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SUSTAINABLE PLASTIC WASTE MANAGEMENT- A CASE STUDY OF THANE MUNICIPAL CORPORATION

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ABSTRACT

Thane Municipal Corporation is located near to Mumbai City in Maharashtra State of India. Thane is growing rapidly since last few decades. The total area of Thane city is 128 Sq. Km. According to census 2011, total Population of city is 18.41 Lakhs and floating population is about 3 lakhs. The Solid Waste generation in the TMC area is around 650 MT per day. Out of which Plastic waste generation is about 60-70 MT per day. TMC don't have any system for processing this plastic waste. This paper suggests a sustainable and one of the most emerging technologies of Plastic waste pyrolysis to TMC. Plastic Waste Pyrolysis is an ideal technology which is eco-friendly as well as generates furnace oil, carbon and hydrocarbon gas as productive output.

INTRODUCTION

Most of the big cities in country produce waste at a rate that outpaces its capacity to collect and dispose it off in a environmentally safe and sound manner. Its current approaches to waste management are neither sustainable effective nor. This necessitates a ideal shift in thinking. Traditional end-of-pipe solutions to waste management problems only deal with symptoms of improper management but unable to find the root causes.

However, Plastics have opened the way for new inventions and have replaced other materials in existing products. They are durable, light and versatile, as well as resistant to decay, moisture and chemicals. Yet these are the same properties that present environmental challenges.

This strategy seeks to achieve sustainable plastic waste management practices that aim at:

- Methods of reducing the production of plastic waste at initial source;
- Arranging social awareness to educate society and future generations which are based on the 3R approach of reducing, reusing and recycling;
- Developing an enabling policy framework for purposes of supporting the 3R concept through market and economic based instruments;
- Enabling resources (markets, finance and technology) for facilitating the implementation of policies of 3R;
- Directing appropriate technologies for increasing effectiveness, service coverage, and environmentally sound modes of disposal;

- Ensuring increased networking and interaction of all bodies involved in 3R activities, including consumers and end-users for purposes of creating new business opportunities;
- Capacity building and commitment through management and transfer of knowledge;
- Availing and providing exact and regular access to information by all stakeholders through capacity building and institutional strengthening;
- Green procurement should be implemented as Culture;
- To create an approach to integrated plastic waste management.

The Government of India has taken initiative by starting movement of 'Swachh Bharat' to see a cleaner future of India. This program is really appreciable and giving hope to live citizens in an enjoyable and safer environment.

PLASTIC WASTE MANAGEMENT IN THANE CITY

The budget reports of last five financial years show that there is no provision for investment in plastic waste management or any recycling project plant. As compared to other expenses in budget PWM is given no money for last five years. That's why Thane Municipal Corporation has a wide scope for implementation of a basic plastic waste management system to be established in Municipal Corporation itself.

Table 1 Last 5 years' budget of TMC for PWM

Year	Major Expenses In Budget			
	Road Cleaning Through Privatization	Channels Cleaning (Before Monsoon)	Ghantagadi Yojana	Total
2011-12	1401.50	258.68	739.67	10742.01
2012-13	1852.78	341.79	786.09	12607.29
2013-14	2056.92	439.91	796.94	13768.13
2014-15	2100.00	400.00	1000.00	14177.34
2015-16	3260.00	650.00	1110.00	17768.56

Source: TMC, Main budget of past four years

2.1 Methodology for data collection

There are a few common methods, which are adopted to analyze the samples at generation point, from the vehicles transporting the waste and at the disposal point.

- **Characterization of Waste:**
  Percentage of waste plastics in the waste reaching the disposal site was derived from the total quantity of waste disposed at the facility. Hence, vehicle survey was carried out to determine quantity of plastic waste generated
- **Quantification of Waste:**
  - Survey at Generation Point: Waste was quantified by visiting and contacting waste generators (e.g., Markets, Residential buildings, etc.)
  - At Prabhag Samittees and Hajeri Shed Point: Records were maintained of quantity of waste generation in their respective areas.
  - From the Vehicles at the Disposal Facility: Waste was quantified on the basis of vehicles arriving at transfer station and also at dumping ground.

- At the Disposal Facility: To quantify the waste plastic from Municipal solid waste, arriving at the dumping ground, waste pickers were interviewed.
- Survey of Plastic Packaging used for consumer goods: The quantification of plastic waste generation was also worked out on the basis of plastic used in consumer goods considering population of Thane City.

Figure 1: Total Quantity of Plastic Waste Generated Per Day

2.2 Plastic Waste and Sources of Generation

The quantity and composition of the solid waste generated by a society provide a mirror that reflects among others the cultural habits of the population. The amount of solid waste generated is also closely related to the overall economic level of the population from which it originates. There are a lot of plastic manufacturing industries in Thane. There are total 38 wards within 9 Prabhag Samitees in TMC. They generate enormous amount of plastic waste which remained unprocessed and less much is processed by unauthorised sources by improper methods.

Table 2. Prabhag Samitee wise plastic waste generation

Sr. No.	Name of PrabhagSamitee	No. of Wards	Quantity of Recyclable Waste (In Kg)	Quantity of Plastic Waste (In Kg)
1	ChitalsarManpada	4	10248.88	9736.431
2	Vartak Nagar	4	10634.45	10102.73
3	Wagle Estate	4	10741.78	10204.69
4	Railadevi	5	12824.68	12183.44
5	Uthalsar	5	13995.98	13296.18
6	Naupada	5	13215.55	12554.77
7	Kopri	3	7734.025	7347.324
8	Kalwa	3	7511.425	7135.854
9	Mumbra	5	10211.78	9701.186
Total		**38**	**97118.53**	**92262.6**

2.3 Technologies available for effective plastic waste management

Disposal of plastic waste is a serious concern in India. New technologies have been developed to minimize their adverse effect on the environment. Currently Worldwide accepted technology used for the plastic disposal is incineration; however, the incinerators designed poorly, releases extremely toxic compounds (chlorinated dioxins and furans) therefore, raising

several environmental issues. In India for safer disposal of plastic waste various technologies have been experimented.

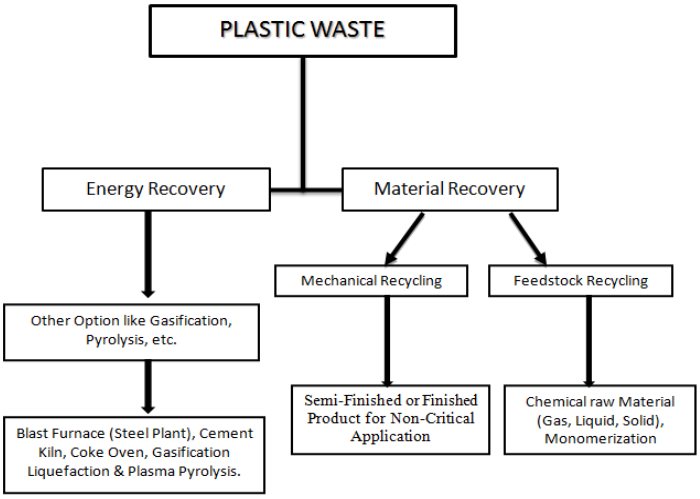


Figure 2: Methods for processing Plastic waste

Several end-of-life options exist to deal with plastic waste, including recycling, disposal and incineration with or without energy recovery. Plastic packaging has the longest established system for the recovery and recycling of plastic waste, hence its recycling rates are higher than those of other streams. It is followed by agricultural waste plastic, which although not under direct legislative obligation to increase recovery, is subject to economic incentives linked to the availability of homogenous materials. Although WEEE and construction plastic waste sources have relatively low rates of recycling overall, the rate of energy recovery is relatively high.

The preferred alternatives from the available technologies are -

- Recycling (consisting of making Plastic Granules to be moulded into goods thereafter)
- In the Construction of Tar roads.
- Conversion into Petroleum (Refuse Derived fuel, or RDF)
- Disposal in Cement Manufacturing Kilns.
- Plasma Pyrolysis Technology (PPT)

Out of all this methods Plastic Plasma Pyrolysis is one of the emerging and promising technologies offering an eco-friendly solution for Plastic Waste Management Problem

PLASTIC PLASMA PYROLYSIS

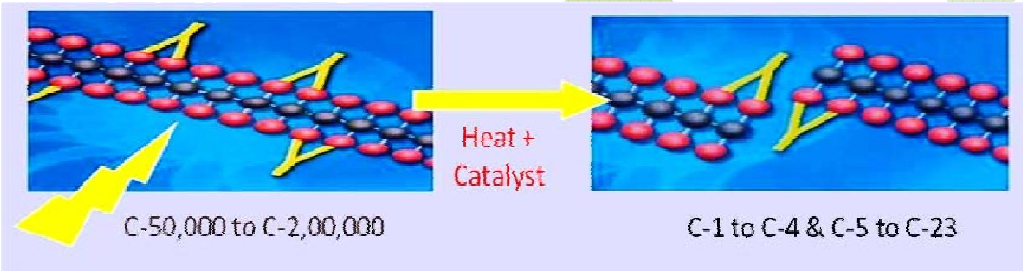
To study and understand the process I visited **Plasma Energy Pvt. Ltd.**, Navi Mumbai. I also visited a working plant at Sanaswadi, Pune to learn detailed working process from waste plastic to oil. It's an ISO 9001:2008 and CE certified company and has vast experience in this field.

3.1 Pyrolysis Technology

Pyro = heat, lysis = breakdown into parts. Pyrolysis is chemical reactions in which large molecules are broken down into smaller molecules. Simplest example of pyrolysis is cooking in which complex food molecules are broken down into smaller & easy to digestible molecules.

Waste plastic and tire are long chain molecules or polymer hydrocarbons. Refer fig. no.3 Pyrolysis Technology is the industrial process of breaking down large molecules of plastic/tire into smaller molecules of oil, gas and carbon black. Pyrolysis of waste plastic or tire takes place in absence of oxygen, at about 375-450 degree C and reaction time is about 45-90 minute.

Long Chain Polymer Short Chain Compounds:



Waste Plastic, Waste Tyre or rubber Hydrocarbon Gas (C1 to C5)

Pyrolysis oil (C5 to C23) Carbon

Figure 3: Conversion of Long polymers into Short Chains

3.2 Raw Materials & Products

Raw Materials:

No need for segregation,

Tolerance: 5% of dust + 5% moisture, PVC + Polycarbonate should be less than 5%

- Waste Plastic
- Electronic scrap
- Mixed plastic (HDPE, LDPE, PE, PP, Nylon, PS, ABS)
- Multi Layered Plastic
- Waste Tyres
- Rubber
- Plastic or rubber parts from vehicles
- Waste oils etc.

Table 3. Recommended materials to system

Description	Example	Guideline
PET (Polyethylene terephthalate)	Plastic Bottles for Soda and Water, Microwave Food Trays, Some of Textiles	Less than 5% uniformly mixed with rest of the raw Material.

HDPE (High-density polyethylene), PE (polyethylene)	Plastic Bags, Milk Jugs, Detergent Bottles, Cosmetic Bottles, Watering cans, Corrosion protection for steel pipelines, Folding chairs Folding tables, Heat-resistant fireworks display mortars, Hula hoops Meter & Valve Boxes, Natural gas distribution pipe lumber, Plastic surgery applications (skeletal and facial reconstruction)	Recommended
PVC (Polyvinyl chloride)	Shrink Wrap, Pipe, Siding, Blister Packs, Laminate Flooring	Less than 5% uniformly mixed with rest of the raw Material.
LDPE (Low Density Polyethylene) , LLDPE (Linear Low Density Polyethylene)	Bags for Dry Cleaning and Produce, Stretch Wrap, Wire Coverings	Recommended
PP (Polypropylene)	Bottle Caps, Appliances, Automotive Parts, Computer Parts, bags etc.	Recommended
PS (Polystyrene)	Cutlery, Cups, CD Cases, Packing Peanuts, Food Containers, Styrofoam	Recommended
Agricultural Waste	Any Agricultural Waste	Not Recommended
Plastic Road Waste	Any Road Waste	Tolerance: 5% of dust + 5% moisture
Tires/Rubber	Vehicle tyres, rubber parts of vehicle, bushes etc	Steel wires to be removed Before processing.

Most of the plastic waste generated around the world is suitable for proposed plant, which is easily available at site at competitive prices. Plastic waste from municipal solid waste shall be cleaned, shredded and the used as raw material for above mentioned plant for manufacture of fuel.
Plastic pyrolysis or tire pyrolysis is the process of converting waste plastic/tires into industrial fuels like **pyrolysis oil, carbon black** and **hydrocarbon gas**.

3.3 Plastic and Depolymerisation (Pyrolysis) Input & Output

Plastic depolymerisation (pyrolysis) plant and machinery consists of feeding system, reactor, carbon removal system, cyclone, condensers, receiver, gas handling system, centrifugal oil cleaner.
The plant and machinery shall be fabricated as per the drawings in 3 to 4 months. After fabrication it will be installed in the shed provided by Thane Municipal Corporation in 45 days. After installation is completed it will be commissioned in three weeks.
The waste plastic material shall be procured from the municipal solid waste and will be used to produce oil. The oil will be sold to oil dealers.

Table 4. Input and Output of Pyrolysis

Input Material	Input Quantity (kg)	Output Quantity
Waste mixed plastic scrap	2000	1000 to 1200 litres Pyrolysis Oil 200 to 300 Kg. Hydrocarbon Gas 200 to 600 Kg. of carbon Black
Nylon Scrap Tyres	2000	700 to 900 litres of Pyrolysis Oil 200 to 300 Kg. of Hydrocarbon Gas 600 to 700 Kg. of carbon Black 150 to 200 kg. Mild steel wire scrap

3.4 Working Procedure

Through the feeder about 25 kg of Plastic waste in supplied with proportionate mixture of catalyst PCAT (an epoxy catalyst) and water. For 100 kg of waste plastic about 1 ltr. Catalyst is supplied to accelerate reaction. Total capacity of plant is 3 tons per day.

Figure 4: Heating System, Raw material feeder and Depolymerisation reactor

The heating system is initially supplied with fuel to heat system at about 400 to 450 C. The plastic waste supplied through is pyrolysis and gratified further to melting process. This Process takes place in depolymerisation reactor.

Figure 5: Cyclone Separator

Figure 6: Condenser Tank

After that with the help of a Cyclone the hydrocarbon gases are separated from dirt and heavy carbon particles. Separated carbon particles are removed and collected separately. Remaining cleaned gas is passed through a set of condenser to condense it into Furnace Oil. The furnace oil is received from condenser to condenser tank and then stored separately (Refer Fig. 7).

Figure 7: Condenser and Receiver assembly

Still few hydrocarbon gases don't condense and remains as it is. They are having energy as compared to C.N.G. and L.P.G. Those gases are collected in a balloon and are used to heat system. Hence practically there is very little quantity of gases which are vented to atmosphere. A separate system is also installed to handle excessive pressures developed in system which allows maintaining required process pressure during operation.

Figure 8: Pressure Controlling System

RESULTS AND DISCUSSIONS

It's obvious that every sachet of plastic is not available for recycling at the plant. Many times plastic remained mixed with other waste and became unable to reach processing even though it is recyclable. It may also happen than oil, soil or other materials contaminate plastic and it became difficult to process without proper washing.

4.1 Financial Viability

So assuming that even half of the segregated plastic waste available for processing, we can design a system which can process a huge amount of plastic waste daily and do have potential to generate an ample amount of revenue. Refer table 1. We need to install same plant of 5 MTD capacity at every Prabhag Samitee i.e. total 9 plants.
Requirement for Municipal Corporation for successful execution:

- Land: 7000 sq.ft. every Prabhag Samitee
- Initial investment for plant equipment: Rs. 1,42,70,000/- every Prabhag Samitee
- Power (50 HP x 0.75 x 24 hrs x 25 days x Rs. 8): Rs. 1,80,000/- per month for every Prabhag Samitee

- Fuel /pyrolysis oil (400 ltrs x 25 days x Rs. 40 per liter): 4,00,000/- per month for every Prabhag Samitee
- Other expenses: Rs. 3,00,000/- per month for every Prabhag Samitee
- Waste plastic: 5000 kg per day for every Prabhag Samitee
- Catalyst (Rs. 100/- per liter): 1250 liters per month for every Prabhag samitee

Availability or can be provided by Municipal Corporation

- Land: On rent of free
- Waste plastic: Free

Total expense to be done at initial level for TMC

- Initial investment for plant equipment: Rs. 12,84,30,000/-
- Power (50 HP x 0.75 x 24 hrs x 25 days x Rs. 8): Rs. 16,20,000/- per month
- Fuel /pyrolysis oil (400 ltrs x 25 days x Rs. 40 per liter): Rs. 36,00,000/- per month
- Catalyst: Rs. 11,25,000/- per month
- Other expenses: Rs. 27,00,000/- per month

Summing up all, Total expense need to be done is **Rs. 13,74,75,000/-**

Rs. 1375.75 lacs seem to be a huge amount. But there should always some budget for such a critical issue. Following table clearly indicate that this much investment can be done if little attention is given to Plastic waste management.

Expected benefits:

- Annual Turnover

All amounts are in Rupees	Turnover (per year for every Prabhag Samitee)	Overall Turnover to TMC (per year)
By selling 3000 LT / day of Industrial fuel @Rs. 40 per liter	36,000,000/-	3,24,00,000/-
By selling 1000 Kg / day of charcoal @ Rs. 2/- per kg.	25,000/-	2,25,000/-
Total Turnover (per year)		**3,26,25,000/**

- **Total Annual Turnover: Rs. 3,26,25,000/-**
- Clean environment and healthy atmosphere
- Extra revenue for municipality which can be utilized for other sectors as investment.

So above calculation is self-explanatory that this system is not only eco-friendly but very much economical also. It covers all of its investment and utility cost within a period **three** years considering all depreciation of equipment, machineries and other interfering costs.

4.2 Pollution Control

i) To air

CO: 1ppm
NO_2: 1ppm
HCl: NIL
Heavy metals: NIL
Hydrocarbons: 2ppm
Others:
Nitrogen: 75%
Oxygen: 2 to 3%
Water vapour: 15 to 20 %
CO_2: 200ppm
SO_2: 2ppm
H_2S: NIL
Cl_2: NIL
Dioxins/Furans: NIL
Smoke: NIL

Gas exit quantity Cubic meters per hour: 400 Cubic Meters
Gas exit temperature °C: 50
Chimney height Meters: 15m
Water Vapour Content %:10-15 %

ii) To Water: NIL

4.3 Suggestion to Thane Municipal Corporation

Above mentioned plant of 3 tons per day is very beneficiary if we install them in every Prabhag Samitees, one for each. There are total 9 Prabhag Samitees in TMC.
As seen earlier,
Total plastic waste separated and mostly available for recycling: 75-80 MT per day.
If we install at least one plant in every Prabhag Samitees, total waste would be recycled and converted into pyro-oil: 9x3=27 MT per day.

Still about 60% waste remains unprocessed. Which can be reduced either by increasing plant capacity to 5 MT or 10 MT. Since project has a considerable initial investment as compared to previous ones, it needs to go slowly and steadily.

This process has potential to convert any type of plastic to useful output. Hence the best option to which any Municipal Corporation to rely on.

4.4 Guidelines for Segregation and Collection of waste

As for any type of recycling the most important issue is of segregation, no better Waste Management is possible without it.

- Bins of moderate size should be placed at public places especially for plastic waste. As many times it happens, people are willing to throw waste in bins but end up littering on roads only because they don't find bins.
- Awareness is made at rush places or more waste producing areas through posters, banners or by any means to reduce use of plastic.
- Household waste compulsorily be separated in two bins viz. dry waste and wet waste. It's most important step because it helps almost every further steps of reprocessing of waste and makes it easier to solve waste management issues.
- Apart from it, the waste should also collected separately and should be sent to processing centres available in municipality.

- There are still many places where Ghanta Gadis never have routes. So many times residents throw their garbage anywhere on roads, causing ill health environment. In populated areas most attention is given for collection of waste as early as possible.
- Rage pickers should be involved in authorised way in collection and transportation system.

4.5 Applications of the Products

Pyrolysis oil is the end product of waste plastic and tyre pyrolysis. Pyrolysis oil is widely used as industrial fuel to substitute furnace oil or industrial diesel. Typical industrial applications of pyrolysis oil as a fuel.

Currently pyrolysis oil manufactured from above plant is sold at Rs. 40 to 45/Lit. Typical industrial applications of pyrolysis oil as a fuel.

- Boilers
- Furnaces
- Hot Water Generators
- Hot Air Generators
- Thermic Fluid Heater
- Electric Generators (mixed with 50% diesel)
- Diesel Pumps (mixed with 50% diesel)

Due to wide range of applications of pyrolysis oil, marketing is easy.

CONCLUSIONS

The objective of the project is to investigate pyrolysis of the hydrocarbon polymers, HDPE/LDPE, PP and PS both theoretically and experimentally. This system can be used in Municipal corporations for effective and efficient plastic waste management. Factors which affect the pyrolysis process have been identified and quantified from the investigation. Based on the achievements, the distribution of the product and the process was optimized. A system which can process about 5 TPD is analyzed and suggested.
From the experiments on the HDPE/LDPE pyrolysis, three types of products can be produced which include,

□□Non-condensable gases,
□□Condensed liquid hydrocarbons (oil) and
□□Charcoal.

The distribution of the product varies greatly under different reaction conditions.

5.1 Importance of Segregation at source i.e. house

If the plastic waste is segregated at source, it can be directly channelized to plastic waste management process avoiding manual segregation and handling, thus saving time and energy. In addition to this larger quantity of waste which is entering the dumping ground can be recycled in effective manner.

Thus it can be concluded that effective plastic waste management can be achieved by proper channelizing of plastic waste in recycling process. Hence we can rightly say that Plastic Waste Management is a Million Rupees Enterprise.

5.2 Importance of 4thR that is Responsibility

Considering the present situation of plastic waste management system in thane city, it is essential that the plastic waste is segregated at source. And before the plastic waste is generated, it is important that one and all should follow the mantra of 3 R's ie. Reduce, Reuse and Recycle and to follow this mantra everyone should remember 4th R that is RESPONSIBILITY. Without understanding that it is our responsibility for managing the waste we generate, effective plastic waste management is difficult to achieve. Implementation of the Extended Producer Responsibility (EPR) or Corporate Social Responsibility (CSR) in management of plastic waste can help in effective plastic waste management.

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