materials should be separated from mixed waste for composting. Composting should serve to complement programs for recycling and reuse rather than substituting for these programs. Composting of mixed waste including recyclables and inorganics should be avoided.
- Standards should be established to set levels of inorganic materials, heavy metals, and organic chemicals in compost appropriate for the use of the compost. Strict control of the incoming waste and periodic testing should be used to insure that these levels are not exceeded.

- Wastewater pre-treatment and treatment should be sufficient to make sewage sludge safe as a soil conditioner or for composting with food and plant wastes. Application of compost or sludge to the land should follow guidelines that will protect the environment and public health.

**LANDFILLING**

It refers to the scientific dumping of municipal solid wastes using an engineering facility that requires detailed planning and specifications, careful construction and efficient operation. It is regarded as one of the best methods of solid waste disposal, if there is sufficient land availability. It is generally safe and comparatively inexpensive. Despite apparent simplicity, there are certain problems that can only be avoided by proper landfill design, construction and operation.

The following refers to various categories of municipal solid waste disposal facilities.

- Sanitary Landfills
- Modified Sanitary Landfills
- Selected Waste Landfills

**Sanitary Landfills**

Sanitary Landfills are defined as disposal facilities which are normally, but not necessarily, located in areas having populations of 5,000 or more and which may accept all types of municipal solid wastes. Sanitary landfills are normally required to comply with all the criteria for landfill siting, design, operation and closure.

**Modified Sanitary Landfills**

Modified Sanitary Landfills are defined as disposal facilities, which may accept all types of municipal solid wastes. These facilities are normally but not necessarily located in areas serving populations of fewer than 5,000 people where a regional or cooperative waste disposal system with neighboring communities may not be practical or feasible.

**Selected Waste Landfills**

Selected Waste Landfills are defined as disposal facilities, which accept selected types of refuse. Wastes received at these landfills may include: demolition, land clearing and construction (DLC) debris; solid industrial wastes (excluding all hazardous wastes) such as foundry sands; and, where recycling options are not available or feasible and only with the approval of the authorities, bulky wastes such as large appliances ("white goods") and derelict motor vehicles. Generally, these Selected Waste Landfills will only receive a few types of waste, which should each be discharged to discrete areas of the site.

Sanitary land filling is being practiced worldwide as an effective means of solid waste disposal. It is being accomplished in following ways:

- The deposition of solid waste section at site, prepared as per norms.
- Spreading and compaction of wastes in thin layers.
- Covering the wastes with a layer of soil which will be compacted daily and
- Final cover of the entire construction with compacted earth layer of 1-1.5 m thickness.

Decomposition of landfills depends on the permeability of the cover material, depth of burial, rainfall, moisture content etc. This method is land intensive and must be avoided in regions where water table is close to the ground surface.

Some of the salient features of this technology, compared to ordinary land filling include:

- Land filling should be limited to materials that cannot be managed through preferable options. Materials entering landfills should be regulated and monitored to prevent the introduction of any harmful substances.
- Sanitary landfill reduces emission of methane, non-methane organic compounds and toxicants into the atmosphere. Land and water contamination due to leachate is minimized. The main advantage is the protection of public health and environment. The menace of birds and rodents, fire hazards and the problem of smelly odour are reduced / minimized.
- Existing land-disposal facilities should be upgraded to make use of improved technology in order to protect public health and the environment from toxic leachates, methane migration, and air emissions. New facilities should be built to meet these objectives. Facilities should be managed to extend their life as long as possible.
- Siting criteria should be established well in advance of choosing a specific site. Landfills should not be located in undeveloped natural areas. Proposed sites should be buffered from residential neighborhoods, provide adequate access and should be geologically secure. There should be adequate time and process for the public to be involved meaningfully in siting decisions.

- Siting and design should minimize groundwater, surface water, soil, and air contamination. Leachate should be collected, tested, and treated, if necessary. Methane should be collected and used as a fuel, if possible. On-site salvaging of materials from the incoming waste should be considered.
- Landfill permits should be reviewed and upgraded periodically to allow for adoption of new technologies.
- A portion of the disposal fee should be set aside for monitoring after closure and for future corrective actions. When completed, sites should be landscaped to approximate native conditions.

Thus Integrated Waste Management encompasses adoption of one or more of above mentioned technologies and or practices, in tune with local conditions. Effective waste management should be based on communities, industries, and individuals taking responsibility for their own wastes. Local governments should be empowered to develop their own solid waste management programs, subject to criteria established and administered by the state or province. Management plans should include, in priority order: waste reduction, reuse, recycling and materials recovery, in addition to adoption of innovative technologies like composting, land filling, etc. Detailed evaluation of the existing ground truth is a pre-requisite prior to setting up of any management plan.

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## PRESENT STUDY

### OBJECTIVES

The present study has been carried out with the following objectives:

1. To study the present status of solid waste generation, its disposal and environmental impact.
2. To assess the quantity of solid waste being generated (quantification) and its chemical characterization with respect to geological and geographical conditions.
3. To suggest adequate technologies of solid waste disposal / treatment and to formulate sustainable management strategies.

## SCOPE OF THE STUDY

The present study and the database generated in the area of quantification will help the urban local bodies in choosing adequate technologies / strategies of solid waste management. The data on characterization will help in assessing the kind of environmental problem the waste can create if not properly disposed off.

## METHODOLOGY

This deals with various methods employed in the collection, segregation, processing and analysis of solid waste samples for generating primary data pertaining to quantity and quality. The entire work has been scheduled in three phases. These include:

I Survey
II Field work and
III Laboratory investigation

**I Survey**

For the sake of convenience, the entire municipal area has been divided into 3 segments as follows:

Segment - 1: Mahe town; Segment - 2: Pandakkal and Segment - 3: Palloor.

A survey has been carried out among residents and business entrepreneurs for bringing out their opinion / suggestion in the area of sustainable solid waste management. A questionnaire was prepared for the above purpose and a copy is enclosed as Annexure I.

Apart from these, municipal authorities and other officials were also interviewed for obtaining a realistic estimate of the existing solid waste management measures operating in Mahe.

## II Fieldwork

Basic information / data pertaining to existing solid waste generation, disposal practices, disposal environment, management, etc. have been updated through necessary primary observations in the field.

Solid waste samples (Triplets) were collected from various waste generating centers. Sampling sites are marked in figure 1. These include 30 samples from 10 locations of Mahe town; 9 samples from 3 locations of Pandakkal and 15 samples from 5 locations of Palloor. For quantification studies, approximate length, breadth and height of major solid waste depositions, together with their representative weights per unit volume has been assessed.

## III Laboratory investigation

Samples from respective locations were brought to laboratory and have been separated into various components (segregation), as per the procedure of CPHERI (1971) and weight percentages of various components were estimated (Plate 6, a & c). Two sets of samples containing organic substances were maintained; of which one set was used for the estimation of moisture on oven dry basis and other on air-dry basis (Plate 6, b &d). The results are presented in percentage.

The samples for chemical analysis were dried in an oven to constant weight and ground to particle size lower than 60 ASTM mesh size. A known quantity of each of the samples were then ashed in a muffle furnace (Lab India), digested using HCl - $HNO_3$ acid mixture and used for the estimation of metals like cadmium, chromium, copper, iron and lead, using an Atomic Absorption Spectrophotometer (Perkin Elmer- 2380). Estimation of Potassium has also been carried out from the same sample using a Flame Photometer (Elico).

**Figure 1. Sampling locations**

**Plate 06**

Similarly Nitrogen and Phosphorus content of the samples were estimated from the air-dried samples using standard procedures (APHA, 1985 and Vogal, 1978). Average of triplicate measurements were taken in most of the above assessments.

## Limitations

Generating data based on solid waste, especially quantity and physical composition, is one of the difficult tasks in solid waste assessment studies because of the heterogeneity of samples, location, disposal means, seasonal variation in refuse composition, etc. However, utmost care has been taken in this investigation to obtain a realistic data based on solid waste generation, quantity and physico-chemical characteristics.

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## MAHE MUNICIPALITY- GENERAL PROFILE

### Location

Mahe, Union Territory of Pondicherry, is situated on the West Coast of the Indian Peninsula between $11^{o}$ 42' and $11^{o}$ 43' Northern Latitude and $75^{o}$ 31' and $75^{o}$33' Eastern Longitude, just between Badagara and Thalassery, 58 kilometers from Kozhikode and 24 kilometers from Kannur in Kerala State. This former small French Town, covering an area of 9 sq. kms, is 630 kms away from its administrative Head Quarters, Pondicherry.

### Accessibility

National Highway 17 (Mangalore – Edappally) and Mangalore Shornur railway lines are passing through Mahe. The entire municipal area, eventhough in three segments, is well connected through a network of paved roads.

### Population

Mahe municipality comprises of 14 wards. The total population, as per 2001 census is 36828 and the total number of households is 6054 (Table 1). The population density of the Municipal area is estimated to be 4092 persons / sq. km. (Table 2). This is expected to reach 4504.4 persons / sq. km. by 2011 (Table 3).

### Physiography

The municipal area falls in the coastal physiographic zone of Kerala. The region has got highly undulating terrain with hillocks and valleys. The general slope is towards southwest.

### Geology

Mahe, which forms the lower region of the Mahe watershed, consists mainly hornblende gneiss, hornblende biotite and quartz mica of migmatite complex and pyroxene granulite of charnockite group.

### Soil

Soil of this area varies in their depth, texture, internal drainage and degree of erosion.

Table 1. Population of Mahe (2001 census – ward-wise)

| Number of ward | Nature of area | No. of household | Male | Female | Total | % of total population |
|---|---|---|---|---|---|---|
| Ward No.1 | Urban | 344 | 1229 | 1350 | 2579 | 7.002824 |
| Ward No.2 | Urban | 386 | 982 | 1200 | 2182 | 5.924840 |
| Ward No.3 | Urban | 234 | 899 | 974 | 1873 | 5.085804 |
| Ward No.4 | Urban | 422 | 970 | 1086 | 2056 | 5.582709 |
| Ward No.5 | Urban | 360 | 996 | 1152 | 2148 | 5.832519 |
| Ward No.6 | Urban | 594 | 1620 | 1880 | 3500 | 9.503639 |
| Ward No.7 | Urban | 534 | 1454 | 1731 | 3185 | 8.648311 |
| Ward No.8 | Urban | 384 | 1057 | 1344 | 2401 | 6.519496 |
| Ward No.9 | Urban | 563 | 1620 | 1768 | 3388 | 9.199522 |
| Ward No.10 | Urban | 523 | 1582 | 1856 | 3438 | 9.335288 |
| Ward No.11 | Urban | 441 | 1179 | 1448 | 2627 | 7.133160 |
| Ward No.12 | Urban | 388 | 1146 | 1142 | 2288 | 6.212664 |
| Ward No.13 | Urban | 501 | 1375 | 1502 | 2877 | 7.811991 |
| Ward No.14 | Urban | 380 | 1044 | 1242 | 2286 | 6.207234 |
| Total | | 6054 | | | 36828 | 100.00 |

Table 2. Population density in various regions of Pondicherry U.T. (2001 census)

| Region | Area in sq. km. (Survey of India) | Males | Females | Total | Density per sq. km. |
|---|---|---|---|---|---|
| Pondicherry | 290 | 369428 | 365904 | 735332 | 2536 |
| Karaikal | 161 | 84487 | 86304 | 170791 | 1061 |
| Mahe | 9 | 17153 | 19675 | 36828 | 4092 |
| Yanam | 20 | 15893 | 15501 | 31394 | 1570 |

The salient attributes of the soils occurring in different physiographic regions are as given below:

| | |
|---|---|
| Texture: | Clay, gravelly clay |
| Depth: | Very deep (>150 cm) |
| Drainage: | Imperfectly drained to well drained |
| Erosion status: | Slight to moderate. |

**Land use**

The Municipal area exhibits two broad land use patterns. They are:

1. Settlements with mixed crops / trees
2. Dense built up area.

Settlements with mixed crops / trees are predominantly seen in Pandakkal and Palloor segments (Segments II and III) and densely built up area is seen in Mahe Town. Of the two landuse categories, the former, i.e., settlements with mixed crops / trees covers greater part (>50%) of the Municipal area. Detailed classification of the area is given in Table 4.

**Climate**

The area enjoys tropical humid climate with summer from March to May and mild winter from December to February. The region receives South - West Monsoon (June to September), North - East Monsoon (October to December), winter rain (January to February) and summer rain (March – May). Rainfall data for the period from 1990 to 2005 is given in Table 5.

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Table 3. Estimated population of Mahe (1991 – 2011)

| Sl. No. | Year | Population | Density / sq. km. |
|---|---|---|---|
| 1 | 1991 | 33447 | 3716.333 |
| 2 | 1992 | 33770 | 3752.222 |
| 3 | 1993 | 34096 | 3788.444 |
| 4 | 1994 | 34426 | 3825.111 |
| 5 | 1995 | 34759 | 3862.111 |
| 6 | 1996 | 35094 | 3899.333 |
| 7 | 1997 | 35434 | 3937.111 |
| 8 | 1998 | 35776 | 3975.111 |
| 9 | 1999 | 36122 | 4013.556 |
| 10 | 2000 | 36471 | 4052.333 |
| 12 | 2002 | 37184 | 4131.00 |
| 13 | 2003 | 37544 | 4170.889 |
| 14 | 2004 | 37907 | 4211.222 |
| 15 | 2005 | 38274 | 4251.889 |
| 16 | 2006 | 38645 | 4293.00 |
| 17 | 2007 | 39019 | 4334.444 |
| 18 | 2008 | 39396 | 4376.333 |
| 19 | 2009 | 39777 | 4418.667 |
| 20 | 2010 | 40162 | 4461.333 |
| 21 | 2011 | 40551 | 4504.444 |

Table 4. Classification of the geographical area of Mahe (2004 – 05)

| Sl. No. | Description | Area in Hectares |
|---|---|---|
| 01 | Total area according to village papers | 870 |
| 02 | Forests | - |
| 03 | Land put to non-agricultural uses | 210 |
| 04 | Barren and uncultivable land | 1 |
| 05 | Permanent pastures and other grazing lands | - |
| 06 | Land under miscellaneous tree crops and grooves not included in net area sown | 2 |
| 07 | Culturable waste | 14 |
| 08 | Fallow land other than current fallows | 12 |
| 09 | Current fallows | 7 |
| 10 | Net area sown | 624 |
| 11 | Area sown more than once | 3 |
| 12 | Total cropped area | 627 |

Table 5. Details of season - wise rainfall in Mahe (1990 – 2005).

| Sl. No. | Year | S-W Monsoon period | N-E Monsoon period | Winter period | Hot weather | Total | |
|---|---|---|---|---|---|---|---|
| | | in mm | in mm | in mm | in mm | in mm | in inches |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 1990-91 | 2182 | 353 | - | 174 | 2709 | 106.7 |
| 2 | 1991-92 | 2765 | 269 | - | 195 | 3229 | 127.1 |
| 3 | 1992-93 | 2991 | 508 | - | 212 | 3711 | 146.1 |
| 4 | 1993-94 | 2221 | 434 | - | 414 | 3069 | 120.8 |
| 5 | 1994-95 | 3200 | 460 | - | 236 | 3896 | 153.4 |
| 6 | 1995-96 | 2358 | 237 | - | 142 | 2737 | 107.8 |
| 7 | 1996-97 | 2464 | 375 | 27 | 121 | 2987 | 117.6 |
| 8 | 1997-98 | 3372 | 444 | - | 236 | 4052 | 159.5 |
| 9 | 1998-99 | 2613 | 535 | - | 26 | 3174 | 125.0 |
| 10 | 1999-00 | 2100 | 432 | 19 | 229 | 2780 | 109.4 |
| 11 | 2000-01 | 2044 | 515 | 5 | 697 | 3261 | 128.4 |
| 12 | 2001-02 | 1977 | 260 | 43 | 429 | 2709 | 106.7 |
| 13 | 2002-03 | 1752 | 905 | 24 | 124 | 2805 | 110.4 |
| 14 | 2003-04 | 2268 | 210 | - | 829 | 3307 | 130.2 |
| 15 | 2004-05 | 1967 | 353 | 21 | 144 | 2485 | 97.8 |
| Normal rainfall | | 2730 | 367 | 10 | 280 | 3387 | 133.3 |

## RESULTS

### Solid waste - sources

The sources of solid waste generation in three segments of Mahe municipality vary considerably. The main sources, apart from domestic discharges are hotels and restaurants, markets, shops, offices and institutions. Mahe town, being a major trade centre, the main source of solid wastes are hotels / restaurants, markets and shops, whereas in Pandakkal and Palloor, waste generation is mainly from domestic sector, in addition to limited releases from hotels, markets and shops.

### Quantification

The present study reveals that Mahe Municipality generates approximately 7.1 tones of solid waste per day, of which 4.6 tons is from Mahe Town (Segment I), 1.0 ton from Pandakkal (Segment II) and 1.5 tons from Palloor (Segment III).

### Physical composition

The solid waste of Mahe municipality, in addition to plastic, comprise a wide spectrum of refuse categories like paper, cartons and packing cases, wood pieces, fruits and vegetables, food refuses, metals, glass, leather, textile refuses, rubber, leaves, twigs, stones, shells, construction and demolition materials etc. These were then put under broad refuse categories such as organic substances, plastic, glass, stone, shell and metal. The weight of above refuse items per limited quantity of the waste collected is given in Table 6 and their percentages are given in Table 7. Relative composition of waste samples from various segments under study is given in Table 8. Also data pertaining to the moisture percentage of organic substances on oven dry and air-dry basis is given in Table 9. The graphical representation of moisture percentage and composition of waste samples from various segments under study are given in Figure 2.

The results indicate that the diversity of components is more in Mahe town followed by Pandakkal and Palloor. Relative proportion of plastic also followed the same trend. In the case of organic substances, a reverse trend has been noticed with higher percentage in Palloor followed by Pandakkal and Mahe town (Table 8).

Table 6. Segregation results of solid waste samples

| Sampling stations | Gross weight (grams) | Organic (grams) | Plastic (grams) | Glass (grams) | Stone (grams) | Shell (grams) | Metal (grams) |
|---|---|---|---|---|---|---|---|
| Segment I (Mahe Town) | | | | | | | |
| S1 | 953.33 | 763.333 | 150 | 40 | 0 | 0 | 0 |
| S2 | 1316.67 | 1068.33 | 226.667 | 0 | 20 | 1.6667 | 0 |
| S3 | 3413.33 | 1170 | 343.333 | 0 | 1900 | 0 | 0 |
| S4 | 2110 | 1743.33 | 366.667 | 0 | 0 | 0 | 0 |
| S5 | 1190 | 926.667 | 193.333 | 36.667 | 33.333 | 0 | 0 |
| S6 | 1546.67 | 1243.33 | 303.333 | 0 | 0 | 0 | 0 |
| S7 | 1033.33 | 826.667 | 180 | 5 | 0 | 0 | 21.6667 |
| S8 | 1653.33 | 1296.67 | 243.333 | 96.667 | 0 | 0 | 16.6667 |
| S9 | 1260 | 1033.33 | 200 | 13.333 | 0 | 6.6667 | 6.6667 |
| S10 | 963.333 | 923.333 | 40 | 0 | 0 | 0 | 0 |
| Segment II (Pandakkal) | | | | | | | |
| S11 | 1460 | 1393.33 | 66.667 | 0 | 0 | 0 | 0 |
| S12 | 1366.67 | 1093.33 | 256.667 | 5 | 0 | 0 | 11.667 |
| S13 | 1856.67 | 1630 | 226.667 | 0 | 0 | 0 | 0 |
| Segment III (Palloor) | | | | | | | |
| S14 | 1243.33 | 1123.33 | 120 | 0 | 0 | 0 | 0 |
| S15 | 1390 | 1336.67 | 53.333 | 0 | 0 | 0 | 0 |
| S16 | 1423.33 | 1213.33 | 210 | 0 | 0 | 0 | 0 |
| S17 | 1580 | 1473.33 | 106.667 | 0 | 0 | 0 | 0 |
| S18 | 620 | 540 | 80 | 0 | 0 | 0 | 0 |

Table 7. Percentage of various components in solid waste samples.

| Sampling Stations | Organic waste (%) | Plastic (%) | Glass (%) | Stone (%) | Shell (%) | Metal (%) |
|---|---|---|---|---|---|---|
| Segment I (Mahe Town) | | | | | | |
| S1 | 80.0699 | 15.7343 | 4.1958 | 0 | 0 | 0 |
| S2 | 81.1392 | 17.2152 | 0 | 1.5189 | 0.1266 | 0 |
| S3 | 34.2774 | 10.0586 | 0 | 55.6641 | 0 | 0 |
| S4 | 82.6224 | 17.3776 | 0 | 0 | 0 | 0 |
| S5 | 77.8712 | 16.2465 | 3.0812 | 2.8011 | 0 | 0 |
| S6 | 80.3879 | 19.6121 | 0 | 0 | 0 | 0 |
| S7 | 80.0000 | 17.4194 | 0.48387 | 0 | 0 | 2.0968 |
| S8 | 78.4275 | 14.7177 | 5.8468 | 0 | 0 | 1.0081 |
| S9 | 82.0106 | 15.8730 | 1.0582 | 0 | 0.5291 | 0.5291 |
| S10 | 95.8478 | 4.1522 | 0 | 0 | 0 | 0 |
| Segment II (Pandakkal) | | | | | | |
| S11 | 95.4338 | 4.5662 | 0 | 0 | 0 | 0 |
| S12 | 79.9999 | 18.7805 | 0.3659 | 0 | 0 | 0.8537 |
| S13 | 87.7917 | 12.2083 | 0 | 0 | 0 | 0 |
| Segment III (Palloor) | | | | | | |
| S14 | 90.3485 | 9.6515 | 0 | 0 | 0 | 0 |
| S15 | 96.1631 | 3.8369 | 0 | 0 | 0 | 0 |
| S16 | 85.2459 | 14.7541 | 0 | 0 | 0 | 0 |
| S17 | 93.2489 | 6.7511 | 0 | 0 | 0 | 0 |
| S18 | 87.0968 | 12.9032 | 0 | 0 | 0 | 0 |

Table 8. Relative composition of waste samples from three segments of Mahe.

| Segment I (Mahe Town) | | Segment II (Pandakkal) | | Segment III (Palloor) | |
|---|---|---|---|---|---|
| Organic materials | 77.2653 | Organic materials | 87.741 | Organic materials | 90.4206 |
| Plastic | 14.8406 | Plastic | 11.851 | Plastic | 9.5793 |
| Glass | 1.4666 | Glass | 0.1219 | Glass | 0 |
| Stone/ Gravel / Sand | 5.9984 | Stone/Gravel /Sand | 0 | Stone/Gravel / Sand | 0 |
| Shell | 0.0655 | Shell | 0 | Shell | 0 |
| Metal | 0.3633 | Metal | 0.2845 | Metal | 0 |

**Figure 2.**

Table 9. Moisture content of the organic fraction of waste samples.

| Sampling stations | Moisture % (Oven drying) | Moisture % (Air drying) |
|---|---|---|
| Segment I (Mahe Town) | | |
| S1 | 53.69409 | 45.94595 |
| S2 | 43.06849 | 32.25806 |
| S3 | 41.57162 | 25.31646 |
| S4 | 62.27485 | 64.28571 |
| S5 | 65.66852 | 37.3494 |
| S6 | 53.40488 | 24.35897 |
| S7 | 64.07762 | 56.25 |
| S8 | 50.94795 | 34.48276 |
| S9 | 46.03673 | 31.57895 |
| S10 | 57.53293 | 55.40541 |
| Segment II (Pandakkal) | | |
| S11 | 59.36598 | 54.21053 |
| S12 | 56.56853 | 36.84211 |
| S13 | 61.76766 | 47.82609 |
| Segment III (Palloor) | | |
| S14 | 60.23483 | 40.27778 |
| S15 | 53.07682 | 42.27726 |
| S16 | 55.56039 | 46.77419 |
| S17 | 53.03671 | 34.375 |
| S18 | 55.51576 | 45.75758 |

Results of the moisture percentage of organic substances, both oven and air dried, indicate that their relative concentration is higher in samples collected from Pandakkal followed by Palloor and Mahe town.

## Chemical composition

### Metals

Metals like Cadmium, Chromium, Copper, Iron and Lead in the waste samples were also assessed and their results are depicted in Table 10. On a general account, it has been noticed that the metal concentration was higher in samples from Mahe town followed by Palloor and Pandakkal.

Table 10. Heavy metal and other elemental composition of waste samples from Mahe.

| Sample no. | Cadmium | Chromium | Copper | Iron | Lead |
|---|---|---|---|---|---|
| Segment I (Mahe Town) | | | | | |
| S1 | 0.037 | bdl | 0.846 | 14.296 | 1.037 |
| S2 | 0.006 | 0.775 | 0.721 | 14.879 | 0.107 |
| S3 | 0.006 | 7.312 | 7.993 | 15.604 | 2.852 |
| S4 | 0.003 | 0.014 | 1.108 | 14.404 | bdl |
| S5 | 0.005 | 1.133 | 2.313 | 15.4 | 0.093 |
| S6 | 0.003 | 0.324 | 0.394 | 14.711 | 0.215 |
| S7 | 0.003 | bdl | 4.985 | 13.868 | bdl |
| S8 | 0.003 | 0.155 | 0.281 | 13.557 | 1.172 |
| S9 | 0.004 | 1.09 | 1.067 | 15.373 | 0.103 |
| S10 | 0.005 | bdl | 0.545 | 14.912 | bdl |
| Segment II (Pandakkal) | | | | | |
| S11 | 0.004 | 1.085 | 1.29 | 15.321 | bdl |
| S12 | 0.004 | 0.094 | 0.421 | 14.68 | 0.274 |
| S13 | 0.004 | 0.89 | 1.894 | 15.261 | 0.119 |
| Segment III (Palloor) | | | | | |
| S14 | 0.003 | 1.589 | 1.058 | 15.03 | 0.626 |
| S15 | 0.003 | 0.067 | 1.482 | 14.556 | bdl |
| S16 | 0.004 | 0.84 | 1.185 | 15.425 | 0.753 |
| S17 | 0.017 | 0.275 | 2.068 | 15.411 | 1.54 |
| S18 | 0.003 | 0.394 | 0.672 | 15.336 | bdl |

**Nutrients**

The variation in the mean values of nutrients (Nitrogen, Phosphorus and Potassium) in the solid waste samples collected from various segments of Mahe is given in Table 11.

Table 11. Mean values of nutrients in waste samples from various locations of Mahe.

| Sampling location | Nitrogen (%) | Phosphorus (%) | Potassium (%) |
|---|---|---|---|
| Segment I (Mahe Town) | 0.66 | 0.34 | 0.36 |
| Segment II (Pandakkal) | 0.80 | 0.42 | 0.46 |
| Segment III (Palloor) | 0.72 | 0.38 | 0.35 |

Higher NPK was noticed in the waste samples from Pandakkal followed by Palloor and Mahe town.

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## SOLID WASTE MANAGEMENT IN MAHE MUNICIPALITY - SUPPORTIVE CAPACITY

### Disposal site

Eventhough the municipality has acquired 40 cents of land at Pondayat in 1987; solid waste disposal has never been successfully materialized due to public protests and disputes against disposal sites. These issues remained unattended for years due to the lack of an elected Municipal council in power. Since an elected council assumed power after 38 years, there can be permanent solutions to the issues of solid waste management.

### Manpower

The municipal authorities are administering solid waste management system. The system consists of 01 sanitary inspector, 03 Supervisors and 37 sanitary workers, of which 22 are regular workers and 15 are casual labourers.

### Transportational capacity

Two vehicles (01 Tipper and 01 Mini Lorry) are available with the municipality for the collection and transportation of solid waste. Apart from these, 06 handcarts are also in operation.

### Collection accessories

The municipal area has not been deployed with waste collection accessories like community bins, metal cases etc. Hence solid wastes are deposited randomly or piled up in major centres of origin, making the face of the tourist town dirtier.

### Disposal practice

Presently waste disposal of Mahe is entrusted to a private party. Their operation includes collection (weekly once) from major centres and disposal (incineration) outside Mahe. A small quantity of waste is also subjected to landfilling in the outskirts of Mahe. These practices of waste disposal are confining to limited areas only and amounts to less then 25%. In spite of all these efforts, large quantities of solid wastes are lying unattended in various parts of Mahe (Plates 01 – 05), which is a serious concern.

Apart from these, there is much of solid waste disposal directly in to the Mayyazhi river and adjoining estuary by local residents and business people. This is adding up to the pollution load of the estuary.

**LEGEND TO THE PLATES**

| Plate no | Title |
|---|---|
| 01 | Solid waste dumping in and around aquatic systems: |
| a | Sewerage system near to Mahe beach |
| b | Mahe beach area |
| c | Slaughter waste in Mahe estuary |
| d | Near Mahe boat jetty |
| 02 | Solid waste disposal in other environments: |
| a | ‘Mayyazhi’ river bank |
| b | Near Mahe court |
| c | ‘Mayyazhi’ river bank – another view |
| d | Near Mahe bridge |
| 03 | Solid waste disposal in other regions of Mahe: |
| a | Near Municipal ground - Mahe |
| b | House-hold waste - Palloor East |
| c | Work shop waste - Near Canara Bank, Palloor |
| d | Near College ground - Mahe |
| 04 | Dumping of solid waste of various categories: |
| a | Packing material – Near Mahe Police Station |
| b | Construction waste – Railway station road |
| c | Packing waste - Near Mahe Govt. Higher Secondary School |
| d | Condemned bathroom fittings – Railway station road |
| 05 | Waste dumping in Palloor and Pandakkal areas: |
| a | Palloor East |
| b | Moolakkadavu, Pandakkal |
| c | Palloor west |
| d | Jawahar Navodaya Vidyalaya junction, Pandakkal |

**Plate 01**

**Plate 02**

**Plate 03**

**Plate 04**

**Plate 05**

**SOLID WASTE MANAGEMENT IN MAHE MUNICIPALITY - MAJOR FINDINGS**

- Mahe municipality does not have an effective and sustainable solid waste management system. The survey report also substantiates the same. The reasons can be attributed to:
- Lack of adequate and operational disposal site
- Lack of adequate technology for solid waste disposal
- Lack of adequate infrastructure.

- The municipality produces approximately 7.1 tones of solid waste per day, of which Mahe town contributes major share (64.7%) followed by Palloor (21.1%) and Pandakkal (14.2%).

- Results on segregation indicated more diverse components in solid waste samples collected from Mahe Town followed by Pandakkal and Palloor.

- The solid waste generated in Mahe contains ~12% plastic. Relative percentage of plastic is higher in Mahe town (14.8%) followed by Pandakkal (11.8%) and Palloor (9.5%).

- Higher organic content of waste samples was noticed with the samples collected from Palloor (90.4) followed by Pandakkal (87.7) and Mahe Town (77.2%).

- Moisture percentage (Oven dry basis) was found to be higher in waste samples collected from Pandakkal (59.23%), followed by Palloor (55.48%) and Mahe town (53.82%). Similarly Moisture percentage on air-dry basis was found to be higher in samples from Pandakkal (46.29%) followed by Palloor (41.89%) and Mahe town (40.72%).

- Elemental analysis of waste samples revealed the following:
- Average Cadmium concentration was higher in samples from Mahe Town (0.0075 mg/L) followed by Palloor (0.006 mg/L) and Pandakkal (0.004 mg/L).

- Average Chromium concentration was higher in samples from Mahe Town (1.08 mg/L) followed by Pandakkal (0.689 mg/L) and Palloor (0.633 mg/L).

- Average Copper concentration was higher in samples from Mahe Town (2.025 mg/L) followed by Palloor (1.293 mg/L) and Pandakkal (1.201 mg/L).

- Average Iron concentration was higher in samples from Palloor (15.151 mg/L) followed by Pandakkal (15.087 mg/L) and Mahe Town (14.7 mg/L).

- Average Lead concentration was higher in samples from Palloor (0.583 mg/L) followed by Mahe Town (0.557 mg/L) and Pandakkal (0.131 mg/L).

- On an overall assessment heavy metal concentration was found to be higher in the samples collected from Mahe Town followed by Palloor and Pandakkal.

- Higher NPK content was noticed in samples collected from Pandakkal followed by Palloor and Mahe town.

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## MANAGEMENT PLAN - PROPOSED

Based on the above findings and taking into consideration the supportive capacity of the existing waste management system, following short term and long-term management plans are proposed for Mahe.

## MANAGEMENT PLAN - SHORT TERM

Sustainable waste management practices like composting and land filling are not advisable to Mahe due to:

Limited area: Mahe has a geographical area of only 9 sq. km. and the available area is put under varied uses (Table 4).

High density of population: As per authentic and reliable reports, the population of Mahe has crossed 36,828 (Table 1). The present population density has reached 4092 / sq. km., which far exceeds the density of other provinces coming under this administration (Table 2). The density of population is expected to increase further and is estimated to reach 4504 / sq. km by 2011 (Table 3).

High rainfall: Mahe receives an average annual rainfall of 3387mm (Table 5). It is considerably high compared to other regions of Pondicherry. In such circumstances, composting and landfilling are not advisable, because it may lead to poor performance of the system together with leaching and / infiltration to nearby water bodies.

Hence, following management strategies are proposed for effective solid waste disposal.

1. INCINERATOR based solid waste management system is ideal to Mahe because of low availability of land, high population density and unfavourable climatological conditions for other management practices like composting / landfilling etc.

2. Incinerators need to be installed in selected ideal locations of Mahe. As waste generation is more in segment I, one incinerator need to be installed exclusively for Mahe Town. Another one can be set up combinely for Pandakkal and Palloor regions as these segments produce comparatively less quantity of waste.

3. Upgradation of the existing infrastructural facilities of collection, transportation and disposal of the solid waste. These include employing of more vehicles, persons and increasing the frequency of collection (At least thrice in a week).

4. Setting up of community bins in selected specific sites (nearly 18 in Mahe Town and 12 each in Pandakkal and Palloor) for facilitating systematic collection of waste. Necessary measures should be taken at these sites to avoid menace due to rodents, flies, birds etc.

5. Employing city sweepers and ensuring regular and periodic collection of waste in community bins.

6. Regular and periodic collection of waste from community bins and its effective transportation to the site of incineration.

7. Systematic segregation of the waste for the recovery of recyclable materials prior to incineration followed by controlled combustion of the refuse.

8. Proper and effective disposal / management of incineration waste and recyclable materials.

Incineration technology, eventhough suggestive to Mahe is a controversial technology. Hence prior to installation, the following aspects need to be taken into serious consideration:

- Incinerators need to be installed only after assessing the suitability of land, equipment and other operational conditions.

- Prior to installation, a detailed study pertaining to the calorific value of the waste need to be carried out. There should be proper assessment of the fuel / energy requirement of the incinerator, processing time required and disposal measures of ash produced.

- The incinerator, being set up, should be of higher quality and should contain sufficient systems to treat the flue gas, before being released to the atmosphere. The gaseous releases should fall within the standard limits prescribed in this regard.

- As Mahe is having more number of health care units, the incineration system associated with Mahe Hospital need to be made more effective for treating medical waste generated exclusively in this area.

**MANAGEMENT PLAN - LONG TERM**

In addition to an Incineration based solid waste disposal system, the following long term plans also need to be adopted for sustainable management.

1. Organizing mass awareness programmes among students, business people and local inhabitants, targeting source reduction, reuse and recycling of waste.

2. Enforcement of law against littering and dirtying of public places.

3. Popularization of degradable consumables followed by restriction and / prohibition of non-degradable components like plastic, based on set standards.

4. Controlling unsystematic dumping of solid waste by major industries and shops in public places and water bodies (natural and man-made).

5. Encourage generators of solid waste to adopt composting and biomethanation practices, wherever possible. Provide incentives / subsidies to those who adopt these technologies.

6. Create awareness among generators of solid waste about segregation of waste into three categories viz. biodegradable, recyclable and non-recyclable.

7. Implement a system of point to point collection of segregated waste by bell ringing vehicles at pre-fixed times.

8. Encourage restaurants to continue with the present practice of supplying refused food items and other organic wastes to piggery / poultry.

9. Earmarking areas for setting up of hazardous industries away from dwelling places and town areas.

10. Set up waste management systems, preferably biomethanation, in educational institutions, with a provision to recover energy. This is appropriate for the disposal of degradable waste being generated in connection with the "Noon feeding" programmes in schools.

11. Monitor and upgrade waste collection and processing facilities periodically. Its possible impacts on the environment should also be assessed effectively. Land, water and air pollution during solid waste management should be made strictly within permissible levels.

12. Maintain a corpus fund separately for the maintenance / repair of the vehicles / instruments as and when required. Financial constraints should not adversely affect the speed and efficiency of waste collection and disposal processes.

13. Develop a green belt of appreciable thickness around waste processing / disposal sites. The species chosen for green belt development should have the capability to assimilate excessive nutrients, toxic gases etc. thereby reducing the net concentration of pollutants in the surrounding environments.

14. Measures can also be taken with the help of NGOs and resident associations to streamline the activity of the informal sector for the betterment of the waste management system.

15. Privatization of waste collection and disposal sectors can be considered as a viable option for ensuring infallible operation. Monitoring of the waste management system, in case of privatization, need to be carried out by the Government machinery.

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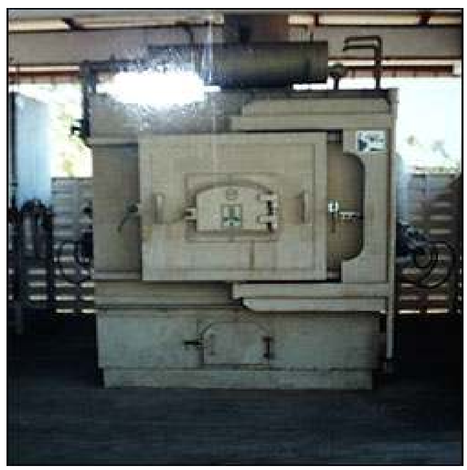
## INCINERATION TECHNIQUE - AN OVERVIEW

Incineration is the combustion of wastes in a controlled way in order to destroy it or transform it into less hazardous, less bulky or more controllable constituents. An incinerator is generally defined as any furnace used in the process of burning solid waste for the purpose of reducing the volume of the waste by removing combustible matter. Emissions of concern include particulates and potentially harmful pollutants depending on what is being burned. Incineration may be used to dispose of a wide range of waste substances including municipal solid waste, industrial waste, commercial, clinical and certain types of hazardous / non-hazardous chemical wastes.

**AN INCINERATOR**



Worldwide, incineration is the second choice method of waste management, after landfill.

This controversial technology has both advantages as well as disadvantages.
The advantages of incineration include:

1 Requires limited area for operation and are having varied provisions of pollution control.

2 A reduction in the volume and weight of waste, especially of bulky solids with a high combustible content. The reduction can be up to 90% of the volume and 75% of the weight of materials that would otherwise go to landfill.

3 Destruction of some wastes and detoxification of others to render them more suitable for subsequent disposal.

4 Destruction of the organic component of biodegradable waste that, when landfilled, directly generates Land Fill Gas (LFG). Estimates suggest that LFG accounts for over 40% methane emissions to the atmosphere.

5 Recovery of energy, if required, from organic wastes with sufficient organic value.

6 Provisions for the replacement of fossil fuel.

Major disadvantages of incineration include:

1 Incineration generally requires much higher capital investments and longer pay-back periods.

2 Chances of release of major pollutants into atmosphere, if not monitored periodically.

3 Lack of flexibility in the choice of waste disposal options once incineration is chosen.

4 The incinerator is designed on the basis of a certain calorific value for the waste. Removal of materials such as paper and plastics for recycling may reduce the overall calorific value of the waste and consequently affect incinerator performance.

5 The incineration process still produces a solid waste residue that requires management.

Hence, in order to derive maximum benefits from this technology, all ideal conditions of operation need to be satisfied.

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ANNEXURE I

## QUANTIFICATION, CHARACTERIZATION AND MANAGEMENT OF SOLID WASTE FROM MAHE, U. T. OF PONDICHERRY

**A study funded by the Department of Science, Technology and Environment. Government of Pondicherry.**

**QUESTIONNAIRE**

| | | |
|---|---|---|
| 01 | Type / Nature of the establishment | Home / Shop / Office / Restaurant / Institution |
| 02 | If shop, names of major products / process. | |
| 03 | Type / nature of solid waste generated, if any? | |
| 04 | Approximate quantity of waste generated per day. | |
| 05 | Existing disposal practices | Open dumping / Combustion / land filling / recycling / composting / others (specify)………………………………………… |
| 06 | If open dumping, site of disposal | |
| 07 | Are you satisfied with the existing solid waste management practices of Mahe municipality? | Yes / No |
| 08 | If no, why? | |
| 09 | What method do you suggest for Mahe in the area of solid waste management? | |
| 09 | Which area of Mahe, you suggest, is ideal for setting up of a solid waste management system. | |
| 10 | Will you support a waste management system for Mahe, incorporating nearby Municipalities? | |
| 11 | Will you pay for the services, if a paid waste management system is introduced in Mahe | Yes / No |