Identification and Evaluation of Appropriate Technology for Economic and Ecological Conversion of Bio-degradable Waste in Mumbai at a Ward Level

FINAL REPORT

Presented to:

MMR Environment Improvement Society

Preparedby:

MEDC

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PREFACE

Mumbai is a great place, not only for Indians, but also to all other nationalities. The commercial capital of India, and now likely to be the financial hub of Asia, due to its unique position, equidistance between London and Tokyo, has also the potential to become a Tourist destination due to its history and waterfront. However, Mumbai has its list of problems and ills, like inadequate housing; 60% of population in slums, snarling traffic congestion, poor infrastructure, the dirt, uncleanliness, pollution etc.

Mumbai needs to be maintained as clean and beautiful. The city, which generates huge wealth and employment, has to be looked after well! In this regard, MEDC offered to undertake an exercise on Solid Waste Management in Mumbai. Municipal Corporation of Greater Mumbai(MCGM) entrusted MEDC the task of carrying out an evaluation of the practices of Solid Waste Management in "B" ward of Mumbai. "B" ward is one of the most difficult area in Mumbai City in view of a higher density of population per sq. km, smaller roads and mixed community. The distance from the dumping grounds is also one of the longest.

While work was being carried out on this ward, MEDC realized the importance of localized processing of Municipal Solid Waste. There were a few technologies available for the same. But somehow the experience of MCGM about the success of the same was not very encouraging. MEDC therefore decided to undertake an evaluation of these technologies and overall system for collection of waste in a segregated manner so that effective localized processing of municipal solid waste can be achieved.

Working on this project has been a rewarding and learning experience for the project team. The team met a number of fascinating people who were dedicated to the cause of environment. Meeting them and seeing their commitment and willingness to share their ideas and knowledge, was very enriching experience. MEDC discovered that Biomethanation has come of age and if we provide a sensible incentive structure it can materially contribute to improvement in the cleanliness as well as improvement in the environment of one of the most congested city in the world i.e., MUMBAI.

It would be appropriate to thank MEDC team members who were involved in the study because they have put their heart into study. Contributions of Ms. Vinda Wagh, Ms. Sailee Bagkar, Ms. Vandana Gharat, Mr Suresh Ghorpade assisted by few research associates, are greatefully acknowledged.

I must specially mention Mr. Srinivas Kasulla who has gained good knowledge on the subject through his curiosity, patience and shear hardwork in collating and questioning the information provided.

Mr. Nandkishor Kagliwal, President- MEDC, Mr. M.N. Chaini, Immediate past President - MEDC, Dr. C. S. Deshpande, Executive Director- MEDC and and Mr. Anil Deshpande , CEO –MEDC, provided strong encouragement when the team faced some difficult movements.

The task of completing this study would haven't been complete without inputs from our major sources of knowledge. Mention must be made of Smt. Jyoti Mhapsekar of Stree Mukti Sanghatana, Dr. Sharad Kale of BARC, Lt. Col Suresh Rege, Mr. Sameer Rege of Mailhem Engineers Pvt Ltd., Mr. Milind Kambl of Ecosolutions,, Dr. Rajamani, Dr. Ramanujam of CLRI Mr. Takalkar and Mr. Harshd Gandhi of Excel Industries Ltd.

The technical backbone for the study was the VJTI team led by Dr. P. P. Bhave and Prof. J.S. Maines assisted by Mr. Manchak Jadav who gave us the perspective and ensured clarity and precision.

It is difficult to recognize and thank all the people who allowed the MEDC team to see their sites, meet and discuss with their people and answer all kind of questions that our team put to them and showed their records among them. I would like to make special mention of Ms. Shanta Chatterji of Clean Air Island, Mr Anil Pawar of Mailhem Engineers Pvt Ltd. and Mr. Jhon Subhakar of Excel Industries,

MEDC owes special thanks to Mr. R.R.Markandeya (Chief Engineer) and Mr S.S.Shotriya (Executive Engineer) from SWM department of MCGM for their active involvement, encouragement and thoughtful advice during the entire course of this project and also for encouragement for looking forward to actual setting up a demonstration project.

ASHOK DATAR
Advisor - MEDC

Index

List of symbols / Acronym used in the Report:

MSW	Municipal Solid waste
MSW_b	Municipal Solid waste 'Biodegradable Fraction'
BIMA	Biologically Induced Mixing Arrangement
TPD	Tons per day
VSS	Volatile Suspended Solids
SDP	Sludge Drying Beds
MCGM	Municipal Corporation of Greater Mumbai
VJTI	Veermata Jijabai Technological Institute
MEDC	Maharashtra Economic Development Council
MMR	Mumbai Metropolitan Region
MMRDA	Mumbai Metropolitan Region Development Authority
MSW (M&H)	Municipal Solid waste (Management & Handling)
MNES	Ministry of Non conventional Energy Sources
PCMC	Pimpri Chinchwad Municipal Corporation
KDMC	Kalyan Dombivli Municipal Corporation

List of Tables

1 Introduction

1.1 Preamble

Maharashtra Economic Development Council (MEDC) has undertaken the study on Identification and Evaluation of suitable technology for ecological and Economical conversion of Municipal solid waste at a ward level. MEDC approached Civil and Environment Engineering Department of VJTI for carrying out the technical evaluation of the existing biomethanation plants installed in Mumbai and other locations and suggestion of suitable technical parameters for setting up biomethanation plants for processing biodegradable component of Municipal solid waste generated in a ward in Mumbai.

1.2 Scope of work

Carry out the assessment of available treatment technologies to treat the bio-degradable fraction of Municipal Solid Waste (MSW). The treatment technologies have to be assessed focusing at urban areas and to be applied on sector / ward level basis for the MSW management.

1. To study and evaluate the methods and costs of garbage collection and its transportation disposal from the households to the dumping grounds.
2. To carry out independent evaluation of the existing (selected) projects for SWM/Biogas/vermiculture etc., at various locations along with VJTI.
3. Design Methods to supervise implementation of the action plan.

Methodology

1.3 A) Methodology for studying treatment facilities.

i) Considering the metropolitan city like Mumbai which has unique nature of its population distribution, space availability, spread / Demography of the city, and heterogeneous nature of MSW, identification of the treatment technologies for MSW was the first step. This was carried out through detailed desk research and discussions with the experts in the filed.

ii) Once the plants were identified, study of existing MSW treatment facilities installed in Mumbai and other locations in India was undertaken. This included study and evaluation of design parameters, performance of individual units, economics and the overall suitability of the plant for a thickly populated city like Mumbai. Following plants were identified for study on the basis of primary research.

The following Biomethanation plants were identified for study:

A) Biomethanation plants of 20 TPD and above

I. Koyambedu Wholesale Market Complex, Chennai, Tamilnadu (CLRI).
II. Vijayawada Municipal Council, Vijayawada, AP

B) Biomethanation plants of 5 TPD capacity

I. BARC, Mumbai
II. Shatabdi Hospital, Govandi, Mumbai.

C) Biomethanation plants of 1 TPD and less capacity

I. Bharat Petroleum Corporation Ltd. Mumbai.
II. Bajaj Auto Ltd. Nigadi, Pune.
III. Kirlosker Oil Engines Ltd. Khadki,Pune.
IV. Mahindra & Mahindra Ltd, Mumbai.
V. Marigold Complex, Kalyaninagar, Pune
VI. Sadhu Vasvani Hospital, Koregaon Park, Pune.
VII. Vanshaj Co-Op. Hsg. Society, Mundhava, Pune
VIII. Tata International Ltd, Dewas, MP
IX. Shirdi Devasthan, Shirdi
X. Dakor Biogas plant, Dakor, Gujrat.
XI. Al-Kabeer , Hyderabad

From the above mentioned plants, it was decided that the detailed study will be undertaken for following plants :

1. Koyambedu Wholesale Market Complex, Chennai, Tamilnadu (CLRI).
2. Vijayawada Municipal Council, Vijayawada, AP
3. Shatabdi Hospital, Govandi, Mumbai.

The selection of these plants was done on the basis of the different technologies, input capacity, operations over a period of atleast more than a year and using biodegrable municipal solid waste.

VJTI team along with MEDC Team as well as MCGM officials (SWM dept.) spent a number of days at these plants located at different parts of the country. Detailed discussions were also carried out with the consultants/experts in the field of SWM and biomethanation.

MEDC team also identified and met suppliers of equipments, fabricators, technology providers et. MEDC team also discussed in detail with the plant operators, rag pickers which collect and segregate the waste to understand practical difficulties in plant operations. (The list of people with whom discussions were held has been given in annexure).

Following Aerobic composting plants were also studied in detail :

1. Vijayawada Municipal Council, Vijayawada, AP
2. CCI, Mumbai
3. M/s Excel Industries; Mumbai.
4. Bio Composting Project, KDMC

We also studied following Vermicomposting plants in detail :

1. Tata Motors, Pimpri Chinchvad
2. PCMC, Pune
3. Orchid Ecotel Hotel, Vile Parle
4. Clean Air Island; Colaba
5. Essel World; Gorai
6. PWD Quarters; Bandra
7. Rodas Ecotel Hotel; Hiranandani Powai

iii) Designing the treatment facilities for various capacities of biodegradable part of MSW. : VJTI has designed basic parameters for setting up biomethanation plants of different input capacities on the basis of the evaluation of the above technologies. (This is discussed in later part of this report)

1.3B. Methodology for understanding how to segregate, collect and transport the waste as raw material in acceptable quality to a neighborhood location for a safe and sensible disposal.

In order to understand how to collect, segregate and transport waste in an acceptable quality to a neighbourhood location, it was decided to study the existing systems for collection and disposal of municipal solid waste in Zone -1. It was also decided to study one ward in detail for exact understanding of generation of municipal solid waste.

After a detailed meeting with the Additional Municipal Commissioner-City and Chief Engineer-SWM, it was decided to study primarily,

1. Institutional waste generated by the markets and hotels and how it should be handled,
2. Current system of waste disposal of a ward in South Mumbai
3. The garbage collection system and collection spots in any particular ward from South Mumbai
4. Possible ways of reducing transportation of bio degradable institutional waste by processing locally, thus reducing the transportation cost as well as pollution impact on the environment.
5. It was decided to study B ward in detail for the purpose of carrying out physical surveys.

Collection of Primary Data :

Primary data regarding generation of waste in each of the four wards selected was collected from the respective solid waste management department of each ward. The information provided by the ward office was cross checked with the reports generated at Deonar dumping ground.

Collection of Secondary Data :

MEDC team carried out detailed survey of around 13 collection spots in B ward and two collection spots in each of the other wards to understand the sources of waste generation, which was necessary for the development of suitable strategy for the cleanliness and better waste management system in a ward.

The data provided by the SWM departments of respective wards was also cross checked by tracking no. of vehicles used for waste transportation, number of trips per day etc. (This detailed analysis was done only for B ward).

MEDC team also held a number of discussions with the staff at the ward level, local corporators (B ward), local citizens etc. Some of the registers maintained at the ward level as well as at the waste receiving stations such as Bulk Refuse container at C ward, Transfer station at Mahalaxmi as well as reports from Deonar dumping ground were also cross checked.

MEDC team personally visited most of the municipal food markets in A, B and C ward. Questionnaires were designed to collect information from hotels, eating houses as well as for housegallis in the three wards. (The copies have been attached in annexures). Around 200 eating houses, food vendors were interviewed and factual information has been collected on waste generation from respondents.

In order to understand the waste generation pattern by the five star hotels, we held detailed discussions with Hotel Taj President, Hotel Oberoi, Taj Mahal Hotel, CCI Club, Bombay Gymkhana etc.

To understand reasons for dumping of waste in the housegallis, surveys were carried out in a few buildings. Out of 900 housegullis in B ward a survey of around 500 housegullis was also carried out.

In order to understand attitudes of manpower working in the conservancy department at these wards, detailed interviews were held with the conservancy staff right from the level of labour to the junior officers, Assistant Health Supervisors (AHS). Details of the of personnel interviewed and source of information are given in (Annexure H)

Chapter - II

2 Treatment Technologies

Municipal solid waste (MSW) contains organic as well as inorganic matter. The organic content of MSW tends to decompose leading to various smell and odor problems. It also leads to pollution of the environment. To ensure a safe disposal of MSW it is desirable to reduce its pollution potential and several processing methods are proposed for this purpose. The latent energy present in its organic fractions can be recovered for gainful utilization through adoption of suitable waste Processing and Treatment technologies. The following different methods are suggested for solid waste processing or disposal.

a) Sanitary landfill
b) Composting
c) Incineration
d) Pyrolysis and Gasification
e) Anaerobic digestion / biomethanation
f) Vermicomposting
g) Pelletization or Refused Derived Fuel (RDF)

In order to have the better understanding of the treatment technologies, we have discussed these in the following paragraphs.

Sanitary landfill (SLF)

Sanitary landfill is the scientific dumping of the MSW using an engineering facility that requires detailed planning and specifications, careful construction and efficient operation.

The Principle methods used for land filling dry areas may be classified as

(1) Area, (2) Trench and (3) Depression.

The area method is used when the tern is unsuitable for the excavation of trenches in which the solid waste is dumped. The filling operation is usually started by building an earthen navy against which wastes are placed in thin layers and compacted. Each layer is compacted as the filling processes until the thickness of the compacted waste reaches a height varying from 2-3 m. At that time and at the end of each days operation, 150 – 300 mm layer of covered material is placed over the completed film. The covered material is brought in by the trucks from the nearby land or borrows pit areas.

As per MSW (M&H) Rules, strict measures have been imposed to discourage unscientific land filling/dumping as these pose problems of.

- Pollution in surface runoff during rainfall
- Pollution of soil/ground water/down stream aquifers
- Unhygienic/unsanitary conditions in surrounding area

Sanitary Landfill will be restricted to non-biodegradable, inert waste and other waste not suitable for recycling or for biological treatment.

SLF emissions of methane (CH_4), non CH_4 organic compounds, toxicants into the atmosphere and contamination due to leachate migration can be minimized by providing suitable control measures

The major objections to SLF are requirement of large size of land, high initial costs for design and construction and public opposition for the site. The efficiency of leachate and gas extraction is also doubtful.

b) Composting

Decomposition and stabilization of organic waste matter is a natural phenomenon. Composting is an organized method of producing compost manure by adopting this natural phenomenon. Compost is particularly useful as organic manure which contains plant nutrients as well as micro nutrients which can be utilized for the growth of the plants.

Composting can be carried out in two ways i.e. aerobically and anaerobically. During aerobic composting aerobic microorganisms oxidize organic compounds to Carbon dioxide, Nitrite and Nitrate. During anaerobic process, the anaerobic microorganisms, while metabolizing the nutrients break down the organic compounds through a process of reduction. The gases evolved are methane and carbon dioxide.

c) Incineration

It is the process of direct burning of waste in the presence of excess air (oxygen) at temperatures of about 800°c and above, liberating heat energy, inert gases and ash. In practice, about 65 to 80% of the energy content of the organic matter can be recovered as heat energy, which can be utilized either for direct thermal applications, or for producing power via steam turbine-generators with typical conversion efficiency of about 30%.

Incineration is associated with some polluting discharges, which are of environmental concern, although in varying degree of severity, and may be controlled by installing suitable pollution control devices.

The Indian MSW contains high percentage of inert (>40%) and puterscible organic matter (30-60%). The calorific value on dry weight basis varies between 800-1100 k-cal/kg. Due to this, self sustaining combustion can not be obtained for such waste and auxiliary fuel will be required. Therefore, incineration has not been preferred in India.

The only incineration plant installed in the country at Timarapur, Delhi way back in 1990 has been lying inoperative due to mismatch between the available waste quality and plant design.

d) Pyrolysis and Gasification

Pyrolysis is referred to as destructive distillation or carbonization. It is the process of thermal decomposition of organic matter at high temperature (about 900°C) in an inert (oxygen deficient) atmosphere or vacuum, producing a mixture of combustible Carbon Monoxide, Methane, Hydrogen, Ethane and non combustible Carbon Dioxide, water, Nitrogen gases, pyroligenous liquid , chemicals and charcoal.

Gasification involves thermal decomposition of organic matter at high temperatures in presence of limited amount of air/oxygen, producing mainly a mixture of combustible and non combustible gases (carbon monoxide, hydrogen and carbon dioxide).

Though it is widely used as an industrial process for production of charcoal from wood, coke and coke gas from coal and fuel gas from petroleum fractions, the pyrolysis of solid waste has not been as successful. The failure is because of the inherent complexity of the system and a lack of appreciation by system designers of the difficulties of producing a consistent feed stock from MSW.

e) Anaerobic digestion/Biomethanation

In this process, the organic fraction of waste is segregated and fed to a closed container (biogas digester) where, under anaerobic conditions, the organic waste undergoes bio-degradation producing methane-rich biogas and effluent/sludge. The biogas production ranges from 50-100 m^3/tonne of feed waste depending upon the composition of waste.

The biogas can be utilized either for cooking/heating applications, or through duel fuel or gas engine or gas/steam turbines for generating motive power or electricity. The sludge from anaerobic digestion, after stabilization, can be used as a soil conditioner, or even sold as manure depending upon its composition

Merits

- Useful products such as biogas and compost are obtained.
- Drastic reduction of pathogens is achieved.
- Needs comparatively much less land.
- No release of green house gases to environment.
- No problem of odour.
- Aesthetically good looking and hence no problem of real estate loss.
- Comparatively more cost effective with view of life cycle cost.
- Digested sludge is used as a fertilizer and the gas (CH_4) produced during digestion is used as fuel.

f) Vermicomposting

Vermicomposting is a bio-oxidation and stabilization process of organic matter that involves the joint action of earthworms and bio-organism. In his process the organic waste gets breakdown and fragmented by earthworms resulting in a stable non-toxic material with good humus material that can be used as a soil conditioner.

g) Refused derived fuel (RDF) /Pelletisation

The process of conversion of garbage into fuel pellets involves primarily drying, separation of combustibles from garbage, size reduction and pelletisation after mixing with binder and or additives as required. The moisture content of the waste should not be more than 35-40% otherwise sun drying (1 to 2 days) is required which needs adequate land. Earlier RDF thus produced, was used along with coal fired boilers but now, due to stricter restrictions on emissions, requires specially designed boilers dedicated to RDF.

The majority of the municipal corporations engaged in MSW management, practice land disposal (Crude open dumping) for biodegradable component of MSW. The land disposal of MSW is a non-scientific way of disposal.

The incineration, pyrolysis and palletisation options are energy, laboratory, and land area intensive as well as have environmental pollution potential. Biomethanation and composting are the two preferred methods of treatment for MSW practiced by some of the municipal corporations / industries.

Hence, the two treatment technologies as Biomethanation and Composting were identified as the technologies for the detailed study

2.1 Identification of MSW Treatment Technologies

The above study aims at identifying appropriate treatment technology for MSW for the city of Mumbai on sector basis (at a ward level). Mumbai is a metropolitan city with a population of approx. 13 Million and 430 Sq Km of area. MCGM has divided the city into wards. The MCGM, SWM Division collects approximately 6800 TPD of MSW daily. Biodegradable component of the MSW is approximately 40%. Today, the MSW generated in Mumbai is managed by disposing it on the dumping sites at various locations spread over Mumbai as Mulund, Deonar and Gorai. The present dumping sites have exhausted to their capacities and there is an urgent need for the proper alternatives for the MSW disposal.

Disposal of Biodegradable waste on the dumping sites has got direct effects on the surrounding environment by the way of leachate, air pollution, bird menace etc.

Biodegradable waste can be effectively converted to energy or useful products. Hence the treatment of biodegradable fraction will help in reduction of a substantial amount of MSW and will curtail pressures on dumping grounds and transportation costs.

Treatment of biodegradable waste fraction will provide an economic and ecological solution to the MSW management problem of the metropolitan cities like Mumbai.

Anaerobic digestion / Biomethanation and composting are the treatment technologies used as one of the treatment option for various types of biodegradable solid wastes collected from the urban areas / vegetable markets / hotels and canteen wastes etc.

2.2 Study of Existing Treatment Facilities

2.2.1 Biomethanation

Biomethanation is an anaerobic digestion process where the segregated organic fraction of waste is fed to a closed container called biogas digester. Under anaerobic conditions, the organic waste undergoes bio-degradation producing methane-rich biogas and sludge. The process is carried out in airtight reactor. Feed Sludge introduced continuously or intermittently is retained in the reactor for varying period of time. The stabilized sludge is withdrawn continuously or intermittently from the reactor.

Process:

Biomethanation process takes place in three stages viz., Hydrolysis, Acidogenesis and Methanogenesis.

In the first stage, called hydrolysis the complex organic matter like proteins, cellulose, lipids are converted by extra cellular enzymes into simple organic matter.

In the second stage, called acidogenesis, the soluble organic matter is converted by a group of facultative bacteria called acid formers into acetic acid, carbon dioxide, hydrogen and other low molecular fatty acids.

In the third stage, called methanogenesis, the intermediate compounds formed in the earlier stage are converted into methane and carbon dioxide. Bacteria involved in this are strict anaerobes, called methane formers.

Conditions required for proper working of digester

1. Temperature

Methanogens are inactive in extreme high and low temperatures. There are two optimal ranges for process operation to produce methane.

Mesophilic range - 20-40^{0}C

Thermophilic range - 40-60^{0}C

For reasonable rates of methane production, temperature should be maintained above 20^0 C. Rate of methane production can be doubled for every 10^{0}C increase in temperature until optimum temp. Is reached. Proper insulation of the digester helps to increase gas production in cold seasons. Higher the temperature lower will be the time required.

2. pH

The most important process control parameter is pH. The optimum pH range for all methanogenic bacteria is 6.5 to 7.5. It can tolerate upto a pH 6.2, below 6.2 the bacteria will die. The system must contain adequate buffering capacity to accommodate the production of volatile acids and CO_2 that will dissolve at the operating pressure. Excess alkalinity to control pH must be present to guard against the accumulation of excess volatile acids. pH is controlled by addition of lime.

3. Mixing

Mixing is an important factor in pH control and maintenance of uniform environmental conditions. Mixing distributes buffering agents throughout the reactor and prevents local building up of high concentration of intermediate metabolic products that can be inhibiting to methanogens. Mixing has the following beneficial effects:

- Maintains intimate contact between feed sludge and active biomass.
- Creates physical, chemical and biological uniformity throughout the digester.
- Rapidly disperses metabolic end products and any toxic chemicals entering the digester.
- Prevents formation of surface scum.

4. Nutrient requirement

A sufficient amount of nutrient such as Nitrogen and Phosphorous must also be available to ensure the proper growth of the biological community.

5. Anaerobic condition

The reactor should devoid of dissolved oxygen. O_2 is detrimental and reduces the efficiency.

6. Loading rate

Loading rate is the amount of raw material fed per unit volume of digester capacity per day. If the plant is overfed, it will result in more acid production, lowering the pH in the digester which is harmful to the methane formers.

7. Retention time

Retention time is the average period that a given quantity of input remains in the digester to be acted upon by the methanogens. The retention time is also dependent on the temperature, higher the temperature, lower the retention time.

8. Toxicity

Mineral ions, heavy metals and detergents are some of the toxic materials that inhibit the growth of bacteria in the digester.

2.2.1. The plants identified for study:

A) Biomethanation plants of 20 TPD and above

III. Koyambedu Wholesale Market Complex, Chennai, Tamilnadu (CLRI).

IV. Vijayawada Municipal Council, Vijayawada, AP

B) Biomethanation plants of 5 TPD capacity

III. BARC, Mumbai

IV. Shatabdi Hospital, Govandi, Mumbai.

C) Biomethanation plants of 1 TPD and less capacity

XII. Bharat Petroleum Corporation Ltd. Mumbai.

XIII. Bajaj Auto Ltd. Nigadi, Pune.

XIV. Kirlosker Oil Engines Ltd. Khadki,Pune.

XV. Mahindra & Mahindra Ltd, Mumbai.

XVI. Marigold Complex, Kalyaninagar, Pune

XVII. Sadhu Vasvani Hospital, Koregaon Park, Pune.

XVIII. Vanshaj Co-Op. Hsg. Society, Mundhava, Pune

XIX. Tata International Ltd, Dewas, MP

XX. Shirdi Devasthan, Shirdi

XXI. Dakor Biogas plant, Dakor, Gujrat.

XXII. Al-Kabeer , Hyderabad

A) Biomethanation plants of 20 TPD and above

i) Study of Biomethanation Plant at Koyambedu, Chennai TN

Capacity	:	30 TPD
Location:	:	Koyambedu Wholesale Market Complex (KMWC), S. No. 90/2, Nerkundram Village, Chennai.
Type of waste:		Fruits and Vegetable market Waste

The Chennai Metropolitan Development authority (CMDA) has set up the project namely 'The Koyambedu Wholesale Market Complex' to decongest the central Chennai city's George Town area. This wholesale market of perishable items like flowers, fruits and vegetables is spread over an area of 60 acres with good infrastructure to facilitate traders and consumers.

This market is one of the largest in Asia accommodating total of 3154 shops of all types including service shops, restaurants, kiosks, banks, post office, police station, telegraph office and other common facilities. The market is having potential of generating solid waste of about 100 T/Day.

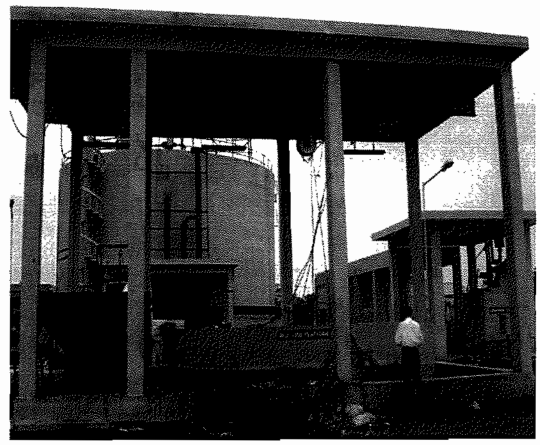
A statutory Market Management Committee (MMC) headed by Member Secretary CMDA manages the market, with Chief Administrative Officer (CAO).

Earlier the waste was collected on daily basis by a private agency, transferred to a transfer station near to market complex and finally to dumping site of Corporation of Chennai. The waste being perishable with high moisture content causes very fast natural decomposition, leading to obnoxious odor and emission of gases like methane, carbon dioxide which are potential green house gases. This may also lead to pest breeding and possibility of vector spread epidemic. Considering this, CMDA proposed to setup waste treatment plant of high rate biomethanation and produce electricity.

Ministry of Non-conventional Energy Sources, (MNES) Govt. of India, has funded 75% of the cost of project under UNDP-GEF programme to reduce green house gases and MNES own fund. MNES appointed Central Leather Research Institute (CLRI), Adyar, Chennai as the nodal agency to select the agency and technology for implementation of biomethanation plant for recovery of energy from vegetable waste. Also CLRI has entered into an agreement with CMDA and MNES for the technical assistance and to monitor the project implementation. Global tenders were invited by CLRI and selected M/s Enkem Engineers Private Limited, the Indian licensee of M/s Entec Ugmbh, Austria for "Design, Detailed Engineering, Turnkey implementation and commissioning of the project".

The project started its construction in 2003 and was expected to commission in Jan'05. Actual commissioning took place in July'05 and electricity generation started on 4/9/2005. The plant is of 30 TPD capacity situated over an area of 1 acre producing 3000-4000 units of electricity and 5 TPD of manure per day. The total cost of project is Rs. 55.0 Million including electricity transfer station.(or step up transformer).

Overall view of the plant



Waste receiving area

Sailent Features of the Plant

1	Place of installation	Koyambedu Wholesale Market Complex (KWMC), Koyambedu, Chennai.
2	Date of commissioning	July 2005.
3	Implementing Agency	M/s. Enkem Engineering Pvt. Ltd. Chennai
4	Technology Provider	M/s. ENTEC, Austria
5	Technical consultant	Central Leather Research Institute, Adyar, supervision: Chennai
6	Client	Chennai Metropolitan Development Authority
7	Technology Used	Biogas Induced Mixing Arrangement (BIMA)
8	Capacity of Plant	30 TPD
9	Area Required	4000 m2
10	Capital Cost	Rs.5.50 Cr including O&M for six months.
11	Type of Waste	Vegetable, Fruit & Flower Waste
12	HRT	26 Days

13	Solid concentration	10 %
14	Biogas produced	2500 m^3 /d (83.33 m^3/T of waste treated)
15	Bio sludge produced	10 TPD wet cake (25 % solids)
16	Gas Engine	230 KW, Deutz, German make
17	Biogas consumption	100m^3 / hr
18	Power generated	Approx. 4000 KW units per day

Analysis Reports

Results obtained from the site office.

A] Effluent:

pH	= 8.69
TSS	= 438 mg/l
TDS	= 5236 mg/l
Chlorides	= 740 mg/l
Sulphates	= 200 mg/l
O&G	= 9 mg/l
BOD_{27}@3days	= 525 mg/l
COD	= 1920 mg/l

B] Manure Flakes (wet)

Solid Concentration	20 – 25 %
Moisture Content	75 – 80 %
Organic Content	30 – 50 %
Nitrogen	1 – 3 %
Phosphorous	1 – 4 %

C] Manure Sample

Nitrogen	2.48%
P_2O_5	2.42 %
Potassium	8.04 %

D] Biogas Sample

CH_4	66.5 %
CO_2	27.5 %
H_2S	Traces
Moisture	-

Observations : KWMC, Chennai Plant

30 TPD biomethanation plant based on BIMA technology is commissioned in Sept.2005. During our study the plant is working at 20-25 TPD because of non-availability of waste. The plant is under observation as it was not stabilized at the time of visit. After stabilization of process, the plant will be able to treat any biodegradable waste available in the market. It is highly mechanized and automated plant. Manpower is used only for partial segregation of waste and for handling of dewatered sludge.

Waste handling and size reduction section

Biogas Holder

Imported Biogas Engine

The biogas produced is utilized for gas engine to generate electricity. The power so generated, after captive consumption is connected to Tamilnadu Electricity Board grid. The dry sludge is sold as manure. There is no full-fledged laboratory set up for monitoring the performance of the plant. The plant is maintained very well and was in operation during the study period.

Comments: KWMC, Chennai Plant

- Digestion process is more effective because of two stages, size reduction of waste material.
- Due to thorough mixing in BIMA digester methane formation is more and scum problems are avoided.
- Due to screw press, moisture levels in the manure are reduced faster and hence total land area required is less.
- No chemicals are required for process and pH adjustments.
- Plant is still under stabilization (at the time of study).
- A full fledged laboratory should be set up for monitoring the performance of the plant.


Odour Control System


Shredder


Screw Press

ii) Study of Biomethanation Plant of Vijayawada Municipal Council

Capacity : 20 TPD

Location : Ajitsingh Nagar, Vijaywada (AP) based on Vegetable and Slaughter house Waste.

Type of waste: Biodegradable Municipal solid waste generated in Vijaywada.


Anaerobic Digester


Vegetable waste loaded at site being observed by VJTI team


Waste Loading on Belt conveyor

The Vijayawada Municipal Council (VMC) having population of around 15 lacs has commissioned three projects for the treatment and disposal of municipal solid waste generated in the city to the tune of 400 TPD. These plants include

(1) M/s.Excel Industries Ltd. Bio compost plant (125TPD)

(2) M/s. Sri Ram Mills power plant (150TPD)

(3)M/s. Mailhem Engineers Pvt. Ltd. biomethanation plant (20 TPD).

The biomethanation plant working on vegetable market waste and slaughter house waste is actually commissioned in Jan '04 and inaugurated by the Chief Minister on 24th September'04. Earlier waste was treated by composting. The plant is designed and constructed by M/s. Mailhem Engineers Pvt. Ltd. Pune. It is operated and maintained by them.

Vijayawada Municipal Council and Ministry of Non conventional Energy Sources (MNES), Govt. of India has financed the plant. The cost of the plant is Rs.30.40 Millions. The plant is situated over an area of 4000 sq.m. The plant processes 16 TPD vegetable wastes and 4 TPD slaughter house waste. It produces 1600m3 of biogas. The power generation will be 150 KWh, which will be partly used for captive use and balance, connected to APSEB grid. 2 T of manure is produced daily. The plant works in two shifts.

Salient Features of the Plant

Place of installation	Ajit Singh Nagar, Vijayawada
Date of commissioning	Jan 2004
Implementing Agency	M/s. Mailhem Engineers Pvt. Ltd, Pune
Technology Provider	M/s. Mailhem Engineers Pvt. Ltd, Pune
Client	Vijayawada Municipal Council
Technology Involved	Biphasic fixed roof anaerobic digestion
Capacity of Plant	20 TPD
Area Required	4000 Sq.M.
Capital Cost	Rs.30.40 Millions
Type of Waste processed at plant	Vegetable, Fruit & Flower Waste and slaughter house waste.
HRT (primary + secondary)	30 Days
Solid concentration	10 %
Biogas produced	1600 m^3 (@80 m^3/TPD of waste treated)
Bio sludge produced	2 TPD
Gas Engine/generator	150 KWh, Libbherr/ Stanford, Switzerland/German make
Biogas consumption	1.8-1.9 units/m^3

Observations : Vijayawada biogas plant

20 TPD Vijayawada biomethanation plant was commissioned in Sept. 2004. At present plant is working at 15 TPD capacity due to non availability of waste. The plant is fully mechanized. The biogas produced is used for generation of electricity. The power generated is approx 3200 units / day After captive consumption (how much?)to be supplied to Andhra Pradesh Electricity Boards grid. The manure is sold as soil conditioner. The laboratory setup is provided to monitor few parameters like total solids, volatile solids moisture and biogas composition. Power requirement is 500 units/day (consumption at full capacity). Manpower requirement is of 30 members which include Plant In charge, Assistant plant In charge, Engineers, Process engineers, Engine operators, Chemists, Laboratory , Watchman, Gardener and House keeper. The plant is well maintained and was in operation in two shifts during the study period.

Biogas Receiving tank and biogas Scrubber


Biogas sample collection point for testing


Imported Biogas Engine

Comments: Vijayawada biogas plant

- Agitator/stirrer is used because of which there is no scum formation. No chemicals are required for process and pH adjustments.
- Though the plant is of 20 TPD, it does not use any weighing system. The total quantity of waste received per day is calculated by counting the number of vehicles and bins. A proper weighing system should be provided.

Sand Separator


Vegetable waste at site - minute observations by Srinivas Kasulla (MEDC)


Nutrient Dosing tank

Plant Comparison

Details	Chennai Biogas Plant	Vijaywada Biogas Plant
Plant Capacity	30 TPD	20 TPD
Running at	20 TPD	15 TPD
Area	4000 sq.m. provided by Chennai Metropolitan Development Authority	4000 sq.m. Provided by Vijaywada Municipal corporation
Technology Provider	M/s Entec, Austria	Mailhem Engg. Pvt Ltd.
Implementing and operating agency	Enkem Engg. Pvt Ltd	Mailhem Engg. Pvt. Ltd.
Date of commissioning	June 2005(Not stabilized*)	May 2004
Raw Material	• Waste generated by Vegetable market in Koyembedu. • Only Raw Vegetable and fruit waste is being processed.	• Vegetable and fruit market waste and animal slaughter waste such as offal waste (which includes liquid, bones etc. • Waste is supplied by Vijaywada Municipal Corporation (VMC) by their hydraulic vehicles (TDP's).
Manpower	12 persons	30 persons
Biogas Produced	2500 m^3/day	1800 m^3/day
Electricity generated	230 KWh/day (approx. 4000 units/day)	140 KWh (approx. 3200 units/day)
Total Electricity Consumption	433 units/day (consumption at full capacity)	500 units/day (consumption at full capacity)
Manure output	~ 5 TPD (if runs at full capacity)	5% of input (at present approx. 600 kgs but if the plant runs at its full capacity then 1 TPD)
Water input ratio	1:1	1:1 + liquid slaughter waste
Retention Time	26 days	30 days (for both primary as well as secondary digester)
Gas Composition	Biogas Composition Methane – 66.5% Carbon dioxide – 27.5% Hydrogen sulphide –traces	Biogas Composition Methane – 65-70% Carbon dioxide – 30-35% Hydrogen sulphide-(in ppm)
Estimated Cost	Rs. 5 Crore + additional cost of a Rs. 50 lacs for transformer	Rs. 3.04Crore
Area per Ton	**133.33 sq.m.**	**200 sq.m.**
Cost per Ton	**Rs. 1.833 Million**	**Rs. 1.52 Million**

* *Although we got adequate information during our first visit in September 2005, when the plant was just commissioned, our request for subsequent visits as well as getting data on plant working did not elicit positive response. Hence we feel that the plant may not have stabilized.*

B) Biomethanation plants 5 TPD capacity

iii) Nisargruna Biogas Plant at B.A.R.C. Mumbai

Capacity	: 5.0 TPD
Location	: Chembur, Mumbai
Type of waste	: Canteen Waste

Nature has been kind to us all along and continues to take care of us with utmost sincerity and precise planning. It is therefore our responsibility that we return this debt appropriately to maintain the positive balance. This is the basic concept of the project "Nisargruna" developed by BARC Five Nisargruna plants have been installed at BARC- Anushaktinagar, Shatabdi Hospital -Govandi, Abbatoirin Deonar and INS Kunjali(Navy quarters) in Mumbai.

The plant at BARC is designed to treat 5 tonnes of canteen waste daily. The waste comes from canteen nearby and from housing colony of the BARC officers.

5 TPD Nisarargruna Biogas Plant

Types of biodegradable waste that could be treated in the Nisargruna plant are Vegetable and fruit market waste, fruit and food processing industries waste, kitchen waste from residential colonies/ schools/ colleges/ army/ big establishment canteens, hotels, hostels, hospital/ religious places, paper, garden waste, animal and abattoir waste etc.

Waste that cannot be treated and to be strictly avoided for Nisargruna plant are Coconut shells, egg shells, big bones, plastic/polythene, glass, metal, sand, slit,debris and building materials, wood, cloth/ clothes, ropes, nylon threads, batteries, tyres/ rubber, hazardous and chemical industries waste etc.

Salient features of biogas plant at B.A.R.C. Mumbai

Details	Biogas Plant at B.A.R.C. Mumbai
Plant Capacity	5.0 TPD
Running at	2 TPD
Technology Provider	BARC, Mumbai
Implementing agency	BARC, Mumbai
Raw Material	Biodegradable canteen & market waste
Manpower	7 persons
Biogas Produced	200 - 220 m^3/day
Total Electricity Consumption	30 units/day
Manure output	0.2 TPD
Water input ratio	1:1
Retention Time	19 days
Estimated Cost	Rs. 15 lacs
Area per Ton	175 sq.m.
Cost per Ton	3 Lacs

Observation: BARC Plant

5 TPD biogas plant is presently working at only 2 TPD capacity because of shortage of waste. Plant is labor oriented and less mechanized. Shredder is not efficient. No mixing arrangement in the digester is provided. There is no facility for sludge dewatering. Biogas produced is used as supplementary fuel in the canteen for cooking purpose. Dry sludge is used as manure in the garden. The biogas production claimed 100 m^3/ T waste processed. BARC laboratory is used for monitoring the plant. The plant was in operation during study.

Comments: BARC Plant

- Waste segregation and handling is done manually.
- The shredder/mixer is not so effective to convert the waste into fine pieces.
- There is no proper sludge dewatering system, only sludge holding tank is provided.
- The mild steel floating roof is provided for storage of biogas produced. The dead weight in the form metal plates is placed on it to maintain the pressure required for gas engine.
- There is no mixing arrangement for waste in digester.
- The biogas production claimed is about 100 $m^3$of waste processed.
- The biogas produced is being used in the canteen.
- Dry sludge is used as manure in the nursery. The plant is operated on trial and error basis. It was in operation during the study period.

- Because of Biphasic digestion, percentage of methane is higher compare to other technologies and also the HRT is reduced.
- No chemicals for dozing and pH adjustments are required.
- Design of sludge drying beds can be improved.
- Because of temperature maintained in the pre digester by adding hot water thermophyllic conditions are maintained and HRT is reduced.
- Design of segregation Platform can still be improved than the present one.
- Digestion would be much faster if the input material is in the form of paste hence designs of the mixer can to be improved.
- Input and output chambers can be further modified.

This being a Pilot plant does not have all the amenities. However, the latest designed plants based on this technology have been further modified.

iv) Nisargruna Biogas Plant at Shatabdi Hospital, Govandi, Mumbai

Capacity	: 5 TPD
Location	: Govandi, Mumbai
Type of waste	: Canteen Waste

Municipal Corporation of Greater Mumbai (MCGM), has installed biogas plant of capacity 5 T/day based on BARC technology in 2001 and commissioned in June 2003. The waste processed is cooked hotel waste and vegetable market waste.

Non Governmental Organization (NGO) called 'Stree Mukti Sanghatana' has played major role in establishing this plant. This NGO, sanghatana works for welfare of rag pickers in Mumbai area. The proposal was submitted by sanghatana to MCGM. There is a repartee MoU between MCGM, BARC and Stree Mukti Sanghatana. The funds provided by MCGM, technology by BARC and construction, operation and maintenance by Stree Mukti Sanghatana.

Full view of 5 TPD Biogas plant at Shatabdi Hospital

Salient features of biogas plant at Shatabdi Hospital, Mumbai

Details	Shatabdi Hospital Biogas plant
Plant Capacity	5.0 TPD
Running at	3 TPD
Area	400 sq mt
Technology Provider	BARC, Mumbai
Implementing agency	Stree Mukti Sanghatana
Technology Provider	BARC, Mumbai
Implementing agency	Stree Mukti Sanghatana
Date of commissioning	2003
Raw Material	Biodegradable canteen & market waste
Manpower	7 persons
Biogas Produced	100 m^3/day per ton of waste
Total Electricity Consumption	30 units/day
Manure output	0.3 TPD
Water input ratio	1:1
Retention Time	19 days
Estimated Cost	20 lacs*
Area per Tonne	**80 sq.m.**
Cost per Tonne	**4 Lacs**

* As this was a Pilot research plant costing didn't include all the other infra structure facilities, other mechanic implements, loading platforms etc., which can be seen in the latest designs of Nisargruna plants and hence the cost of the hardware equipments of the plant will rise.
MCGM, BARC, MNES and SMS have contributed for the project.

Observations

- The material is brought in tempo either loose or in plastic bags and unloaded on platform manually.
- The material includes waste from hotels and vegetable market shop.
- The material is segregated manually by women helper by sitting.
    - One helper segregates 1 TPD of waste in 2 to 3 hrs in sitting position.
    - There are chances of health problems due to working in sitting position.
    - If standing arrangement like platform is made then work can be done in faster way.
- The material is filled in plastic buckets for loading in mixer.
- Material is weighed on platform weigh balance. Weight of material varies from waste to waste.
    - The hotel waste when weighed was observed to be appr. 35-40 kg per bucket.
    - The vegetable waste weighs 28-32 kg per bucket.

- Waste from hotel in Andheri weigh 50-60 kg per bucket which is stored for 2-3 days in hotel and then brought to site which had a bad odour.

- The bucket is lifted by two persons and emptied in the mixer.
  - There should be some mechanical lifting and loading arrangement so that labor involved and time can be saved
  - One batch of mixer takes 15 min to mix 5-6 buckets appr. 150-200 kg waste. There fore one tone waste needs 1-1.5 hrs for mixing purposes.
  - Mixer blades need to be redesigned so that waste will be finely shredded.
  - Mixer and recycle pump switch board is little away which consumes time in putting mixer and pump on and off every time i.e. batch.
  - The mixer outlet valve chokes frequently because of large size material which is not shred or cut into the pieces.
- The homogeneously mixed waste is stored in inlet chamber till it is filled completely and then emptied in pre digester by opening alternate holes provided for the same.
  - Sudden loading of pre digester may disturb the layers formed in it and pass the fresh material in the main digester.
  - There should be continuous discharge from inlet chamber to pre digester so that plug flow conditions will be maintained.
  - The waste needs to be pushed in pre digester manually from inlet chamber.
  - 4 hrs of aeration with the help of compressor and hot water pouring is required. 500 lit of hot water is poured daily by the worker manually.
  - Pungent smell is observed near pre digester. [may be H_2S and NH_3]
  - pH in the pre digester observed about 5.
- From the pre digester material flows to main digester.
  - Two levels are maintained in the digester manually with the help of outlet pipe to have additional capacity.
- The biogas generated is stored in floating roof. Dead weight is placed on it to maintain 10 mbar pressure required for generator. The biogas is used to generate power and to make hot water.
  - The generator is run only for 6-8 hrs in a day.
  - Excess biogas needs is being flared as it contains green house gases like CH_4 and CO_2.
- The discharge from digester flows to sludge holding tanks through outlet chamber and pipe.

- pH of discharge observed was between 7 and 8.
- Colour was blackish.
- The BOD of slurry in the manure tank is less than 100 mg/L
- There is no filter bed. Sludge is sun dried.
- Supernatant is recycled back for mixing and dried sludge is used/sold as manure. Also some medicinal plants are planted and sold.

- Electricity consumption for the month of November, 2005 was 993 units.

  Power consumption as per specifications is as under:

  - Mixer = 7.5 hp x 0.75 kw x 3 hrs = 16.88 units
  - Compressor
    - [1] = 1.0 hp x 0.75 kw x 4 hrs = 3.00 units
    - [2] = 0.5 hp x 0.75 kw x 4 hrs = 1.50 units
  - Slurry pump = 2.0 hp x 0.75 kw x 2 hrs = 3.00 units
  - Water pump = 1.0 hp x 0.75 kw x 2 hrs = 1.50 units

TOTAL =25.88 units/day

Extra units for general lighting are required.

- Manpower observed on site

Supervisor	1 no
Plant operator	1 no
Asst. plant operator	1 no
Helper	3 no
Watchman	1 no
TOTAL	**7 no**

- House keeping was good.
- Greenery was developed around plant.

Comments : Shatabdi hospital

- Percentage of methane is higher as compared to other technologies due to Biphasic digestion and also the hydraulic retention time is reduced (HRT).
- No chemicals for dozing and pH adjustments are required.
- Design of sludge drying beds needs modification.
- Because of temperature maintained in the pre digester by adding hot water thermophyllic conditions are maintained and HRT is reduced.

- Design of segregation platform, Input and output chambers can be further modified.
- Digestion would be much faster if the input material is in the form of paste hence designs of the mixer needs to be modified.
- This being a Pilot Research plant is not with all the amenities but the latest designed plants of this technology are further modified.

Plant Comparison:

Since both the plant technology provider and operating agency were the same, the separate comparison is not given.

C) Biomethanation plants 1.0 TPD and less capacity

v) Biogas Plant of M/s. Bharat Petroleum Corporation Ltd (BPCL)

Capacity : 1 TPD
Location : Mahul Refinery, Chembur, Mumbai.
Type of waste : Canteen Waste

Biogas plant at BPCL

M/s. Bharat Petroleum Corporation Ltd (BPCL) is located at Mahul in Chembur suburb of Mumbai. BPCL is having its ultra modern refinery producing the fuel to meet the Euro-III/IV norms & other petroleum products.

There are about 3000 persons working in the refinery in shifts. Canteen facility is available for them at subsidized rates serving tea, snacks and food for lunch and dinner which generates about 1000 Kg of waste per day which is treated in biogas plant installed. There are three canteens namely Main canteen, North canteen and east canteen.

The company's residential colony has500 flats. The waste generated from there is not taken for producing biogas but disposed off in MCGM waste collection bins. Also the considerable green waste is produced from trimming of lawns, trees and gardens which is not used but disposed on MCGM dumping grounds. The separate plant is under consideration for green/colony waste.

M/s. Aryan Associates, a Baroda based firm has installed biogas plant for 1tpdintake capacity producing 85-100m^3 of gas per day in 2001.The plant costing Rs.2.9 Million (Excluding land & infrastructure) is spread over an area of 900 sq. M.(Is the cost as on 2001?)

Salient Features:

Details	BPCL plant
Unloading platform	5 m x 1 m x 1 m with ramp.
Mixing/ segregation tank	2 nos. 1.2 m x 1.2 m x 0.5 m
Mixer / crusher	2 HP, 2 Nos
Pre digestion tank	2 no,1.2m x1.2mx1m

Mixer/ agitator	2 HP, 2 Nos
Inlet chamber	2 m x 1.5 m x 1 m
Main digester	7 m in dia. and 5 m deep
Gas holder	M.S. Floating roof weighing 4 MT
Outlet chamber	1 m x 1 m x 0.5 m
Sludge holding tank	under ground sludge holding tank
Sludge Drying Beds	4 Units; 3 m x 3 m
Water storage tank	under ground water storage tank 1.2 m x 1 m x 1 m
Water pump	1.5 HP, 2 Nos.

All civil works are done in brick masonary.

Observations:

1TPD biogas plant is commissioned in 2001. Plant operates at full capacity. It is not mechanized.

- The waste is collected in plastic buckets in the canteens and brought to plant in the jeep.
- Unloading, mixing and sorting are done manually.
- From the mixing tank waste mixed with water is loaded into mixer manually by buckets.
- Waste flows by gravity into digester. Also digested slurry flows by gravity in slurry sump and to sludge drying beds. Filtrate flows to water sump.
- Filtrate is reused for mixing purpose.
- Biogas is used in canteen for heating milk and tea.
- The dry sludge is removed from SDB weekly which is used as manure in the gardens.
- Monthly O&M is Rs. 47000/-
- Electrical consumption is very less as manual operation & gravity flow.

No smell observed. House keeping was good.

Comments: BPCL Plant

- There is no laboratory for monitoring of plant performance.
- Segregation should be done on loading platform instead of carrying out in the container.
- Plant is maintained properly. It was in operation during visit.
- Land utilized was more and the plant costs indicated are very high.

vi) Biogas Plant of M/s. Bajaj Auto Ltd. Nigadi, Pune.

Capacity: 0.5 TPD

Location: Nigdi, Pune

Type of waste: Canteen Waste

M/s. Bajaj Auto Ltd. Nigdi is located about 25 km from Pune on Mumbai Pune highway. The industry manufactures automobiles like three wheelers and four wheelers.

M/s. Mailhem Engineers Pvt. Ltd. Pune installed first biogas plant at M/s. Maharashtra Scooters Ltd. Satara (a Bajaj groups unit) in 1995. After its successful running, they installed the second biogas plant at Pune in 1997 costing Rs. 5.75 lacs of 500 kg/day processing capacity.

Overall view of the plant

Shredder and sorting table unit

Bajaj Auto Ltd. has two canteens. One is for officers and other for general workers. Both canteens generate approximately 1200 kg to 1500 kg of solid waste i.e. food waste, vegetables, fruit peels, etc. daily. The plant is designed for 500 kg/day processing capacity. The remaining waste is disposed off in municipal dust bins along with other solid waste. From 500 kg of waste per day about $43m^3$ of gas is generated. The gas is used in canteen for cooking food of about 125 persons daily.

Salient Features:

Loading table	Mild steel lined with glass fibers to avoid corrosion. 2 m x 0.6 m
Shredder/cutter	3 HP motor, Tungsten Carbide Cutter, 1 MT/hr. Capacity
Inlet chamber	Brick masonry 1 m x 1 m x 1 m
Feeding pump	1 HP
Primary digester with stirrer	Mild steel, 3.2 m dia , 4.2 m liquid depth,0.5 HP
Secondary digester	Mild steel, Retention time 7 days.
Gas holder	Neoprene rubber balloon
Gas compressor	1 HP with MS gas receiver tank.
Outlet	Brick masonry. 0.9 m x 0.9 m x 0.6 m

Observations

0.50 TPD biomethanation plant is commissioned in 1997. It is operated at full capacity.

- The waste is brought to site in buckets loaded on trolley.
- The waste is segregated at source of generation and at plant before loading into shredder.
- Shredder is very compact and efficient which converts waste into slurry.
- Waste to water ratio is 1:1
- Two digesters namely primary and secondary are provided to enhance the process.
- The biogas produced is stored in Neoprene rubber balloon.
- The gas is used in the canteen for cooking food.
- The stirrer and compressors time and pressure are automatic controlled.
- Power consumption is very less. Automatic control panel is provided.
- Only one person supervises the plant. Salary Rs. 4000/- per month.
- pH is checked once in 15 days. Effluent is tested once in six month
- No smell observed near the plant. House keeping was good.

Comment: Plant at Bajaj Auto, Pune

- Plant is maintained properly.It was in operation during visit.

vii) Biogas Plant of Kirlsoker Oil Engines Ltd. Khadki, Pune.

Capacity	: 0.3 TPD
Location	: Khadki, Pune
Type of waste	: Canteen Waste

M/s. Kirlsoker Oil Engines Ltd. Khadki is located about 15 km from Pune on Mumbai Pune highway. The Kirlosker groups unit engaged in manufacturing oil engines (for export only) is situated on the bank of river Pawana.

Biogas plant at Kirloskar Oil Engines – with Underground digester

M/s. Mailhem engineers Pvt. Ltd. Pune has installed biogas plant 9 months ago. The plant total cost is Rs. 4.5 lacs [plant Rs. 3.5 lacs + civil works Rs. 1.0 lacs. The space required is very less (6 m X 12 m). Company has a staff canteen generating about 300kg of food/vegetables solid waste per day. The plant is designed to treat 300 kg / day waste and to take shock loads of 25% more. This produces nearly 24 m^3/day of gas. It is used in canteen for making tea.

Salient Features:

Loading table	Mild steel lined with glass fibers to avoid Corrosion, Size1.2m x 0.6 m.
Shredder/cutter	3 HP motor, Tungsten Carbide Cutter, 1 MT/hr capacity.
Inlet chamber	Brick masonry 1 m x 1 m x 1 m
Digester with stirrer	under ground RCC, 0.25 HP
Gas holder	Neoprene rubber balloon with level indicator of rope pulley type
Gas compressor	1 HP with MS gas receiver tank and pressure gauge meter.
Outlet / recycle chamber	Brick chamber. 0.9 m x 0.9 m x 0.9 m
Recycle pump/sludge pump	1 HP

Observations

0.30 TPD biomethanation plant is commissioned in Dec.2004. It is operated at full capacity.

- The loading platform is located near canteen on first floor only. The waste is stored in buckets kept near loading platform.
- The waste is segregated at source of generation and at loading table before loading into shredder.
- Shredder is very compact and efficient which converts waste into slurry.
- Waste to water ratio is 1:1
- As loading table along with shredder is located on first floor, the slurry moves down under gravity through pipe into the inlet chamber.
- Only one digester is provided.
- The biogas produced is stored in Neoprene rubber balloon.
- The gas is used in the canteen for cooking food.
- The stirrer and compressors time and pressure are automatic controlled.
- Power consumption is very less. Automatic control panel is provided.
- Only one person supervises the plant. Salary Rs. 4000/- per month.
- pH is checked once in 15 days. Effluent is tested once in six month
- No smell observed near the plant. House keeping was good.
- Sludge is removed once in a year.

Comments: Plant at Kirloskar oil engines

- Plant is maintained properly. It was in operation during visit.
- The process is almost online.

viii) **Biogas Plant at Mahindra & Mahindra Ltd. (Auto Div), Akurli road Kandivli(E), Mumbai-400101**

Capacity : 0.80 TPD(800 kg/day)
Location : Kandivli(E), Mumbai
Type of waste : Canteen Waste

Mahindra & Mahindra Ltd. (Auto Div) is located at, Kandivli (E), Mumbai on western express highway. The company is engaged in manufacturing of jeeps. It has one common canteen for officers and general workers. Canteen generates approximately 800 kg of solid waste i.e. cooked food waste, vegetables, fruit peels, etc. daily. M/s. Mailhem Engineers Pvt. Ltd. Pune has installed biogas plant in 1999 to treat the solid waste generated. This will produce nearly 80 m^3 of gas per day. The plant cost was between 7- 8 lacs.

Salient Features:

Loading table	Mild steel lined with glass fibers to avoid corrosion
Shredder/cutter	3 HP motor, Tungsten Carbide Cutter, 1 TPD/hr. capacity
Inlet cum recycle chamber	Brick masonry (2mx1mx1m ht).
Feeding pump	KSB centrifugal slurry pump
Primary digester	capacity 35 m^3, 5mm thick MS with FRP lining of 1mm
Stirrer assembly	2 stage cyclo reduction gear box & a motor of 0.5hp
Secondary digester	capacity 9 m^3, 3mm thick MS with FRP lining of 1 mm thick
Gas holder	40 m^3 capacity Neoprene rubber balloon
Biogas blower	Roots type 2HP with MS gas receiver tank of 1 m^3 capacity
Outlet	1 m x 1 m x 0.6 m

Observations

0.80 TPD biomethanation plant is commissioned in 1999. It is operated at 0.60 TPD capacities.

- The plant is located near to canteen. The waste from dish washing section flows to mixer in troughs.
- The waste is segregated at source of generation and at plant before loading into shredder.
- Shredder is very compact and efficient which converts waste into slurry.
- Waste to water ratio is 1:1
- Two digesters namely primary and secondary are provided to enhance the process.
- The biogas produced is stored in Neoprene rubber balloon.
- The gas is used in the canteen for cooking food.
- The stirrer and compressors time and pressure are automatic controlled.
- Power consumption is very less. Automatic control panel is provided.
- The company operates and maintains the plant.
- pH is checked once in 15 days. Effluent is tested once in six month

House keeping needs improvement.

Comments: Mahindra and Mahindra

- Plant is not maintained properly. It was in operation during visit.

ix) Biogas Plant of M/s. Marigold Complex, Kalyaninagar, Pune

Capacity : 1.5 TPD
Location : Kalyaninagar, Pune
Type of waste : Canteen Waste

Biogas plant at Marigold Complex

Marigold complex is a residential cum office complex area located in Kalyaninagar, the suburb outside Pune. The quantity of waste generated will be about 1500 kg/day. A plant is provided as a part of compliance for obtaining the occupancy certificate from the Pune Municipal Corporation.

M/s. Mailhem engineers Pvt. Ltd. Pune has installed biogas plant.

Salient Features:

1) Loading table - Mild steel lined with glass fibers to avoid corrosion.
Size 0.6 m x 1.2 m

2) Shredder/cutter - 3 HP motor, Tungsten Carbide Cutter, 1 TPD/hr. capacity.

3) Primary digester with stirrer - 0.25 HP

The plant is operated by rag picker women's society. The gas generated is not used presently. It is just flared out. In future gas will be used for producing electricity which can be used for operation of STP.

x) Biogas Plant of M/s. Sadhu Vasvani Hospital, Koregaon Park, Pune

Capacity : 75 Kg per day
Location : Koregaon Park, Pune
Type of waste : Canteen Waste

Sadhu Vasvani Hospital, located at Koregaon park area in Pune is run by Sadhu Vasvani Charitable Trust.

It is having general canteen as well as lodging and boarding facility for admitted patients. The waste generated is 75 kg per day. The plant is designed for 100 kg solid waste plus 2500 lit sewage from cancer patient department after disinfection.

M/s. Mailhem engineers Pvt. Ltd. Pune has installed biogas plant. The plant consists of

1) Loading table - Mild steel lined with glass fibers to avoid corrosion. Size 0.6 m x 0.6 m
2) Shredder/cutter - 1 HP motor, Tungsten Carbide Cutter,
3) Primary Digester - 2.8 m x 1.2 m x 2.8 m deep.
4) Secondary digester - 5.2 m x 1.2 m x 2.6 m deep.
5) Gas holder - Haplon rubber balloon kept inside secondary chamber.

The sewage is taken to secondary digester directly. The gas is used for canteen in the hospital.

xi) Biogas Plant of M/s. Vanshaj Co-op. housing Society, Mundhava, Pune.

Capacity : 50 Kg per day
Location : Mundhava, Pune
Type of waste : Canteen Waste

50 kg/day capacity compact biogas plant in Pune

Vanshaj Co-op. housing Society, Mundhava is a residential complex comprising of about 100 flats. The waste generated is 50 kg per day.

M/s. Mailhem engineers Pvt. Ltd. Pune has installed biogas plant. The plant is very compact consisting of

1) Loading table - Mild steel lined with glass fibers to avoid corrosion. Size 0.6 m x 0.6 m.
2) Shredder/cutter - 1 HP motor, Tungsten Carbide Cutter,
3) Digester -1.5m x 1.8m x1.2m deep.

Since the quantity of gas produced is very less, it is flared at present society.

xii) Biogas Plant at M/S. Tata International Ltd (TIL), Dewas, M.P.

Capacity : 2.0 TPD
Location : Dewas
Type of waste : Canteen Waste, treatment of shaving dust/ trimmings with alkali at an high temperature and isolating the inorganic.

M/s Tata International ltd. is a unit of Tata group of companies engaged in manufacturing of leather and leather products such as leather garments, foot wear and finished leather. The leather processing operations generate solid waste like shaving dust, wet blue trimming and other waste which is classified as hazardous waste as per schedule-II of Hazardous Waste (M&H) Rules 1989 amended in 2003, as it content chromium.

The treatment and disposal of chromium bearing waste is a very difficult task. The R & D wing of TIL have developed a methodology for treatment of this waste through in house experiments and decided to use the same on large scale. The technology is developed by TIL which involves biomethanation with following objectives.

- Recovery of energy through biomethanation.
- Recovery of chrome from waste.
- Reduction of GHG.
- Disposal of hazardous waste.

The plant having capacity of treating 700 T/year and costing Rs.1crore was commissioned in September, 2002. Ministry of Non-conventional Energy Sources (MNES), Govt. of India has sponsored 50% of cost and 50% is invested by TIL. Central Leather Research Institute (CLRI), Chennai has worked as a technical consultant for the monitoring of plant. The MoU was signed between MNES, TIL and CLRI in this behalf.

The process involves treatment of shaving dust/ trimmings with alkali at an high temperature and isolating the inorganic. These inorganics are treated with H_2SO_4 and the chrome is recovered as Basic Chrome Sulphate (BCS).

Wet blue is being 85% collagen and 15 % inorganics. Collagen is extracted by hydrolysis and used for anaerobic digestion.

Salient Features:

Solid waste treated	-	Chrome leather waste
Plant capacity	-	700 T/Yr.(Per day?)
Digester effective volume	-	240m^3
Feed rate	-	10-15 m^3/d
Biogas production	-	approx. 200 m^3/d(per tonne?)
HRT	-	16-24 Days
Efficiency of digester	-	60%
Chrome recovery	-	99%
BCS recovery	-	1-1.5 T/month
Power consumption	-	60 kWh/day

The canteen, which prepares food for 1500 employees, uses the biogas generated. This is one of best plant operated and maintained by TIL.

xiii) Biogas Plant at Biogas Plant at Shirdi Devasthan

Capacity : 105 m^3 per day
Location : Shirdi
Type of waste : This plant is actually for treatment of human waste. Some part of food waste is also mixed

Shirdi a small village has come up as new pilgrimage place on national map in last 25 years. It is well known for Shirdi Saibaba Temple. There are regular devotees visiting Shirdi. The floating population in Shirdi is from 2000 to 25000 on holidays and even in lacs on some occasions. There is a devasthan committee headed by nominee of Charity Commissioner. Being small village pilgrims were facing various problems during their stay or en-route to Shirdi. The committee decided to construct 'dharamshala', the lodging for visitors. There is one of the largest toilet complexes in world having 256 toilet blocks. But there was a problem of disposal of sewage as there was no drainage line or STP. There fore decided to set up a biogas plant on human excreta and generate a electricity.

M/s. Sulabh International has installed the plant and commissioned in 1997. MNES,GOI and (Maharashtra Energy Development Authority) MEDA have funded the plant. The plant is having 3 digesters of 35m^3 capacity treating 105 m^3waste per day. The electricity generation is 20KVA. The plant is operated and maintained by Dr. Mhapuskar of M/s. Sulabh International.

xiv) Biogas Plant at Biogas Plant at Dakor Biogas Plant

Capacity : 2.0 TPD
Location : Dakor ,Gujarat
Type of waste : Animal Waste (Cow dung)

Dakor is also a devotee place in Gujrath near Anand. The devasthan is having a 'Goshala' accommodating around 500 cows. The cow dung is easily available for biogas plant. There are 3 digesters of 40 T capacities. The digested slurry is used for vermin composting where manure is produced.

They also have a 'Bhojanalaya, where food is served and a lodging facility is provided for visitors. There is another small biogas plant working on food waste and human excreta.

The plant is designed and constructed by M/s. Aryan Associates, Baroda. They also operate and maintain the plant at the cost of manure produced in the plant.

xv) Biomethanation Plant (60TPD) of M/s Al-Kabeer Exports Pvt. Ltd. At Rudraram Village Patancheru Mandal in Medak Distt.(Andhra Pradesh)

Capacity:
Location: Medak
Type of waste: Animal Waste & slaughter waste

M/s Al-Kabeer Pvt. Ltd. has set up a modern integrated meat processing unit at Rudraram Village (35 km from Hyderabad) Patancheru Mandal in Medak Distt. of Andhra Pradesh in the year 1993 with the slaughtering capacity of 1500 sheeps and 500-800 buffalos per day. This is a 100% export oriented mechanized slaughtering unit. The slaughter house processes generate 1400 m^3 of liquid and 60 tons of solid waste per day. The waste water treatment plant consisting of UASB reactor generates about 1800 m^3 of biogas 500 kg of bio sludge per day. The high rate biomethanation plant for solid waste generates 2600$m^3$of biogas to generate electricity and 7 tons of bio manure and reduces the green house gas emission to the atmosphere.

Biogas Digester and the Gas holder

This is the full scale demonstration plant for energy recovery from solid waste of abattoir in India based on high rate biomethanation technology developed by Entec, Austria and adopted to Indian conditions with international collaborattion. The gas engine is installed to generate electricity from the biogas generated from liquid and solid waste treatment plant. It is used for generating steam to use in the meat processing unit as well as to maintain the temperature for operator the digester under mesophilic conditions. Adoption of biomethanation technology has resulted in saving of furnace oil as well as chemicals used for treatment of wastewater. The sludge from the anaerobic digester is dried and is being marketed as a nutrient rich soil conditioner.

The demonstration plant of biomethanation process for solid wastes is built with active co-operation and sponsorship of Ministry of Non-conventional Energy sources (MNES), Govt. of India, United Nations Development Programme/Global Environment Facility (UNDP/GEF), Al-Kabeer Exports Pvt. Limited through the technology partnership with Entec Austria, Enkem Engineers Pvt. Limited Chennai and Central Leather Research Institute, Chennai. The plant is commissioned in November 2001.

Salient Features of the Plant:

Capacity of the biomethanation plant	60TPD
Number of digesters	One
Volume of the anaerobic digester	2250 m^3
Type of anaerobic digester	Single-phase, highrate Biomethanation reactor with biogas induced mixing arrangement (BIMA)
Temperature of the digester	33^0c – 38^0c
HRT of the digester	25 days
TS feed rate	7750 kg/day
VS feed rate	5425 kg/day
Organic loading rate	2.46 kg/m^3/day
Designed percentage of VS destruction	55%
Designed specific gas production	0.82 m^3/ kg of VS destroyed
Biogas generation	2600 m^3/day
Process control	Automatic microprocessor based programmable logic control (PLC) system
Auxillary power requirement	420 KWh/day
Electrical energy equivalent of biogas generated	5000 KWh/day
Bio manure generated	7 tonnes/day
Type of gas holder and volume	Membrane type 500m^3
Cost of the Project	Rs. 3.75 crore

Comparison of Small Capacity Plants Biomethanation plants (1.0 TPD and less):

The comparison of small capacity plants i.e. less than 1TPD is carried out for select plants because these plants have same raw material as biodegradable canteen waste.

Details	Bajaj Auto Indus. Biogas Plant	Kirloskar Oil Engines biogas Plant	BPCL biogas Plant	Mahindra and Mahindra ltd. biogas Plant
Plant Capacity	0.50 TPD	0.30 TPD	1 TPD	0.80 TPD
Running at	0.50 TPD	0.30 TPD	1 TPD	0.60 TPD
Area	100 sqmt	100 sqmt	900 sq mt	100 sq mt
Technology Provider	Mailhem Engg. Pvt. ltd	Mailhem Engg. Pvt. Ltd	Aryan Associates	Mailhem Engg. Pvt. ltd
Implementing agency	Mailhem Engg. Pvt. ltd	Mailhem Engg. Pvt. Ltd	Aryan Associates	Mailhem Engg. Pvt. ltd
Date of commissioning	1997	Dec'2004	2001	1999
Raw Material	Biodegradable canteen waste	Biodegradable canteen waste	Biodegradable canteen waste	Biodegradable canteen waste
Manpower	2 persons	1 person	7 persons	2 persons
Biogas Produced	43 m^3/day	24 m^3/day	85 m^3/day	80 m^3/day
Total Electricity Consumption(Per tonne consumption)	8 units/day.	8 units/day	12 units/day	30 units/day
Manure output(per tonne)	0.015 TPD	0.010 TPD	0.4 TPD	0.02 TPD
Water input ratio	1:1	1:1	1:1	1:1
Retention Time	28 days	28 days	20 days	28 days
Estimated Cost	5.75 lacs	4.5 lacs	29 lacs	8 lacs
Area per TPD	**200 sq.m.**	**333 sq.m.**	**900 sq.m.**	**125 sq.m.**
Cost per TPD	**Rs.1.15 Million**	**Rs.1.5 Million**	**Rs.2.9 Million**	**Rs.1.0 Million**

Limitations of Technology: Biomethanation:

a) Being biological process highly sensitive to the shock loading during the initial phase of commissioning.

b) Biomethanation being anaerobic decomposition process needs rigorous monitoring of the following parameters for its optimal operation.

c) Regular monitoring of pH

    i. Alkalinity
    ii. Volatile acids
    iii. Rate of gas generation
    iv. Gas Composition
    v. The raw material should avoid strictly the unwanted components of MSWb i.e. the segregation of the MSW is to be practiced thoroughly.

d) The capacity of Biomethanation units is recommended for a maximum capacity of 30 TPD. Preferably the Biomethanation units are in a set of two or three units as required for better operation.

e) The end uses of the methane gas generated is for Gas supply as cooking gas to near by canteen / restaurants / similar setups as a supplementary fuel. While using the gas as fuel for electricity generation, the recommended electricity generators should be equipped with modern control devices as microprocessor controls for gas quality, quantity, pressure and temperature etc.

f) During the construction of all units of Biomethanation the metallic units and slurry and gas carrying pipes, metallic components of digesters should be of corrosion resistant material. The concrete used must make use of corrosion resistant / sulphate resistant cement.

g) Odour nuisance: The transport of MSW to the unit will generate unpleasant odour. To minimize the odour nuisance, MSW should be covered during its transport and enclosing the MSW segregation operation, and unloading platforms and other units prior to the digestion. Location of the treatment plant is to be kept on the downwind side and preferably away from the residential areas.

2.2.2 Composting:

Decomposition and stabilization of organic waste matter is a natural phenomenon. Composting is an organized method of producing compost manure by adopting this natural phenomenon. Compost is particularly useful as organic manure which contains plant nutrients as well as micro nutrients which can be utilized for the growth of the plants.

Composting can be carried out in two ways i.e. aerobically and anaerobically. During aerobic composting aerobic micro-organisms oxidize organic compounds to Carbon dioxide, Nitrite and Nitrate. During anaerobic process, the anaerobic micro organisms, while metabolizing the nutrients break down the organic compounds through a process of reduction. The gases evolved are methane and carbon dioxide.

There are two types of aerobic composting viz. aerobic bacterial composting and vermi composting.

A) Aerobic composting

In this method, the organic materials are separated from MSW and are subjected to bacterial decomposition; the end product remaining after dissimulatory and assimilatory activity is called as 'HUMUS'.

Processing method

The method involves controlled conversion of city garbage (MSW) into organic fertilizer through two stages -1) a biological process for decomposition of MSW and 2) a mechanical process for screening the decomposed organic matter.

The garbage received is arranged in heaps of, five cu.m., sprinkled with specially prepared mixture of bio-enzyme and herbal extracts. The garbage becomes odor free within couple of hours after spraying and encourages multiplication of the desirable aerobic bacteria, which helps in speedy decomposition of organic waste. Then the waste is stacked in 50 to 100 m long windrows of about 5 m width and 2 m height. Due to exothermic reaction, the temperature inside the heap reaches 70 to 75^{0}c within 48 hours. The heat generated kills the pathogens and ensures accelerated decomposition. Measuring inside temperature of heap and moisture content monitors the progress of the composting. About 50 to 60 % moisture content is maintained by spraying water. Turning the windrows once in week does the aeration.

As the decomposition progresses, the organic bio mass changes color to dark brown humus like substance and its volume is reduced by 35 to 45%. Decomposition or stabilization is accomplished in 4 to 5 weeks.

The stabilized compost is heterogeneous in nature having impurities of various shapes, sizes and texture. Hence mechanical process is required for screening out the digested organic matter in pure and powder form. This is done with the help of mechanical and gravity separators as also with grading and sieving machines. Inorganic and non-biodegradable material like plastic, metals, rubber, stones, bricks, etc. are recovered for recycling/ reuse purpose. The other remnants about 15% of original volume which are non-recyclble are disposed off for sanitary or low lying landfills.

Fully matured and stabilized organic compost/manure is recovered. Quality control is done for chemical nutrients and microbial counts. If required, it is enriched with nutrients and various microbes like Azetobactor, Rhyzobium etc.The product is finally weighed and bagged.

Process Microbiology

During the aerobic composting process, a succession of facultative and obligate aerobic microorganisms is active. In the phases of the composting process, mesophilic bacteria are the most prevalent. After the temperatures in the compost rise, thermophilic bacteria are predominate, leading to thermophilic fungi, which appear after 5-10 days. In the final stages or in the curing period actinomycetes and molds appear. Because significant concentration of these microorganisms may not be present in some types of biodegradable waste e.g. newspaper, it may be necessary to add them to the composting material as an additive or inoculum.

The microbiology of all aerobic composting process includes moisture content, C/N ratio and temperature. For most biodegradable organic waste, once the moisture content is brought to a suitable level (50-60%) and the mass is aerated, microbial metabolism speeds up. The aerobic microorganisms, which utilize oxygen, feed upon the organic matter and develop cell tissue for nitrogen, phosphorous and some of the carbon and other required nutrients. Much of the carbon serves as the source of energy for the organisms and is burned up and respired of CO_2. Because organic carbon serves both as a source of energy and cell carbon, more carbon is required than nitrogen.

Conditions required for proper working of aerobic composting

1) Aeration

It is important to ensure that oxygen is supplied throughout the mass and aerobic activity is maintained. During the decomposition, the oxygen gets depleted and has to be continuously replenished. This can be achieved either by turning of windrows or by supplying compressed air.

2) Moisture content

The composting mass should have certain minimum moisture content in it for the organisms to survive. The optimum moisture content is known to be between 50 to 60 %.

3) Temperature

Under properly controlled conditions temperature rises beyond 70^0c in aerobic composting. This increased temperature results in increased rate of biological activity and hence results in faster stabilization of the material. The temperature range of 50^0 to 60^0c is optimum for nitrification and cellulose destruction.

4) C/N Ratio

The organisms involved in stabilization of organic matter utilize about 30 parts of carbon for each part of nitrogen and hence an initial C/N ratio of 30 is most favorable for composting. Whenever the C/N ratio is less than the optimum, carbon source such as straw, saw dust, paper are added while if ratio is to high, the sewage sludge, slaughter house waste, blood etc. are added as a source of nitrogen.

Important Factors Required For Aerobic Composting Process

S. N.	Item	Comment
1	Particle Size	Should be between 25-50mm
2	Seeding and Mixing	Composting time can be reduced by seeding with partially decomposed solid waste of about 1-5% by weight. Sewage sludge can be added to prepared solid waste.
3	Mixing and Turning	To prevent, caking and air channeling material in process being composted should mixed for uniform distribution of nutrients and microorganisms and turned regularly for maintaining the aerobic activity.
4	Air Requirement	Air with at least 50% of initial oxygen concentration remaining should reach all parts of composting material for optimum results.
5	Moisture Content	Moisture content should be between 50 to 60% during the composting process and optimum being 55%.
6	Temperature	The optimum temperature for biological stabilization is 45 to 55^{0}C. For best results it has been found that temperature should be maintained 55^0 - 60^{0}C for remainder of the active composting period. If temperature rises above 65^{0}C the biological activity can be reduced.
7	C/N Ratio	Initial C/N ratio (by weight) should be 35-50 for optimum results. At low ratios nitrogen is in excess and will be given as ammonia. Biological activity is also impeded at lower ratios. At higher ratios nitrogen may be limiting nutrient. After composting C/N ratios for most of the MSW will fall below 10-20
8	pH	pH should not be raised above 8.5 to minimize the loss of nitrogen in the form of ammonia. It should be between 5-7
9	Control of Pathogens	It is possible to kill all the pathogens weed and seeds during composting and to do this the temp must be maintained between 60-70^{0}C

2.2.2.1 Plants identified for study:

1. Vijayawada Municipal Council, Vijayawada, AP
2. CCI, Mumbai
3. M/s Excel Industries; Mumbai.
4. Bio Composting Project, KDMC.

1. Study of 125 TPD Composting Plant installed for Vijayawada Municipal Council at Ajitsingh Nagar, Vijayawada (AP) based on Municipal Solid Waste

M/s Excel Industries Ltd. Mumbai, the pioneers of Agro chemicals and Industrial chemicals have developed cost effective technology for solid waste management. Years of research and pilot scale trials have resulted in development of this eco friendly technology. The technology being economically feasible for commercial adaptation, many municipal corporations have adapted the technology.

Plant at Vijayawada has been commissioned in 1996 for Vijayawada Municipal Council (VMC) and has been operating at full capacity.. The Vijayawada city having population of 15 lacs generates 400 Tons of waste daily. This plant treats 125TPD of waste converting to compost. The plant is spread over an area of 8 acres. The capital cost of plant and machinery excluding land is Rs. 30 Million.

Waste processing Unit

MSW loading on Conveyor

Salient Features:

The machinery and power requirement is as under

A] Preparatory section:

1) Feeding Belt conveyor - 3 HP
2) 35mm and 16mmm tromel (Rotary screen) - 20 HP

3) Bucket elevator (1) - 3 HP

4) Bucket elevator (2) - 3 HP

5) Belt conveyors 2 nos. - 2HP (1HP each)

6) Out going conveyor - 3 HP

B] Finishing section:

1. Drag conveyor - 3 HP
2. Bucket elevator (1) - 5 HP
3. Vibro shaker - 3 HP
4. Reject conveyor (1) - 2 HP
5. Stone separator - 3 HP
6. Reject conveyor (2) - 1 HP
7. Bucket elevator (2) - 3 HP
8. Crude conveyor - 3 HP

Other machinery:

1. JCB – front end loader - 2 nos.
2. Bobcel – Dozer - 1 no.

Manpower at Vijayawada plant:

Permanent staff on Excel industry roll - 10

Daily labor - 30

MSW after sanitization process being observed carefully by Srinivas Kasulla (MEDC)

End product obtained after Mechanical process

Observation

- Waste brought to site was mixed garbage including plastic, thermacol, tree cutting, coconut shells, mattresses, rubber sheet waste from foot wear industry, plastic bottles, debris, etc.
- Waste was inoculated with sanitreat and bioculum as soon it reaches site.
- There was no foul smell, no flies and birds observed.
- Spraying of inoculums was done manually.
- Turning of heaps/windrows was carried out by JCB.

- The composting platform was concreted completely to avoid the seepage of leachate and thereby preventing contamination of under ground water. This platform is open to sky.
- Rag pickers were observed collecting recyclable items from windrows and from screen rejects in mechanical process section.
- Mechanical process section is covered with roof.
- Plant operates in three shifts and produces 10 TPD of finished product per shift i.e. 30 TPD per day.
- In monsoon no waste is received and mechanical process section is shut down for maintenance.
- Preventive/routine maintenance includes oil change, motor servicing, belt change, etc.
- There is 16 % yield, 50 % decomposition and moisture loss, 34 % rejection

Comments : Vijaywada municipal council aerobic compost plant

- Land required for processing waste is more or less same as required by biomethanation .?
- More waste cane be treated if segregated waste is processed.
- Plant gets disturbed in the in monsoon season.
- Plant is maintained properly. Plant was in operation during study period.

2. Cricket Club of India, Churchgate, Mumbai.

The Cricket Club of India is situated at Churchgate, Mumbai, generates canteen waste of 200 Kg per day. M/S Excel has provided the aerobic treatment facility for the waste generated.

Salient features:

Waste type	: canteen/ hotel waste
Waste generation	: 200 kg / day
OWC machine	: 100 kg capacity
Processing shed	: 21 compost beds
Total period	: 21days
Manure use	: Lawn, garden.
Manpower	: 2 laboratorys.

Observations:

- Machines are suitable for cooked and uncooked canteen waste.
- Initial cost of machine is high.

- High power consumption.
- Recurring cost is more i.e. about Rs. 2 per kg of waste processed.
- Stock of saw dust, bioculum and biosanitizer is required.

3) Organic Waste Converter (OWC) developed by Excel Industries Ltd., Environ ; Biotech Division, Jogeshwari, Mumbai.

Excel Industries Ltd. is basically involved in manufacturing of pesticides and herbicides required for crop and farming/ agricultural application. Their Environ- Biotech division is engaged R & D of products for pest control and odor control. It had set up a plant for o composting of MSW in Mumbai, at Chincholi bunder dumping ground at Malad. They were engaged in aerobic composting of MSW especially vegetable waste, producing manure known as 'CELLRICH', the trade name. However this project had to close down due to improper segregation of waste leading to lower than expected production of manure.

Excel Industries has now developed a compact machine called 'Organic Waste Converter' (OWC) for processing small quantities of waste. The machine fabricated in stainless steel consists of a closed drum in which mixing arm and cutting blade are rotated with the help of motor. Automatic control panel for time control and motor operations is provided. The waste is loaded from top opening, motor is run for specific time duration and homogeneously mixed material is obtained from bottom opening. The machine accepts vegetable waste of 75 to 100 mm size and cutting blade makes pieces of size 5-10mm.

The cooked food waste contains moisture on higher side than uncooked vegetable waste. To reduce moisture, saw dust/ waste paper and dry manure is added. The proportion is maintained at 25kg waste: 2.5 kg saw dust/ paper: 2.5 kg dry manure. Also bio-culture of about 1 gm/kg of waste and organic odor removal additive is added. After mixing for 10-15 minutes uniformly, mixed and sized waste is taken out and transferred to storage beds/ tanks in shed for further process of composting. The composting process is completed within a period of 10-15 days depending upon type of waste either cooked or uncooked waste. During this period of composting moisture content up to 40-50% is maintained by sprinkling water. After composting it is sun dried for 3-5 days wherein moisture content of 15-20 % is maintained in the finished product i.e. manure. Finally it is packed in bags and stored in shed for further disposal. There is yield of about 40%. It is used for kitchen garden, landscaping, etc.

The waste also can be converted to fuel pallets called refuse derived fuel (RDF). After mixing it is matured for 2-3 days in shed and then sun dried for 3-5 days. Sun dried waste is compacted to form pallets which are used as fuel for various applications.

The OWC machines are available in different models. The model No., power required, capacity and cost are as in below given table.

Model	Cost	Power	Segregated organic waste capacity
OWC 60	Rs. 5.00 lacs	4 HP	20kg per batch/ 500 kg per day per shift
OWC 130	Rs. 6.10 lacs	8 HP	50kg per batch/ 1000 kg per day per shift
OWC 300	Rs. 9.60 lacs	13.5 HP	120kg per batch/ 3000 kg per day per shift

* Batch cycle time is 10-15 min.

The area required for OWC installation and for further processing activity is as under.

Organic Waste Converter	OWC 60	OWC 60	OWC 60
Cabin space for OWC	3m x 4m	3m x 4m	3m x 4m
Open space for processing	40 m2	60 m2	150 m2

Operating cost of the OWC is as under

Model	OWC 60	OWC 130	OWC 300
Max. Org. waste load kg per day per shift	500 kg	1000 kg	3000 kg
Estimate of coverage (no. of families)	1000	2000	6000
Waste treatment per month	15000 kg	30000 kg	90000 kg
Minimum Billing Rs. Per month	30000	60000	180000

- Family means unit of 5 persons generating waste 100gm/capita/day.
- The cost of treatment come Rs. 2/- per kg of waste treated including electricity, bio-culture, additive, saw dust and manpower, etc.

Comments

- Organic waste converter machine developed by Excel Industries is used for processing of waste. The cost per kg of waste treated is high as use of saw dust, bioculum and sanitizer is recommended. This is not suitable for large quantity of waste. This machine is suitable for industry canteens, hotels, clubs and housing society etc. The area requirement is also large as 21 no of beds are required. The compost obtained is used as manure. Plant is maintained properly and was in operation.

- Being a higher capacity plant overall land requirements are more but per ton land required for processing compare to biomethanation is more or less equal.
- More yields can be obtained if segregated waste is processed.
- Working schedule of the plant is disturbed in monsoon season.

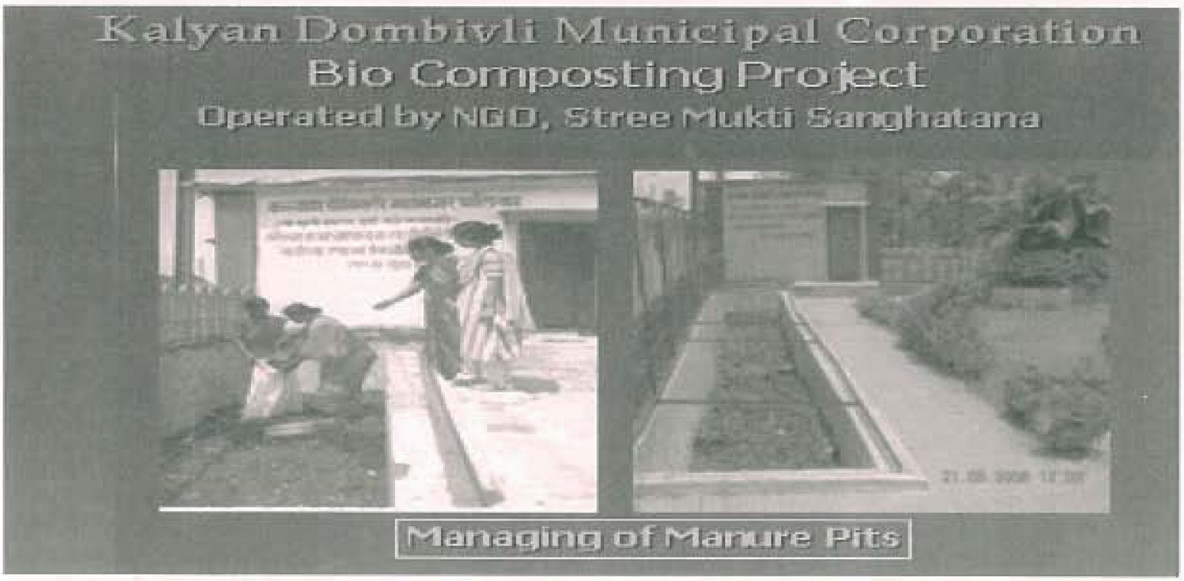
4). Bio Composting Project (Kalyan Dombivli Municipal Corporation)

Salient features:

Waste type	: Mixed Market Waste
Waste quant processed	: 1000 kg / day
Wet waste	: 1000 kgs/day
Dry waste	: 200 kgs/day
Process Used	: Bio composting
Cost	: 2 lacs for civil works.
Operated By	: Stree Mukti Sanghatana

In order to comply with the Municipal Solid wastes (management and handling) Rules, 2000, Bio composting project was executed on 1st Novemeber, 2004 at Talkoswadi, Dombivli which is operated by NGO, Stree Mukti Sanghatana, Mumbai.

Daily 1.2 tonnes of Solid waste is involved, of which 1 ton of wet garbage is utilized for Bio composting and remaining 0.2 tons of dry waste is disposed off after segregation. This project is running successfully since laste 2 years. Approximately 360 tons of waste is being processed per annum. Quality manure is used by Horticulture Department of KDMC for gardens. TO run this project KDMC is paying Rs. 8000/- per month to the concerned NGO.



- As the project is eco-friendly there is no bad odour, t is accepted by the surrounding locality. Space saving at dumping ground.
- Considerable savings of approximately Rs. 1.5 lac p.a. in Transportation.
- Employment generation of ragpickers.
- Area beautified and environmental benefits.
- Easy to replicate and no complicated technology and hence easy for operation. (since the quantity of waste processed is less).

Composting for small / residential setups:

Composting is a method of processing biodegradable waste by using Bioculture. This method is ideal for residential complexes.

Composting pits of size 1.6mx1mx0.6m are set up for processing biodegradable waste. On an average, for a housing complex, a set of three such pits is required for 100 families. Average cycle time is 21 days. For successful composting, segregation at household level is very important

Limitations of Technologies: Aerobic Composting:

a. Large area is required for aerobic composting.

b. Odour is a nuisance in aerobic composting as large amount of waste (unsegregated) i.e. MSW is handled at site open to atmosphere.

c. After sieving the decomposed waste the unused part of MSW needs segregation for proper recycling and or disposal of various components of MSW.

d. During sieving the rainy season, the odour and the runoff generated from the MSW site creates pollution.

B) Vermi-composting

Vermi compost is the dropping of the earthworm after the intestinal digestion of the organic matter. These dropping are high in nutritive value and high-grade organic fertilizer. This helps in growth and multiplication of beneficial microorganism by creating favorable environmental conditions.

Vermi composing is a bio-oxidation and stabilization process of organic matter that involves the joint action of earthworms and bio-organism. In his process the organic waste gets breakdown and fragmented by earthworms resulting in a stable non-toxic material with good humus material that can be used as a soil conditioner. The earthworms are in fact, used in this process as the agents for turning fragmentation by earthworms resulting in a stable non toxic material that can be used as a soil conditioner. The earthworms are in fact used in this process as the agents for turning fragmentation and aeration. In this process it is absolutely necessary to segregate the Municipal Solid Waste (MSW). Earthworms require moist conditions and hence a large quantity of water is required in this process. The tree shed is also necessary. No water logging is permitted.

Type of earthworms

There are over 4000 species of earthworms identified till date. These are primarily divided into three groups.

1) **Epigeic** :These are litter dwelling, feed on highly organic materials. They live in upper part of the soil i.e. 30-45 cm deep where large quantity of degradable organic matter is present. Species : Eisonia Foetida, Eudrelus Eugeniae & Perionyx Excavatus.
2) **Endogeic :** These are, deep soil earthworms, need less organic matter. These are observed in monsoon.
3) **Anecic:** These are burrowing, soil dwelling earthworms. These earthworms stay in under ground network of tunnels. They collect feed from top and take deep. They eat soil along with organic matter. There fore mixing of soil takes place. Species: Pheretima Elongata

"Eisonia Foetida, Eudrelus Eugeniae & Perionyx Excavatus are the commonly used earth worms for vermin composting. "

Process of Vermi composting

Vermi composting can be done at any scale household composing food waste in a large slotted plastic bin outside the kitchen window, to the city scale vermi - composting. Household level vermin composting can easily be done on just 0.2 sq., m. for a family of five whereas large scale vermi-composting require 2.5 to 3.5 hector of land for 100 TPD of garbage to be treated. Here unlike aerobic composting, unsegregated waste cannot be used for vermi-composting as toxic substances can kill the earthworms. Only segregated wastes or domestic food waste can be composed through this process.

Incoming biodegradable waste preferably collected from the markets and domestic food waste collected from house to house, is first heaped in the compost yard. Thereafter partial composting of waste is carried out. To expedite the process of decomposition of waste private entrepreneurs prefers strong befouling and degrading culture. The heap of waste is turned after about a week for aeration and allowed to cool. Moisture level of 30 to 40% is maintained and the temperature in the range of 25 to 35 degree centigrade. Garbage heap attains this temperature in about 2 weeks time when it is transferred to the vermi-composting pits or shed for further processing.

Vermi pits are generally made having a maximum depth of about 0.6m Width of 1.5 to 2m and can have any suitable length. In the pit bottommost layer of 10 cm thickness of baggase, coconut coir or saw dust is given on which second layer of 10cm thickness of decomposed cow dung is spread. The earth worms at the rate of 4000-5000 nos. or 1 kg per sq.m. areas are inoculated. Above this partially decomposed organic matter is filled up to top of pit. The pit is covered with gunny bag or rice husk. The water is sprinkled on it daily to maintain the moisture.

The earthworms eat the organic waste and vermi castings start getting deposited on the surface of the heap. The harvesting of vermin casting starts from the 40th day from receipt of garbage and 28th day of the introduction of the earthworm. The harvesting continues for about 15 days by which time most of the garbage gets composites. The vermin castings collected are sieved by using simple sieves.

The waste which is left behind un composed is allowed to remain in the vermi pits at the same place and fresh waste is added as per the cycle and over a period of time the portion of waste which did not get composted in first round get composted in the subsequent rounds along with the other waste. The end product looks like fine granular soil and it has good acceptability in the market.

Conditions required for proper working of pits.

1. **pH :** pH should be within range of 6.8 to 7.5.
2. **Temperature :** Optimum temperature required for vermi composting is 25-35°C.
3. **Moisture content :** Earthworms require moisture of about 30 to 40 % for their growth and reproduction. So vermi composting should be done nearer to a source of water.
4. **Toxicity :** Earthworms are very sensitive to heavy metals and toxic substances or pesticides as these can poison the worms. Hence the market waste or food waste shall be kept free of heavy metals and toxic substances.

2.2.2.2. The plants identified for study:

1. Tata Motors, Pimpri Chinchvad
2. PCMC, Pune
3. Orchid Ecotel Hotel, Vile Parle
4. Clean Air Island; Colaboratorya
5. Essel World; Malad
6. PWD Quarters; Bandra
7. Rodas Ecotel Hotel; Hiranandani Powai

1. TATA Motors Ltd. Vermi Compost plant at Pimpri-Chinchwad

TATA Motors Ltd is a company engaged in manufacturing of four wheel vehicles. It is having about 13000 employees working in the factory daily in three shifts. The food is prepared in the factory canteen for these workers daily. About 4.5 TPD of solid waste is generated from the canteens daily. The company has installed a vermi compost plant for the treatment of this waste.

M/s. Energy Tech Solutions Pvt. Ltd. Pune has designed and installed the plant based on Aerobic Vermi Bacterial (AVB) system. The plant installed in two phases. First phase was for treatment of 1.5 TPD waste per day which was commissioned 3 years back. Second phase, of 3.0 TPD per day capacity commissioned in Jan'2005. The second phase cost is Rs. 5.0 lac.


Vermi Compost pits at TATA Motors – Pimpri chinchwad

Salient features of the plant:

A) Capacity - 4.5 TPD per day

B) Type of waste - Canteen waste

C) Area Required - 2250 sq.m.(0.5 sq.m. per kg of waste processed)

D) Size of pit - 17m long, 4m wide, and 0.6m deep.

E) Cost - Rs. 1.5 lac per TPD

F) Man power - Labours - 5 nos. ; Supervisor - 1 no.

G) Water and electricity provided by TATA Motors.

Observation:

There is no nuisance due to smell. Deep burrowing worms like *Pheretima Elongeta* are used in the process. The waste is stabilized in 7 to 10 days. 15 to 18% yield is observed. The plant is operated by laboratorys only. The vermi compost produced is sold as soil enriched to use in the farms. The plant is maintained properly and was in operation during the visit.

Comments:

Plant is maintained properly. It was in operation during visit.

2. Pimpri Chinchwad Municipal Corporation (PCMC) vermi compost plant at Moshi, Pune .

PCMC Corporation is having the largest number of industries in their jurisdiction. Industrial areas like Bhosari, Nigadi, Akurdi, Pimpri- Chinchwad comes under PCMC. The total MSW generated in the area is about 350 TPD per day out which 100 TPD is biodegradable. The hotels in the area generate about 5 TPD of bio degradable waste per day. The corporation has installed vermi composting plant for the treatment of this waste.

M/s. Energy Tech Solutions Pvt. Ltd. Pune has designed and installed the plant based on Aerobic Vermi Bacterial (AVB) system. The plant installed in two phases. First phase was for treatment of 2.3 TPD waste per day which was commissioned in 2002. Second phase of 2.7 TPD per day capacity commissioned in Jan'2006. The second phase cost is Rs. 4.7 lac.

Vermi compost pits at Pune

Salient features of the plant:

A) Capacity	- 5.0 TPD per day
B) Type of waste	- Hotel waste
C) Area Required	- 2500 sq.m.(0.5 sq.m. per kg of waste processed)
D) Size of pit	- 4m wide, 0.6m deep and suitable length.
E) Cost	- Rs. 1.5 lac per TPD
F) Man power :	- Labours - 6 nos. ; Supervisor - 1 no.
G) Water and electricity	- provided by PCMC.

Observation:

There is no nuisance due to smell. Deep burrowing worms like *Pheretima Elongeta* are used in the process. The waste is stabilized in 7 to 10 days. 15 to 18% yield is observed. The plant is operated by labours only. The vermi compost produced is sold as soil enricher to use in the farms. The plant is maintained properly and was in operation during the visit.

Comments on PCMC plant:

Plant is maintained properly. It was in operation during visit.

3. Orchid Ecotel Hotel, Mumbai

This Hotel is located near international airport at vile parle. This hotel practices environmental friendly methods for the disposal of waste generated in their premises. They have vermicompost plant installed in 2001 to treat wste generated from kitchen and restaurant.

Salient features of the plant:

• Type of waste	Canteen waste
• Total waste generated per day	- 380 – 390 kgs/day
• Waste treated by vermicomposting	- 112 kg/day
	- 3360 kgs/month
	- 40320 kgs/year
• Manure produced @ 12% yield	- 400 kg/month
	- 4800 kg – 5000 kgs/year
• Processing period	- 15 days
• Cost of project	- Rs. 1,00,000 /-
• Operation and maintenance cost	- cowdung – Rs.450 + 1 labour – Rs. 4000/-
	- Rs.4450/month
	- Rs. 53400/annum
• Manure cost @ Rs. 4.5/kg	- 5000 x 4.5
	- Rs.22500/annum.
• Area of vermipit	- 9 x 1 = 9 sq.mts.

Comment:

Only part of waste generated is used for vermicomposting and the remaining waste is given to piggery farm. The waste after segregation and shredding is used. Equal amount of cowdung is added to enhance the process. The time required for processing is 15 days. Manure is sold to staff @ Rs. 4.5/kg and the remaining is used in the garden.

4. Colaba Pumping Station - Clean Air Island, Mumbai

This Plant is located at Colaba pumping station, land required for the plant is 2000 sq.m. this land is provided by MCGM. Waste is collected from Crawford market, colaba markets and navy nagar and is processed in the plant. Plant is installed, operated and maintained by clean air islant (NGO)

Salient features of the plant:

• Type of waste	- market waste
• Total waste collected and processed per day	- 5000 kgs/day
• Waste treated by vermicomposting	- 5000 kgs/day - 125 tons/month - 1500 tons/year
• Manure produced @ 22% yield	- 27500 kgs/month - 350 tons/year
• Processing period	- depedingon the waste input (input output cycle is 1 year)
• Cost of project	- Rs. 5.8 lacs
• Operation and maintenance cost	- 9.99 lacs/annum
• Manure cost @ Rs. 12/kg	- 350000 x 12= Rs.42 lacs /annum.
• Resource used per day	
Water	- 1500 ltr/day
Electricity	- 24 units/day
Manpower	- 6 members.

Comment:

Project implemented in a complete eco friendly manner. Environment friendly electric trolleys are used for collecting waste from the markets. There was no stink at the project site. No machines and chemicals are used for the process. Process Cycle time is very long.

5. Pan India Paryatan Ltd. – Esselworld, Mumbai

Plant is located at Esselworld, Gorai. Vermicomposting plant started in the year 2000. Plant is operated and maintained by Pan India Paritan ltd.

Salient features of the plant:

- Type of waste - Garden waste and Organic waste.
- Waste treated by vermicomposting - 190 tons/annum + 70 tons cowdung/annum
- Manure produced - 180 tons/annum
- Processing period - 15 days + 40 days
- Cost of project - Rs.3,16,000/-
- Operation and maintenance cost - 1,40,500
- Area required - 250 sq.mt

Comments:

Space required by the plant is minimum and very well maintained. NPK values of the manure are good compared to MCGM specifications. Since waste generated by two parks is completely treated within the premises hence these parks can be called as zero garbage zones.

6. Government Housing colony, PWD quarters Bandra:

Plant is located at Bandra east, main source of waste in this plant is from residential government colony. This plant is installed, operated and maintained by an NGO – MUKTA.

Salient features of the plant:

- Type of waste - Residential kitchen waste
- Waste treated by vermicomposting - 98.55 tons/annum
- Manure produced @ 10% yield - 10.5 tons/year
- Processing period - continuous 1 year
- Operation and maintenance cost - Rs.30000/month
- Area - 700 sq ft.

Comments:

Deep burrowing earthworms are used for the process and very well maintained. Rock dust is added to maintain the pH and moisture content and foul odor is also controlled by adding the same. Manure produced is utilized within the gardens in the premises. No machinery and chemicals are used in this process.

7. Rodas Ecotel Hotel, Powai , Mumbai

The Hotel is located at Hiranandani housing complex powai.Vermicomposting pit was started in the year 2001 to treat the biodegradable waste generated by the hotel.

Salient features of the plant:

- Type of waste - Hotel waste
- Waste treated by vermicomposting - 100 tons/year
- Manure produced - 69 tons/yr
- Processing period - 15 days
- Cost of project - Rs. 4,50,000
- Operation and maintenance cost - cowdung--Rs.900+2 labour – Rs.5000/- - Rs.10900/month ; - Rs. 1,30,800/annum
- Manure cost @ Rs. 4.5/kg - 69000 x 4.5 - Rs.3,10,500 /annum.
- Total area - 2000 sq.ft.

Comments:

Waste generated in the hotel is processed in this plant. The waste after segregation and shredding is used. Equal amount of cowdung is added to enhance the process. The time required for processing is 15 days. Manure is sold to staff @ Rs. 4.5/kg and the remaining is used in the garden.

Limitations of Technologies: Vermi-Composting:

a) The earth worms are sensitive to the surrounding environment and conditions around the prepared heap such as light, moisture content, temperature etc.

b) The area required for the unit quantity of MSW to be treated is much larger than the area required for aerobic composting. Area required for aerobic composting is 166 Sq.M./TPD of MSW of 300 TPD plant and for vermi composting area required is 374 Sq.M./TPD of MSW waste of 1 TPD plant.

Analysis of Compost, Vermi Compost and Digester Sludge

	Sample Location	pH	Moisture	NO_3-N	P	K
A	Shatabdi Hospital (Biogas digester sludge)	7.48	41.83 %	1.47%	1.92 %	1.0 %
B	Makarand Society (Vermi compost)	7.25	8.95 %	1.33%	0.08 %	0.25 %
C	Colaba Pumping Station. (Vermi compost)	7.86	20.45 %	0.83%	0.35 %	0.85 %
D	CCI, Churchgate (OWC compost)	8.42	48.65 %	1.16%	0.45 %	2.18 %
E	Chennai biogas plant (Biogas digester sludge)	7.48	35.28%	2.20%	1.92%	2.40%
F	Mailhem Vijayawada (Biogas digester sludge)	7.55	30.42%	1.48%	1.76%	1.56%
G	Excel industries Vijayawada (compost plant)	7.35	23.85	1.21%	0.72%	0.78%
H	PCMC (AVB vermi compost)	7.2	28.92%	1.71%	0.68%	0.65%

Specifications for compost as per Municipal Corporation of Greater Mumbai circular dated 29.10.2005

1. pH - 6.5-8.0
2. Moisture content - 25 %
3. Nitrogen - 1 to 2 %
4. Potash - 0.2 to 1.0 %
5. Phosphorus - 0.4 to 1.0 %

Analysis of Anaerobic Digester Sludges

Parameters to be analyzed:

1. pH
2. Volatile matter
3. Alkalinity
4. Volatile acids

Sample collected at:

1. Fresh feed at inlet chamber after mixer
2. Pre digester outlet OR inlet of main digester
3. Outlet of main digester

Date of sample collection: 28.03.2006

Date of analysis: 28.03.2006 to 04.04.2006

Analysis results:

No.	Sampling Point	pH	Volatile matter	Total Alkalinity As $CaCO_3$	Volatile Acids as Acetic acid
1	Inlet chamber	6.96	87.46 %	1820 mg/l	2468 mg/l
2	Pre digeste	6.51	72.51 %	2110 mg/l	9531 mg/l
3	Digester	7.55	57.83 %	1510 mg/l	411 mg/l

Analysis of canteen waste

Type of waste	Av. Moisture content	Av. Volatile matter
Vegetable waste	90.20%	86.56%
Cooked food waste	80.54%	89.34%

Chapter – III

3. Abstract of Preliminary Design and Costing of Treatment Facilities

The preliminary design of the facilities for the treatment of MSW and MSW were carried out using the following details and data.

3.1 Biomethanation

Biomethanation plant of 1TPD, 5TPD and 15 TPD are designed. The following assumptions were made while designing the treatment plant:

- Raw material -Canteen waste
- Moisture content of raw material - 80%
- Volatile matter - 20 %
- Biogas generation - 0.8 m^3/kg of VSS? destroyed/day
- Biogas contains - 60% CH_4 @ 200 mm of water
- Fixed solids - 20 %
- destruction of volatile matter - 60%
- Solids in digested sludge - 5%
- Sludge drying period - 10 days
- Power required for mixing in digester - 8 watts/m^3 of tank volume

T- 3.1: Abstract of 1 TPD Biomethanation plant :

Item	Dimensions	Power	Remarks
Loading platform with grinder	3m x 3m	2.25 kWh	Suitable unloading ramp. 10 mm size particles
Digester with mixer	5.50m dia, 5m deep	3.0 kWh	Fixed roof type. To brake scum & mixing
Gas storage	4.5m x 4.5m x 4m (height)		Rubber balloon in close room.
Sludge drying bed and slurry pump	1 beds of 12mx5.7 m	2.25 kWh	10 days drying cycle. 10 lps discharge.
Sludge storage	3m x 3 m		For 1 month manure.
Office cum laboratory	3m x 3 m	5.0 kWh	
Open space	Approx. 140 m²		For parking and movement.

Actual unit area - 140 sq.m.
Open space - 140 sq.m.
Total - 280 sq. m
Plot size - 20m x 14m
Power requirement - 15 kWh

T- 3.2: Abstract of 5 TPD Biomethanation plant:

Item	Dimensions	Power	Remarks
Loading platform with grinder	5m x 3m	3.75 kw x 5 h	Suitable unloading ramp. 10 mm size particles
Mixing tank & Stirrer	1.73 m dia, 2.6 m deep	1.50 kw x 1h	
Digester with agitator	9.50 m dia, 7.0 m deep	10 kWh	Fixed roof type; To brake scum & mixing
Gas storage	6 m x 12 m x 5.50 m (height)		Neoprene Rubber balloon in close room.
Sludge drying bed and slurry pump	3 beds of 30 m x 6 m	2.25 kw x 1h	10 days drying cycle. 10 lps discharge.
Mechanical Sludge dewatering	4 m x 4 m	3.75 kw x 1h	
Sludge air / sun drying area	10 m x 5 m		
Sludge storage	5 m x 3 m		For 1 month manure storage.
Office cum laboratory	5 m x 3 m	9.6 kWh	
Store room	5 m x 3 m		For spares, chemicals etc
Open space	Approximately 799 m^2		For parking and movement.

Actual unit area - 771 sq. m. (Area with mechanical dewatering, 297 sq.m.)
Open space- 799 sq. m. (Area with mechanical dewatering, 663 sq.m)
Total area - 1570 sq. m. (Area with mechanical dewatering, 960 sq.m)
Plot size - 34 m x 46 m (30 m x 32 m)
Power - 45.85 kWh ≈ 50 kWh

T- 3.3:Abstract of 15 TPD Biomethanation plant:

Item	Dimensions	Power	Remarks
Loading platform with grinder	5 m x 5 m	5.60 kW x 5hr	Suitable unloading ramp. 10 mm size particles
Mixing tank stirrer	2.5 m dia, 3.75 m deep	1.50 kW x1hr	
Digester with agitator	12.2 m dia, 11.50 m deep	28 kWh	Fixed roof type. To brake scum & mixing
Gas storage area	7 m x 14 m x 8 m (height)	-	Neoprene Rubber balloon in close room.
Sludge drying bed and slurry pump	3 beds of 30 m x17 m	3.73 kWx1 hr	10 days drying cycle. 20 lps discharge.
Sludge dewatering machine	4 m x 4 m	7.5 kWx 2 hr	
Sludge air/sun drying area	10 m x 10 m	-	
Dry Sludge storage	5 m x 5 m	-	For 1 month manure.
Office cum lab.	5 m x 5 m	18 kWh	
Store room	5 m x 5 m	-	For spares, chemicals
Engine room	5 m x 5 m	-	
Open space	Approximately 461 m^2	-	For parking and movement.

Actual unit area -	1875 sq. m. (Area with mechanical dewatering, 461 sq.m.)
Open space -	1149 sq. m. (Area with mechanical dewatering, 619 sq.m)
Total area -	3024 sq. m. (Area with mechanical dewatering,1080 sq.m)
Plot size -	36 m x 84 m (30 m x 36 m)
Power -	94.25 kWh ~ 100 kWh

3.2 Aerobic Composting

Aerobic Composting Plant (Mechanical) for Treatment of Municipal Solid Waste :

Wind row yard is to be designed on the following assumptions:

- 500 kg/m^3 as density of raw waste.
- 28 day retention on the windrow yard.
- Size of windrow - 2-3 m high, 4- 5m wide and of any specified length as per availability of land.
- Space between windrow - minimum 5m to enable front end loader to move. Similarly clear space of 5m to be provided at the end of windrows.
- Windrow area should be provided with impermeable base. Such base shall be made of concrete or compacted clay, 50 cm thick having permeability coefficient $< 10^7$ cm/sec. the base shall be provided with 1-2%slope and circled by lined drain for collection of leachate or surface run off and to take it to a sump.

T- 3.4: Abstract of Aerobic Composting

Capacity	150 TPD	300 TPD
Area	40,000 sq. mtr	50,000 sq.mtr
Power Required	1200 kWh	1800 kWh
Manpower	55	80
Project Cost	35 Million	45 Million
Manure Yield	150 kg /T	150 Kg/T
Water requirement	0.40 m^3/T	0.30 m^3/T
Area required per MT	266.67 sq.m/T	166.67 sq.m/T

Above designs are based on Technology developed by Excel Industries Ltd, Mumbai for processing municipal solid waste by Mechanical Aerobic Composting

3.3 Vermi Composting

Vermi Composting Plant for Treatment of MSWb:

Vermi Composting Plant for Treatment of MSWb is designed on the following assumptions:

- Density of MSWb 800 kg/m^3
- Thickness of waste applied per day 6 cm
- Composting period 6 weeks
- Width of vermin pit 2 m
- Yield of manure 15 % to 17 %

T- 3.5: Abstract of Vermi composting for 1 TPD

Capacity	1 TPD
Number of Pits required	7 Pits
Area required for Pits	154 sq.mt
Segregation Platform	1 no. (6 sq.mts)
Office cum store room	16 Sq. mts
Labour room	-
Total Area Required	374 sq .mt
Power required	5 kWh
Water required	2 m^3/day
Manure Yield	15 – 17%
Project cost	5 lacs

T – 3.6 Abstract of Vermi composting for 5 TPD

Capacity	5 TPD
Number of Pits required	35 Pits
Area required for Pits	770 sq.mt
Segregation Platform	3 no. (18 sq.mts)
Office cum store room	96 sq.mts
Labour room	16 sq.mts
Total Area Required	1700 Sq.mts
Power required	9 KWh
Water required	10 m^3/day
Manure Yield	15 – 17%
Project cost	22 lacs

3.4 Cost Analysis

T - 3.7: Comparison of Studied Technologies

SN	Technology for MSWb treated	Area required	Total Area	Total Capital Cost Excluding Land Cost	Operation & Maintenance Cost	Earning from biogas & Manure	Net earnings per annum
		Sq.M/ MT	**Sq.M**	**Million Rs.**	**Lac Rs. Per annum**	**Lac Rs.per annum**	**Lac Rs.per annum**
1	Biomethanation (plz refer to the chapter of Business model for biomethanation plants at a ward level in Mumbai)	-	-	-	-	-	-
2	Aerobic Composting i) 150 TPD plant ii) 300 TPD plant	 266 166	 40,000 50,000	 35.00 45.00	 98.208 163.152	 246.300 492.700	 148.100 329.500
3	Vermi composting i) 1 TPD plant ii) 5 TPD plant	 374 340	 374 1700	 0.5 2.2	 1.530 4.170	 2.740 13.680	 1.210 9.510
* With Mechanical dewatering of Sludge							

T- 3.8: Operation and Maintenance of plants

SN	Technology For MSWb treated	Skilled labour	Semiskilled labour	Unskilled labour	Laboratory Staff	Remarks
1	Biomethanation i) 1 TPD plant ii) 5 TPD plant iii) 15 TPD plant	 1 2 5	 Nil 1 2	 2 3 19	 Nil 1 1	 One Engineer
2	Aerobic Composting i) 150 TPD plant* ii) 300 TPD plant*	 8 10	 15 20	 30 45	 2 5	*One Engineer per shift
3	Vermi composting i) 1 TPD plant ii) 5 TPD plant	 1 1	 1 2	 1 6	 - -	 - -

T- 3.9: Abstract of cost analysis of biomethanation

(plz refer to the chapter of Business model for Biomethanation plants at a ward level in Mumbai)

T- 3.10: Abstract of cost analysis of aerobic composting

Capa city TPD	Power cost Lac Rs / annum	Manpower cost Lac Rs / annum	Bioculture Lac Rs / annum	Sundries 10% of (2 +3 + 4) Lac Rs / annum	O. & M. Lac Rs / annum (2+3+4+5)	Earnings (manure) Lac Rs / annum	Net Earnings Lac Rs / annum
1	2	3	4	5	6	7	8
150	17.28	39.60	32.40	8.93	98.21	246.30	148.10
300	25.92	57.60	64.80	14.83	163.15	492.70	329.50

* based on 100% utilisation

T- 3.11 Abstract of cost analysis of vermin composting

Capacity	Power Consumption Rs / annum	Cost of manpower Rs / annum	Sundries 2 % of (2 +3)	O. & M. Rs/annum (2 + 3 + 4)	Earnings (manure) Rs/annum	Net Earnings Rs / annum
1	2	3	4	5	6	7
1 TPD	6,148	1,44,000	3,002	1,53,150	2,73,750	1,20,600
5 TPD	12,702	3,96,000	8,174	4,17,000	13,68,000	9,51,000

*based on 100% utilisation

Chapter – IV

4 Laboratory, Corrosion Control & Utilization of Bio-gas

4.1 Laboratory facility

Anaerobic processes are very sensitive to the changes in the quality and quantity of raw material and the conditions for which the process is designed.

To have better control over the working of the treatment units, adequate laboratory facilities with qualified personnel are essential.

The laboratory is intended to check the quality of raw material, contents of the treatment units, sludge, and biogas.

The following parameters need to be determined in the laboratory:

- pH
- Moisture content
- Alkalinity
- Solids
- Volatile solids
- Volatile acids
- Biogas composition
- Digested sludge composition

Instruments required for determining the above parameters will include oven, gas chromatograph, pH meter, Muffel furnace, titrators, flame photometer, analytical balance, Orset apparatus, necessary chemicals and glass wares etc.

The working benches should be of suitable heights (0.75 to 1.0 m) with acid resistant tops. Adequate gas, electric power supply and water points must be provided along the benches and services of gas, electricity and water can be fitted against the wall, under the bench work.

The analytical work in the laboratory requires provision of ample window space and fluorescent artificial lighting.

Minimum area of 50 m^2 will be adequate for the laboratory.

The minimum staff recommended is one chemist, one laboratory technician, one sample taker and two laboratoryoratories cleaner.

To optimize the utilization of the laboratory, a centralized laboratory can be set up where samples from various treatment facilities can be analyzed.

4.2 Corrosion Control measures

Anaerobic systems are liable to corrosion very fast because of generation of gases like hydrogen sulfides which is likely to be aggravated under the tropical and humid atmospheric conditions. Utmost precaution needs to taken during the design and operation and maintenance of the treatment plants.

Corrosion can affect the units and in turn efficiency, cost of the treatment project. Use of proper corrosion resistant materials / coatings like use of M-25 grade of concrete with corrosion resistant grade of cement, FRP, Fiber reinforced plastics, PVC, Polyvinyl Chloride, HDPE etc is strongly recommended. This will increase the cost but in long term proves to be economical.

- Reactor Tank / Digester: Use of corrosion resistant materials as stated above
- Distribution boxes: M-25 grade of concrete with corrosion resistant grade of cement
- Bolts and nuts for adjustments: Stainless steel
- Pipes : HDPE,PVC, PE, FRP
- Sludge withdrawal pipes : HDPE,PVC, PE, FRP
- Gas Collectors: Neoprene rubber balloons , Concrete / metallic with proper lining as gas collector
- Digester hoods / covers: With PVC, FRP linings.
- Electrical switches: Located distant from the gas collection / generation with material /contact points resistant to corrosive atmosphere.

4.3 Utilization of biogas

The biogas produced in the biomethanation process contains methane content about 60%, carbon dioxide about 40% and Ammonia, Hydrogen sulfide and moisture in traces. The calorific value of biogas is about 5000k-cal/M^3 and varies with the percentage of methane content. The calorific value of compressed natural gas (CNG) supplied by Mahanagar Gas Ltd. (MGL) in Mumbai at 97.9% of methane content is about 8224 k-cal/ M^3.

The biogas by virtue of its good calorific value can be used as fuel for heating or for power generation through IC engines or steam turbines.

Gas use as fuel

The use of biogas as fuel for cooking or heating is the simpler and cost effective option. It requires the gas to be transported, by a dedicated pipe line, from the point of collection to the point(s) of gas use. A single point of use is most preferable so that pipe line construction and operation cost can be minimized.

Prior to transporting the gas to the user, the gas must be cleaned. Condensate and particulate are removed through a series of filters and or driers. The biogas with minimum 60% methane is generally acceptable for use in wide variety of equipments, including boiler and engines. Generally engines are designed to handle natural gas, which is having 98% methane, the equipment can be adjusted easily to handle the gas with the lower methane content.

Depending upon the pressure and type of material to be transported, the type of pipe material can be selected. Following are the pipe materials and pressure that MGL uses in distribution of CNG in Mumbai.

S. N.	Pipe material	Pressure	Location
1	Carbon steel pipe	38 bar	From GAIL to city gate station
2	Carbon steel pipe	19 bar	From city gate station to District Regulation Station(DRS)
3	PE Medium pressure pipe	4 bar	From DRS to Service Regulation(SR)
4	GI pipe	100 mbar	From SR to Meter control
5	Copper pipe	21 mbar	From meter to appliance valve
6	Rubber hose	21 mbar	From valve to home appliance

District regulation station, Service regulator and meter regulators are the devices used to reduce the pressures as per requirements. All the regulators are designed to suit the pressure and flow/quantity required.

Pipeline injection

If large quantity of gas is produced and no gas user is available, then another option is to inject the gas in nearby pipe line carrying the gas. This requires gas processing so that it is dry and free of corrosion causing impurities. Pipe line injection requires compression of gas to match the pipe line pressure.

Electricity generation

Electricity can be generated for on site or for distribution through local electric power grid. Internal combustion (IC) engines are mostly used for biogas to power generation. There are three types of engines classified on fuel they use.

1. Diesel engines,
2. Gas engines and
3. Duel fuel engines.

Diesel engines operate purely on diesel as its fuel while gas engines are designed to work on natural gas. The duel fuels engines operate on either of fuel i.e. diesel or gas.

Generally the duel fuel or gas engines are designed to operate on natural gas as a fuel with high calorific value. These engines need modifications in carburetor and intake manifold to handle the lower quality gas other wise there will be less efficiency. These are stationery engines that can use medium quality gas to generate electricity.

The rating of the gas engines is given on the basis of calorific value of natural gas. e.g. 125 kVA/100 kW gas engine will consume 37 m^3/hr of natural gas having its LCV 36.117 MJ/std.m^3. The biogas with methane content of about 60% and having calorific value of about 5000 k-cal/m^3(20.92 MJ/std.m^3) may give only 55% efficiency.

The engines for biogas can be tailor made depending upon composition of gas. Such engines will give higher output than readily available engines used for natural gas.

The sulfur content in the biogas should not exceed 0.1% (1000 ppm) to avoid corrosion. If more sulfur is present than prescribed, then its removal is necessary. There are engines designed with anti corrosive lining, but are more costly.

The gas should be perfectly dry, clean and free from liquid hydrocarbons, foreign particles, dust, etc.

For gas engines low compression ratio should be selected, when any one of the composite gas exceeds its permissible limit.

Rating and diesel substitution depends on gas composition. The pressure required near engine skid is 15 to 20 psig.

There are various manufacturers of gas engines in India and abroad like Kirloskar Oil Engines Ltd., Cummins Power Generation, Greaves Cotton Ltd., FG Wilson Engineering Ltd., etc. These are available in the range of 100 kW to 500 kW costing between Rs. 7.5 lacs to Rs.65 lacs.

Though the initial cost of gas engine seems high, pay back period is early.

Gas engines are having following advantages;

- Lowest running cost.
- Complete and particulate free combustion.
- Low emission.
- Longer service life.
- No dilution of lube oil.
- Compact size.
- Easy paralleling.

- No fuel storage and handling.
- Extended lube oil and filter change period.

Economics of power generation:

- Diesel as fuel
- Fuel cost - Rs. 35 per liter.
- Power generation - 3.5 units/liter (approx.).
- Cost per unit - Rs. 10/-
- Biogas as fuel
- Fuel cost - no fuel cost, only operation and maintenance cost at Rs. 2 per unit produced.
- Net saving on fuel is Rs. 8/- per unit produced for captive use.
- Assume efficiency of biogas engine as 50%.
- 100 kvA/80 kW genset will produce 40 units / hr.
- Assume operation for 8 hrs a day, 25 days in a month and for 12 months in a year.
- Saving on captive consumption = 8 h /day x 40 units / hour x Rs. 8 /Unit x 25 days x 12 months = Rs. 7, 8,000/- per year.

Revenue generation

If power produced is sold at the rate of Rs. 4/- per unit and assuming Rs. 1/- expenditure against operation and maintenance.

Revenue =

Rs 3 per unit x 40 units per hour x 8 h x 25 days x 12 months = Rs. 2, 88,000/-. Per year

Chapter – V

5 A Business Model for Bio Methanation Plants at Ward Level in Mumbai

Rationale:

With rising prices of and rising pressure on land use in Mumbai as well as rising cost of transportation and increasing congestion, it has become imperative and urgent to look at the issue of solid waste management in a holistic manner. Higher income levels and changing life style are leading to a rapid increase in the generation of more waste per capita. Hence and in addition to increasing ecological concerns, the waste management has become a critical issue, which needs a different kind of solution. Current model of collection (labor is from MCGM and transportation by the private operators) and transporting all the mixed waste to the dumping grounds -which are nearing choking point - cost as much as Rs. 2000/ton of mixed waste. This is both bad from ecological and economic viewpoint. Dumping mixed waste in an unscientific manner is simply no longer an option. At the same time, despite all the rhetoric, we have made very little progress in the segregation of waste. Hence it is important that our biomethanation model must be superior to the current approach on both the grounds - economic and ecological.

Fortunately, our study covering observations of several plants in Mumbai and other locations in India indicates that segregation and bio methanation at an intermediate level that is equivalent to a ward in Mumbai is not only possible but economically worth taking the trouble. The process can be predictable and a plant can be managed as a business. We have to create conducive environment for an operator to find the business of bio methanation worthwhile. We find that a plant in a capacity range of 5 to 10 tpd (of input of bio degradable waste) would be appropriate if we can identify the end user of gas as well right location and an operator (if he is a user all the better) supported by a commercial enterprise which can provide an interest free loan for over half the project cost as a social venture capital as a part of "corporate social responsibility" . The site should be convenient to the end user who should consume the gas in a captive manner. A no of hotels or hospitals which use gas in commercial quantities for boilers or cooking are ideally suited .The economics between gas and electricity as end product favors gas using plant very favorably.

Following discussion is about the economic viability for the operator and for the civic authority and identification of factors which can lead to sustainability of this model at a significant scale in Mumbai and possibly other large cities so that it can make a material impact on the waste management effort of the city in a comprehensive manner.

Requirement of Investment for Bio Gas Plants (5tpd- 10tpd)

Table 5.1 shows that the investment for gas based plant for 5 tpd and 10 tpd for two suppliers of technology for whom we have collected information as well as verified from their plants currently in operation/under installation. VJTI team led by Prof Bhave has recommended some modifications and the plant cost takes these into consideration. The plant involves digestors and shredders as primary equipment. The site development and civil work would vary depending upon the site. We have chosen two suppliers of technology (who can also build the plants) and find that they can now offer reliable plants at a reasonable cost. Needless to say, there could be other suppliers who can also offer equal or better value or plants. Our choice of these suppliers is due to the fact that we could see their plants, understand their specs and working and feel that for illustration and assumptions, we can use their data to make our findings actionable.

We feel it is necessary to provide for the pre operative expenses and expenses incurred during the stabilization period as the process is organic and some training is required for the staff. Besides, the raw material procurement needs to stabilize. In a well planned project (and after the experience of few more projects and with advance planning with regard to permissions, clearances, availability of land we can reduce the cost and even increase the efficiency. But it would be prudent at this stage to provide for this as it would help ensure stable and efficient operation thereafter. Hence our estimates include such non equipment costs which could be Rs 16 laks for a ten tpd plant .

Indicative equipment cost could vary between Rs. 68 lakhs and Rs. 80 lakhs depending upon the supplier for 10 tpd plant gas based plant. Total cost would be in the range of Rs. 84 to 96 laks for the same. while it would be around Rs. 50 laks for a 5 tpd plant. This cost includes cost of low pressure gas storage and pipeline for a distance of one km. Since it is low pressure gas, there should be no safety or emission issues . For higher sized plants with longer distances, it becomes a different issue altogether.

Table 5.3 indicates the cost of plants with end product as electricity which include the cost of generator for conversion of gas into electricity and hence the cost goes up by Rs. 21 laks for 10 tpd. In terms of equipment cost, the investment per tpd is Rs. 8 to 9 lakh which is in line with what is accepted by MNES. In fact, we notice that the cost of plant does not go down on a per ton basis as the capacity increases. This is a very critical factor in favor of plants upto ten tpd size. However, below 5 tpd , unless it is completely captive , the cost of management would be a critical factor. We learn that a few entrepreneurs are developing plants which can work on even 100 kg to 300 kg input/day . These would be ideas for medium sized restaurants and eating establishments where internal generation waste can be converted to gas without requiring much space. But as of now, we do not have reliable info on such models.

Financing of the projects

If the municipality agrees that serious public private partnership model should be tried in the area of SWM, our report and findings offer a good working base for inviting interest from the operators as well as financial support from private sector. We should recognize the value of such participation and invite , appreciate , recognize and welcome such participation and provide some defined conditional support in the form of land, advertising rights and some viability gap funding. This will ensure a sustainable financing and management support both of which are very critical for a few early successes. We are offering a lot of rewarding opportunities to builders in the form of fsi/tdr with a very implicit cost and significant financial benefits. In the area of waste management , the opportunities of profiteering are very limited whereas the value of commitment, motivation and knowledge should be leveraged.

We recognize that a no of commercial, financial and industrial organizations in private sector are interested in participating in such projects under their corporate social responsibility programs if this sector offers them some profile. We feel that such involvement can be considered "social venture capital participation." It should be in the form of one time interest free but risk bearing loan without interest. The quantum of such funding would depend upon the involvement and interest of a particular corporate. We believe that if viability gap funding is offered by municipality or other civic agency upto half of the requirements of funds after obtaining the central govt subsidy. Our report identifies specifications, norms and costs and can help evaluation of proposals in an objective manner. We believe this method of financing ensures that these plants can run with basic financial sustainability by being realistic. We believe the net investment to be contributed by the corporation (thru viability gap funding) will be small and help ensure that this model will attract right kind of operators and social venture capital providers. This model has potential to win goodwill of people and we should provide the funding corporate an opportunity to conduct a social communication program whereby the concerned corporate gets image mileage along with achievement of civic goals. The reason for viability gap funding is also not to let the project be left unsupervised over a period of time. A joint partnership of an organization with a civic body would be essential. For this purpose, one or more senior officer of SWM dept of MCGM must be empowered to supervise and support in a pro active manner in a laid down guide lines. This is essential since the projects may or may not earn return depending upon various factors and we should ensure that they do make profits so that it becomes a worthwhile , if not, an attractive avenue .

Operating Costs and Revenue Streams for the Plant

Table 5.2 (for Gas)and Table 4(for Electricity) give indicative working of operating costs for 5 tpd and 10 tpd plants (at costs considered for tech 2 option) Input /output norms are similar for both the technologies. We have considered 10% lower outputs than indicated by the suppliers. Also we have considered plant operation at 300 days although the tech suppliers think that the plants can operate for 330 days. These two buffers make the working more realistic and at the same time indicate what is possible thru higher efficiency.

For revenue streams, we have considered the current price of commercial gas and converted it to calorific equivalent to make valuation meaningful. Price of manure (to be supported by testing) at Rs. 5 is realistic. In the working presented we have given two options – i.e. at 50% efficiency and at 90% efficiency .We believe that in the long run relative cost of energy from fossil sources is bound be higher and hence the revenue streams should expect higher price realization and have a positive impact on the bottom line. The electricity alternative assumes a value of Rs. 4/unit. Since after conversion of gas into electricity, there is energy loss and since the investment also is higher, the surplus will be significantly less. But the electricity can always be connected to the grid and hence potentially marketing is not critical.

We have not added the value that can be generated from the sale of carbon credits and , more particularly, the saving from the realization of revenues towards collection efforts. We have proposed that as against the current municipal cost of collection and transportation of Rs. 2/kg , the municipality should offer the operator Rs. 1.50/kg subject to certain conditions.

We have considered depreciation at the rate of 15% considering the plant life to be 6 to 7 years. And this is taken as an operating cost. The ROI analysis is considered the basic tool of financial evaluation and hence prior interest cost is not considered. The underlying assumption is that investors should not expect interest but must get at least capital thru depreciation. On the other hand, thru higher efficiency and thru revenues from a surplus to be earned thru collection charges and carbon credits .

Reimbursing the collection expenses

This is one of the key element in the viability of the neighborhood plant not only from the angle of financial sustainability but since the operator considers the bio degradable waste as a raw material , he will be quite keen to work out the segregation from the area in which he will be collecting his waste. We believe that a plant operator will be much more careful for ensuring segragation and collection of waste. He should be allocated a specific feeding area for his plant and that should be mutually agreed between the ward management and the operator. He should be allowed to pick up the waste from all the eating establishments from where he will be getting more bio degradable waste. He must be also responsible for the proper disposal of the waste that he wont use as r.m. in his plant. A framework for an agreement between an operator and the corporation needs to be worked out which identifies his rights, duties, responsibilities , quantification, authorization of payments to him etc. This will ensure that the operator correlate the design of the plant with the type of waste (whether more cooked waste or more market yard veg waste) and design proper routing, timing , equipment and vehicle for the collection and delivery of the waste so that he can operate on "just in time " basis ensuring smooth operation and zero stink . Similarly, the ward SWM management also must ensure that the operator does not behave like a ragpicker leaving unwanted waste anywhere.

It is clearly possible that from the charges MCGM should agree for collection (which would be less than what it incurs) to be paid to the plant operator, he should produce good surplus. We should not grudge that and try to look at his costs. He should be encouraged to make a good surplus thru honest effort and the system should reward maximum collection of such waste which would be converted into useful products. We should not reimburse him for the operating costs but rather pay him for the waste collected by weight. We believe this is perhaps the most crucial point for the basic economic viability of the plant. The net revenue from this stream could be higher than even the value of gas produced depending upon the specific conditions and type of waste. This working would be submitted next week.

Similarly, the entitlement of carbon credits and their value is also being analysed and an annexure will be submitted shortly. We believe that surplus from collection effort and possibly carbon credit will be two important revenue streams and sensitivity analysis will be presented based on realistic figures on revenue streams from these two sources.

Return on Investment analysis

At the base line assumptions of 50% and 90% capacity utilization on 300 day working with adequate provision for manpower cost and maintenance and other ovhs (typically in the past for such "non business projects" such exp as well as pre op and stabilization expenses were not identified and that led to poor financial working . This also led to false expectations followed by loss of credibility and failure of projects. We have taken care while making estimates of all the variables in as realistic a manner as possible . ROI analysis presented in table 5 clearly indicates the following :

For 10 tpd plants – 50% capacity utilization

Without any carbon credits and any savings from possible collection charges, there is 3% negative return on gas using plant and 18% negative return on electricity using plant. t 90% capacity utilization plant

For 10 tpd plants – 90% capacity utilization

The return becomes 18% plus for gas and still 9% negative for electricity. This would mean that the capacity utilization is critical for profitability and electricity producing plants would be giving negative return even at 90% capacity utilization.

For 5 tpd capacity

For smaller capacity, the return on gas based plant is 9% negative for 50% capacity utilization whereas it becomes positive at at 9% at 90 % capacity utilization.. Predictably, the ROI for electricity producing plants, the returns is negative at 21% (for 50%) and 15% (for 90% capacity utilization.

From the above it is clear that electricity converting plants would be unremunerative at any capacity and efficiency level. Gas based plants can be remunerative at capacity utilization beyond 60 to 70%

What is financially Feasible ?

Obviously, we should concentrate on gas using locations and operators so that the plants could be viable. In fact, it is necessary to provide the incentive in the form of collection charges as discussed earlier. It is possible that managing smaller quantity from a local area, the cost and logistics will be much lower. Reliability could be higher. There could be more uniformity of the type of waste and hence possibilities of higher efficiency and a superior profitability. We believe that efficiently run gas plant can provide upto 50% ROI and that should be the reason for economizing on the incentive structure as higher profitability would make such projects attractive and entrepreneurs and corporates will come forward. We should appreciate the plants making profit rather than grudge it and reduce the charges payable to them because that will spur very positive energy to work in this important but neglected area. If there is more enterprise in converting waste into energy in and eco sensitive manner, we should have more of it. There is no need to think that only builders and waster transporters are to prosper amongst the civic and infra structural service providers.

Such possibilities will lead to further innovations and more city friendly approach. We should compare the real working of incentive mechanism across various areas such as SRA , road building, road maitenance, garbage transportation and compare with such genuine problem solving and eco and people friendly areas and then we will realize how and which activities need self sustaining support.

Business model for capital cost estimates for decentralized biomethanation projects.

Capital Cost Estimation for biomethanation projects

END USE – METHANE/BIOGAS

Table – 5.1 (rounded to rs lacs)

Item	10 tpd plant		5 tpd plant	
	Technology A	Technolog y B	Technolog y A	Technolog y B
land - FREE frm MCGM	2500 sq mt	2500 sq mt	1000 sq mt	1000 sq mt
site development/civil works	8	10	5	8
digestors and equipments	45	40	23	19
utilities (elec& plumbing)	12	5	5	3
storage + pipelines ###	7	7	4	4
Instruments (pumps,compr etc)	7	5	4	3
Office equipment	1	1	1	1
sub total (A) Hardware!	**80**	**68**	**42**	**38**
pre op exp (3 months of exp)	4	4	3	3
Stabilization (4 mnth of exp)	5	5	4	4
working capital^ (2 months of revenue)	8	8	4	4
sub total (B)	**16**	**16**	**10**	**10**
Total cost	**96**	**84**	**52**	**48**
Cental govt sub##	16.0	13.6	8.4	7.6
private social equity (CSR)*	48	43	26	24
viability funding*	32	28	17	16
Suggested financing C	**96**	**84**	**52**	**48**
Investment Per TPD	9.6	8.4	10.4	9.6

20 % of the Hardware cost (A)

*After deducting govt subs from total cost(B) then 60% of the total the balance is between Private social equity and 40% from MCGM/Other civic agency as a viability funding

Some corporates have already shown interest and they expect some communication rights

Pipelines to be covered upto a distance of one kilometer and High pressure Bottling technology at such a small scale is under development

!These are indicative figures from the well known and reliable suppliers who have supplied plants which are working successfully and actuall quotations can be produced when required and the prices and specifications are subjected to negotiations but should not vary materially

^ Working capital = two months revenue

Operating economics of bio methanation projects in Mumbai

END USE – METHANE/BIOGAS

Table – 5.2 Rupees/month

	10 TPD		5 TPD	
	at 50% eff	at 90 % eff	at 50% eff	at 90 % eff
No. of tons of input per day	5	9	2.5	4.5
Collection * (refer to table A1)	?	?	?	?
Utilities	10000	10000	5000	5000
Maintenance	20000	20000	10000	10000
Manpower	10	10	6	6
wages and exp**	60000	60000	36000	36000
Supervisor salary #	12000	12000	12000	12000
sales and adm exp	25000	25000	25000	25000
depreciation @15%/annum (B)	105563	105563	59925	59926
Grand total cost/mnth * (A)**	**232563**	**232563**	**147925**	**147926**
Operating Expenses A-B=C	127000	127000	88000	88000
Outputs/day				
Biogas - Cu.mtr/day $	400	720	200	360
Manure- Kgs/day $ @ 8% of input	400	720	200	360
Revenue Stream/mnth				
Carbon Credits^^	0	0	0	0
Saving due to efficiency in Collection	0	0	0	0
sale/use value gas	160000	288000	80000	144000
sale of manure	50000	90000	25000	45000
Tot revenue/month	**210000**	**378000**	**105000**	**189000**

we propose- the Plant operator should be paid in the range of Rs.1200- 1500/ton of waste collected which is clearly and significantly less than what MCGM incurs today

*** Exclusive Cost of collection

** wages@ 6000/m for labours and @ Rs12000/m for supervisor

one supervisors are required for 10 tpd plant and one for 5tpd plant

Administration will also include the professional fees of the monitoring agency @ 20000/m

Rate of manure @ Rs. 5/Kg

Cost of Biogas is calculated by comparing its calorific value with LPG, assumtption-

Calorific value of LPG is 9000 Kcal/Kg and calorific value of Biogas is around 4500 - 5000 Kcal/m^3,

Equvivalent to 40*0.4 = 16/m^3 (considering 300 working days)

^^It is possible to earn CER in a significant amount a detailed working note will be submitted separately

$ we have considered output eff to be 10% lower than what is promised by the technology providers

Assuming 80 Cu.mtr of gas per ton of input

Handling and transportation charges incurred by MCGM for Mixed waste in ward (2004-05)

Table – 5.2 A

	Per ton Cost
transportation cost paid to contractor	500
labor cost incurred by MCGM (2 lab)	660
total incurred by MCGM/ton	1160
Cost per kg of mixed waste*	**1.16**

These rates were finalized in 2005 and diesel rates have changed after that which were substantially increased due to diesel cost

* Currently Municipal Corporation of Greater Mumbai is spedinging
around 2000 per ton of waste i.e. **Rs 2 per Kg of waste.**

MCGM actually carries mixed waste which comprises of atleast 50 % dry waste. Hence actual transport cost
Incurred by MCGM for carrying one tpd of wet waste is actually double.

Assumptions : One Municipal Labour per day per tonne

Cost of collection of mixed waste by MCGM and transport upto Deonar for G North
Cost of Labour to MCGM incl. Salary, medical, PF, gratuity etc. per month will be Rs. 10,000
Cost per day will be Rs. 330 per day

Capital Cost Estimation for biomethanation projects

END USE - ELECTRICITY

Table – 5.3 (rounded to Rs lacs)

Item	10 tpd plant		5 tpd plant	
	Technology A	Technology B	Technology A	Technology B
land - FREE frm MCGM	2500 sq mt	2000 sq mt	1000 sq mt	1000 sq mt
site development/civil works	8	10	5	8
digestors and equipments	46	41	24	20
utilities (eclec@ plumbing)	10	4	5	3
Generator (1)	30	30	10	10
Instruments	7	5	4	3
office equipmen	1	1	1	1
sub total A (hardware)	**102**	**91**	**49**	**45**
pre op exp (3 months of exp)	4	4	3	3
Stabilization (4 months of exp)	5	5	4	4
working capital ^ (2 months of rev)	3	3	2	2
sub total B	**13**	**13**	**8**	**8**
Grand total cost	**115**	**104**	**57**	**53**
cental govt sub##	20	18	10	9
private social equity (CSR)*	57	51	28	26
viability gap	38	34	19	18
Suggested financing C	**115**	**104**	**57**	**53**
Investment Per TPD	11.5	10.4	11.4	10.6

20 % of the Hardware cost (A)
*After deducting govt subs from total cost(B) then 60% of the total the balance is
Between Private social equity and 40% from MCGM/Other civic agency as a viability funding
Some corporates have already shown interest and they expect some communication rights
^ working capital is 2 months revenue

Operating economics of bio methanation projects in Mumbai

END USE - ELECTRICITY

Table – 5.4 Rupees/month

	10 TPD		5 TPD	
	at 50% eff	at 90 % eff	at 50% eff	at 90 % eff
No of tons per day	**5**	**9**	**2.5**	**4.5**
Utilities	15000	15000	8000	8000
maintenance	20000	20000	10000	10000
Manpower	10	10	6	6
wages and exp**	60000	60000	36000	36000
supervisor salary #	12000	12000	12000	12000
sales and adm exp	25000	25000	25000	25000
depreciation @15%/annum **(B)**	129575	129575	66350	66350
grand total cost/mnth (A)	**261575**	**261575**	**157350**	**157350**
Operative Expenses A-B=C	**132000**	**132000**	**91000**	**91000**
Outputs/day				
Electricity – units/day $	450	810	225	405
Manure - Kgs/day$	400	720	250	360
Revenue Stream/mnth				
Carbon Credits^^	0	0	0	0
From Collection	0	0	0	0
sale/use Elec	45000	81000	22500	40500
sale of manure	50000	90000	31250	45000
Total Revnue/mnth	**95000**	**171000**	**53750**	**85500**

** wages@ 6000/m for labours and Rs12000/m for supervisor

Two supervisors are required for 10 tpd plant and one for 5tpd plant-

Administration will also include the professional fees of the monitoring agency @ 20000/m

Rate of manure @ Rs. 5/Kg

Electricity @ Rs. 4/unit

^^It is possible to earn CER in a significant amount a detailed working note will be submitted separately

$ we have considered output eff to be 10% lower than what is promised by the technology providers

while the plant can run for 330 days we have assumed the working

of 300 days for the calculations of output revenues

As there will be some losses in conversion of gas into electricity we have assumed the figures on lower sid

ROI for Biomethanation projects

(For Gas Vs Electricity as End product and @ 50% and 90% effeiciency)

Table – 5.5 A

For 10 tpd plants

(Rs in 000)

	Gas Using Plants		Electricity Conversion plants	
	10 TPD at 50% eff	10 TPD at 90% eff	10 TPD at 50%	10 TPD at 90%
Investment (one time) E	**9645**	**9645**	**11466**	**11466**
Operation costs/mnth – **B**	233	233	262	262
Total Revenue per month - A (rs in 000)	**210**	**378**	**95**	**171**
(Operating surplus C (A-B = C) per month	-23	145	-167	-91
Operating surplus per year D	-271	1745	-1999	-1087
Returns on Investments F {F=D/E * 100 (%)}	**-2.8**	**18.1**	**-17.4**	**-9.5**

These calculations are without taking any benefit from carbon credits as well as possible surplus from efficiency in collection

This will emphasize the importance of carbon credits as well as efficiency in collection and need for MCGM to pay the plant operators

Collection charges - what the corporation incurs now in a manner which loads the dumping ground with mixed waste in an unsustainable fashion

This table also illustrates the superiority of the gas producing plants vs plant that have to convert gas into electricity

Table – 5.5-B

For 5 tpd plants

(Rs in 000)

	Gas Using Plants		Electricity Conversion plants	
	5 TPD at 50% eff	5 TPD at 90% eff	5 TPD at 50%	5 TPD at 90%
Investment (one time) E	5194	5194	5708	5708
Operation costs/mnth – **B**	148	148	157	157
Total Revenue per month - A (rs in 000)	**105**	**189**	**54**	**86**
(Operating surplus C (A-B = C) per month	-43	41	-104	-72
Operating surplus per year D	-515	493	-1243	-862
Returns on Investments F {F=D/E * 100 (%)}	**-9.9**	**9.5**	**-21.8**	**-15.1**

Conclusion & Recommendation

Conclusion

Alternative technologies were considered for treatment of MSWb,

a) Sanitary landfill
b) Composting and Vermi composting
c) Incineration
d) Pyrolysis and Gasification
e) Anaerobic digestion / Biomethanation
f) Pelletization or Refused Derived Fuel (RDF)

At ward level , following technologies were studied as they were appropriate in terms of scale

i) Biomethanation
ii) Composting
  a) Aerobic Composting
  b) Vermi Composting

Our findings from the study of approx 25 sites are as follows:

1. Biomethanation is found appropriate for 1TPD to 30 TPD of MSWb at Ward level and may be put up in multiple units in a ward (typically each ward generates Biodegradable waste from high volume waste generating locations in the range of 20 – 50 tpd)
2. Aerobic composting – to be considered only if segregation of waste is just not possible, we can consider this as an alternative and a method of disposing waste better than the current method of just transporting and dumping waste at the dumping grounds. Large quantities of MSW starting from 75 TPD to 600 TPD of MSW at Municipal ward levels either a single unit for a ward or one for each zone can be set up. Aerobic composting is also normally carried out in very small units at residential buildings level.
3. Vermi composting is appropriate for treating small quantities of MSW for less than 1TPD at colonies / societies of residential buildings level.

In Mumbai availability of land is extremely difficult and transportation over long distances is very expensive and is congestion causing. Hence choice of technology would be governed by the optimizing of these two factors. We find the land requirement for the above technologies equalized at one ton basis is as follows:

Technologies	Sq. mts/ton of waste input
Biomethanaion	72
Aerobic composting	167
Vermicomposting	374

4. As seen earlier Biomethanation plants would be ideal and economical viable if run with care, attention to details and involvement of the operator, this would be possible only if it is financially attractive (not only viable). Biomethanation project would become attractive if it is run efficiently, it is based on identification of a committed end user of gas and the operator is properly incentivized through -
   a) Institutional support in terms of earning CERs.
   b) Getting full collection charges equivalent to what MCGM incurs currently.
   c) In case the operator is a gas user by virtue of being high volume waste generator such as Restaurant, Hotel or Hospital he should get the benefit of substantially reduced TRC and on the other hand any large volume food waste generator should have a compelling high TRC.
5. Since these projects are fundamentally viable and can make a material difference in terms of quality of environment and cleanliness (value of which is beyond monetary considerations).
6. We believe that MCGM can experiment with at least two projects based on different technologies, cost and incentive structure that we have suggested. It should also be willing to provide/arrange about 1/3 of the project cost as a viability gap funding as a interest free loan, provide advertising rights subject to efficiency in the operations. We feel such conditional support can make a world of difference to the cleanliness and the environment of the city.
7. We have tried to combine the recognition of technological reliability operational efficiency and some dose of idealism. We do feel if such innovative thinking is adopted we can definitely help MCGM to identify the operators, corporate and technology providers, so that it becomes a real viable model from learning all the past experiences and mistakes committed by number of individuals and organizations both in terms of time and money spend in a selfless manner.

Recommendation

We feel that Biomethanation technology has an important role to play at a ward level disposal of biodegradable waste in an economically and ecologically sustainable manner. Besides requiring minimum land, it also requires very little transportations compared to the current practice. Biomethanation technology has now achieved a level of reliability and replicability and hence this can be adopted at several locations in the city which justify a minimum input in the range of two to three tons and a maximum input of 30 tons of biodegradable waste per day. It is preferable that the choice of location should be governed by the usage of the gas as a direct use of gas at or near the site can make a huge difference to the economics of the plant as can be seen in the economic viability chapter earlier. Reasonably well managed plant can be safe to be located in residential areas as we have found out that the odour nuisance is virtually not there and since these plants would be operated on just in time inventory basis and on a smaller scale risk of failure is minimized. Further there is no fear of emission of toxic gases or fire hazards because the generation and handling of gas is at low pressures.

Considering ward level or sectoral treatment of municipal solid waste i.e. where the selection of treatment technologies is very much dependant on the area required for the process, the Biomethanation technology appears to be the first priority. The Biomethanation technology is best suited from the point of collection and conveyance of waste[†], type of waste available[‡] and odour nuisance.

The biomethanation of MSWb is an environmental friendly approach of MSWb treatment. The methane gas generated is a known green house gas and hence the gas utilization is strongly recommended, this will convert harmful methane and will be used, which is relatively safer.

The aerobic composting is also suitable for MSW at ward level basis provided there is available land for such investment but compared to biomethanation which are wealth creating investments both in terms of manure as well as gas whereas in aerobic and vermicomposting technologies we will get the manure as a end product with the loss of valuable end product, gas. But the actual composting (large scale) need be carried out away from thickly populated residential areas in the ward where more land could be made available the aerobic composting becomes economical for treating MSW by making use of mechanized processing units but at the loss of another by product obtained from biomethanation i.e., Gas. The aerobic composting also has the odour nuisance as the quantity of total MSW generated is to be handled openly. More than one ward can be combined to handle aerobic composting.

Vermi- composting can not be applied on the ward level basis in the urban area because the land area requirement for the quantity of MSWb generated from the Ward/Sector is much higher than area required for aerobic composting and biomethanation. Although Vermi-composting have been in practice and can be practiced for individual buildings where the required area for vermin-composting is available. And no more extra requirement of land is required and also with less investment and with semi skilled supervision.

† The present MCGM rules for MSW collection (March 2006) insist upon the segregation of solid waste at the house hold level only as wet waste and dry waste. Violation of the same by the citizens is liable for penalty. This type of collection practices is better from the Biomethanation technology point of view.

‡ The type of wastes collected from the eateries and vegetable, fruit markets etc. contribute to the specific type of MSWb, which is well suited for the operation of Biomethanation plants.

PART II

Introduction to the Study

To understand how to segregate, collect and transport the waste as raw material in acceptable quality to a neighborhood location for a safe and sensible disposal

Maharashtra Economic Development Council (MEDC) , a non profit non government organization had approached MMR Environment Society, for financial assistance for undertaking a study on "Identification and Evaluation of appropriate technology for economics and ecological conversion of bio-degradable waste in Mumbai at a ward level."

Rationale for the Study :

Municipal Corporation of Greater Mumbai (MCGM) is responsible for solid waste management as well as overall cleanliness of Mumbai. However, the solid waste management by MCGM involves merely collection of wastes at various locations throughout the city and its transportation to the three dumping grounds located in the outskirts of the city. The waste form some places like A and B ward travels a distance of almost 20 km thus polluting the entire city. In spite of employing a large work force and a large number vehicles, one can still see heaps of garbage around. MEDC therefore felt that processing of waste locally could be one of the solutions to the vast problem of solid waste management in the city.

Based on the knowledge available with MEDC on Solid Waste Management (SWM), we felt that it will be important to study and understand the large projects of biomethanation set up for management of Municipal solid waste (MSW) generated by the entire city (As in the case of Lucknow) and the smaller size projects set up and being operated by individual entrepreneurs(As in case of Shatabdi Hospital) which have not been able to operate successfully.

It will be important to study identify a technology and design a system right form collection of waste, segregation and delivery to a location where the biomethanation plant will be located. Such a study along with a proper system which will operate on the principle of minimum space requirement, without any bad smell will be of immense important from the city's point of view. Such a better designed system which will transport the waste to minimum distance and will convert the waste into some useful bye product will certainly have a better impact on the environment.

Likely Benefits and Beneficiaries of the Study :

The principle beneficiary of the project will be MCGM which will implement the recommendations of the findings. This will help in reduction in transport cost for MCGM.

Likely Benefits of the project :

Establishment of Quantitative performance yardsticks such as :

1. Reduction in ton/Km of the garbage.
2. Reduction in quality of garbage going to the dumping grounds.
3. Quality of end product and manure produced to be utilized substantial.
4. No. of ton /mk handed by municipal vehicles.
5. Substantial savings in transportation cost to MCGM.

Chapter No 1

Introduction to Municipal Solid Waste

Mumbai, the commercial and financial capital of India is spread over an area of around 437.71 sq.km and houses more than 12 million people and is increasing on a daily basis. Geographically, the city of Mumbai can be divided into three sections, namely, the Island city (or main city), the Western suburbs and the Eastern suburbs, which are divided into 5 zones respectively for administrative purposes. Such a huge habitat generates a huge amount of municipal solid waste (msw) of many kinds. The management of this is a massive task for the local administration and this has a direct impact on health and environmental safety of the city.

Population Projections:

The population of Mumbai as per 2001 census was 11.91 million. The past data shows that the population has grown four folds from 1951 (2.97 million). Though, the growth rate has been coming down, the last decade shows 20% growth in population. The population has been projected for a period of 25 years using the arithmetic method. Similarly, waste quantity generated per capita per day has also projected for a period of 25 years to estimate the quantum of waste generated as tabulated below (Table 1). It is estimated that the waste quantity will increase from the present.

As per the MSW 2000 rules, 0.475 kilograms/capita/day to 0.65 Kilograms/capita/day is the generation of waste during the projected period.

(Mixed waste and dry waste being 35% by weight and 65% by volume)

Population and MSW Generation Projection

Year	Population (million)	Waste quantity in TPD	Per Capita/kgs
2005	12.8	6,000	0.47
2015	14.4	8,100	0.57
2025	15.9	9,780	0.62
2030	16.2	10,530	0.65

Source: IL&FS Report on Selection of Waste Processing Technology and Scientific Management of Landfills

For successful implementation of localized processing of biodegradable waste through biomethanation, it is very important to get the segregated waste to the plant size. (Vermicomposting/culture is observed at some of the places in Mumbai. These are mostly small residential colonies. Biomethanation plant at Shatabdi is not running at the full designed capacity because the plant fails to get purely segregated 5 tonnes of wet waste per day.

Some facts about Waste Generation in Mumbai:

Average Generation of Waste by a Citizen of Mumbai

Following table gives standard norms for per capita waste generation for different cities:

The generation of waste by an individual depends on the socio-economic conditions to which the person belongs. As per an evaluation carried out by ALILSG and a few ALMs in Mumbai, a rich family will generate nearly four to five kg of mixed waste per day; a middle class family will generate between one to three kg of mixed waste per day and a poor family, in slums, will generate close to 500grams per day. The survey was carried out in different localities such as Cuff Parade(Which represents the higher class of society, Western Suburbs such as Mahim, Santacruz which represent middle class of the society and slums in eastern suburbs such as Chembur and Kurla which represent lower class of the society).

Data on SWM as per SWM dept of MCGM

	Tons	Unit
Total Waste Generation	**8500**	**Tpd**
Biodegradable waste	4500	Tpd
Recyclable waste	2000	Tpd
Debris	2000	Tpd

(Source: office of Chief Engineer-SWM dept. MCGM)
Note: tpd – tons per day

Many people feel that solid waste management is a simple affair - simply putting waste into a vehicle and unloading it at a Collection spot or at dumping ground. Most of the municipalities are following this simple method for SWM. However, if this was true, then why do so many areas in Mumbai suffer from uncollected refuse blocking streets and drains, with flies and rats, and degrading our Environment?


Above photographs of some of the public collection spots are self explanatory.

Based on the surveys carried out by MEDC in the identified wards (which has been discussed in detail in the following chapters), there is much evidence to show that solid waste management is much more than a technological issue - it usually involves managing a large workforce and working together closely with the public, designing and implementation of proper systems for collection, segregation and disposal of municipal solid waste.

As per the data provided by MCGM, following resources are employed for SWM of Mumbai :

Resources used for collection and disposal of waste generated in Mumbai

	Number	Landfill sites	Hectare
Municipal staff (Class IV labour)	20874	Deonar	111
Vehicles of all kinds	1500	Mulund	25
Vehicles of all kinds	1500	Gorai	14
		Kanjur (New)	141

(Source: Office of Chief Engineer-SWM dept of MCGM)

The MCGM uses latest equipments and vehicles for storage, handling and movement of waste. However it doesn't mean that equipments, vehicles and machines which work well in other developed countries will definitely show their impact at any place in case of solid waste management. The preparation and management of a good solid waste management system needs inputs from a range of disciplines, and careful consideration of local conditions.

Types of Municipal Solid Waste (MSW)

Before understanding the system for SWM employed by Municipal corporation, it is important to understand the different types of wastes generated in Mumbai . An attempt has been made in following paragraphs to explain the same.

Municipal solid waste comprises of:

- Wastes from households including garbage
- Animal Waste
- Dry waste
- Rubbish
- Sanitation waste
- Street sweepings
- Wastes and discarded materials from institutions and commercial complexes and Debris from construction and demolition activities.

Domestic wastes

These wastes are generated by household activities such as cooking, cleaning, repairs and redecoration and include empty containers, packaging, clothing, old books, newspapers, old furnishings, etc.

Animal waste

Though official slaughtering is supposed to be carried out at Deonar Abbatoir, unauthorized slaughtering is being carried out at many places in Mumbai. This waste is dumped at the community collection spots. Apart from this MCGM provides offal vans to collect the offal waste from municipal markets that have a sell of non-vegetarian items such as chicken, mutton, fish etc.

Commercial wastes

Wastes generated in offices, wholesale stores, restaurants, hotels, markets, warehouses and other commercial establishments are classified as commercial wastes. These are further categorized into garbage and rubbish.

Dry waste

Most of the times commercial waste is the major source of both dry and wet waste, which is recyclable. Their dry waste buyers are contracted as it gives them fat cash, for example five star hotels such as Taj Mahal, earn more than a lakh of Rupees per month from the sale of dry waste. This activity has a chain of sellers and buyers such as the Arab Gully in south Mumbai or Dharavi are the areas, which are famous for the dry waste business.



Dry waste recycling units in a ward (C and E ward)

Considerable wastes are generated from institutions such as schools, colleges, hospitals and research institutions. Such wastes include garbage, rubbish and hazardous materials.

Garbage

Waste dumped at collection spot

Garbage is a general term, which includes animal and vegetable wastes associated with

Various activities like storage, preparation, sale, cooking and serving of food. These Wastes are biodegradable in nature.

Ashes

Residues from the burning of wood, charcoal and coke for cooking and heating in Houses, institutions and small industries are also defined as waste. Ashes consist of a fine powdery residue, cinders and clinker often mixed with small pieces of metal and glass.

Rubbish

Apart from garbage and ashes, other solid wastes produced in households, commercial establishments and institutions are termed as rubbish.

Bulky wastes

Bulky wastes are large household appliances such as cookers, refrigerators and washing machines as well as furniture, crates, vehicle parts, tyres, wood, trees and branches. The bulky metallic wastes are sold as scrap metal but some portion is disposed of in sanitary landfills.

Street wastes

Street wastes consist of paper, cardboard, plastic, dirt, dust, leaves and other vegetable matter collected from streets, walkways, alleys, parks and vacant plots.

Dead animals

Animals die naturally or are sometimes accidentally killed. If left untended, the carcass will generate nuisance. This category, however, does not include carcasses and animal parts from slaughterhouses as these are considered industrial wastes.

Construction and demolition wastes

Construction materials like cement, bricks, cement plaster, steel, rubble, stone, timber, plastic and iron pipes and major components of the building industry.

Debris can be seen dumped at open spaces

Hazardous wastes

Wastes from hospitals, clinics and laboratories fall under a separate regulation called the Biomedical Wastes (Management & Handling) Rules, 1998. Hazardous wastes generated by industries fall under a specific regulation called the Hazardous Wastes (Handling & Management) Rules, 1989 (as amended).

E-Waste

E- Waste comprises waste electronic goods ranging from personal computers to various household appliances such as TVs, refrigerators, discarded cellular phones, etc It contains over 1000 different substances and chemicals, many of which are toxic and are likely to create serious problems for the environment and human health if not handled properly. However, classification of e-waste as hazardous, or otherwise, depends on the amount of hazardous constituents present in it. E- waste contains many toxics such as heavy metals, including lead, cadmium, mercury, Polychlorinated Biphenyls, Poly Vinyl Chloride, etc in some components.

Risks and problems associated with solid wastes

There are number of Negative Impacts which may result if Solid Waste is not managed properly, some of the most important impacts are mentioned below.

- Uncollected wastes which are either dumped at the collection spots or at any open places often end up in drains, causing blockages which result in flooding and insanitary conditions. In case of south Mumbai where there are number of house gullies, (especially in the city side), often waste ends up blocking the chambers and further creating number of problems.

House gully with full of waste

- Flies breed in some constituents of solid wastes, and flies are very effective for spreading number of diseases.
- Mosquitoes breed in blocked drains and in rainwater that is retained in discarded cans, tyres and other objects. Mosquitoes spread disease, including malaria and dengue.
- 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.
- The open burning of waste causes air pollution; the products of combustion include dioxins, which are particularly hazardous.
- Uncollected waste degrades the environment, discouraging efforts to keep streets and open spaces in a clean and attractive condition. Solid waste management is a clear indicator of the effectiveness of a municipal administration - if the provision of this service is inadequate large numbers of citizens (voters) are aware of it. Plastic bags are a particular aesthetic nuisance and they cause the death of grazing animals, which eat them.

- Waste collection workers face particular occupational hazards, including strains from lifting, injuries from sharp objects and traffic accidents.
- Dumps of waste and abandoned vehicles block streets and other access ways creating number of traffic problems.

- 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 (waste pickers) and also to the municipal labors working in the waste.
- Heavy refuse collection trucks can cause significant damage to the surfaces of roads that were not designed for such weights.
- Waste items that are recycled without being cleaned effectively or sterilised can transmit infection to later users. (bottles and medical supplies.)
- Polluted water (leachate) flowing from waste dumps and disposal sites 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.
- Waste that is treated or disposed of in unsatisfactory ways can cause a severe aesthetic nuisance in terms of smell and appearance.

- Landfill gas (which is produced by the decomposition of wastes) can be explosive if it is allowed to accumulate in confined spaces.
- Methane (one of the main components of landfill gas) is much more effective than carbon dioxide as a greenhouse gas, leading to climate change.
- Fires on disposal sites can cause major air pollution, causing illness and reducing visibility, making disposal sites dangerously unstable.

Chapter No 2

To understand how to segregate, collect and transport the waste as raw material in acceptable quality to a neighborhood location for a safe and sensible disposal.

As per MSW 2000 Rules finalized by Government of India, reduction, reuse and recycling the waste are the core principles of solid waste management. The Municipal Solid Waste Handling Rules require that municipalities follow some system of door-to-door collection of garbage; promote segregation and ensure that the recyclables go for recycling; reduce pressure on landfills and ensure that organic garbage is processed using non-polluting biological methods.

However segregation is hardly practiced in any appreciable manner. In fact, current system of collection of waste in Mumbai mixes all types of waste.

Solid waste Managément in South Mumbai

South Mumbai which is Zone I of the MCGM consists of five wards namely A, B, C, D and E. MEDC carried out a detailed study on the SWM of B ward and observed waste management practices in A and C and D ward. The entire garbage movement starting from waste collection to waste transportation was observed.

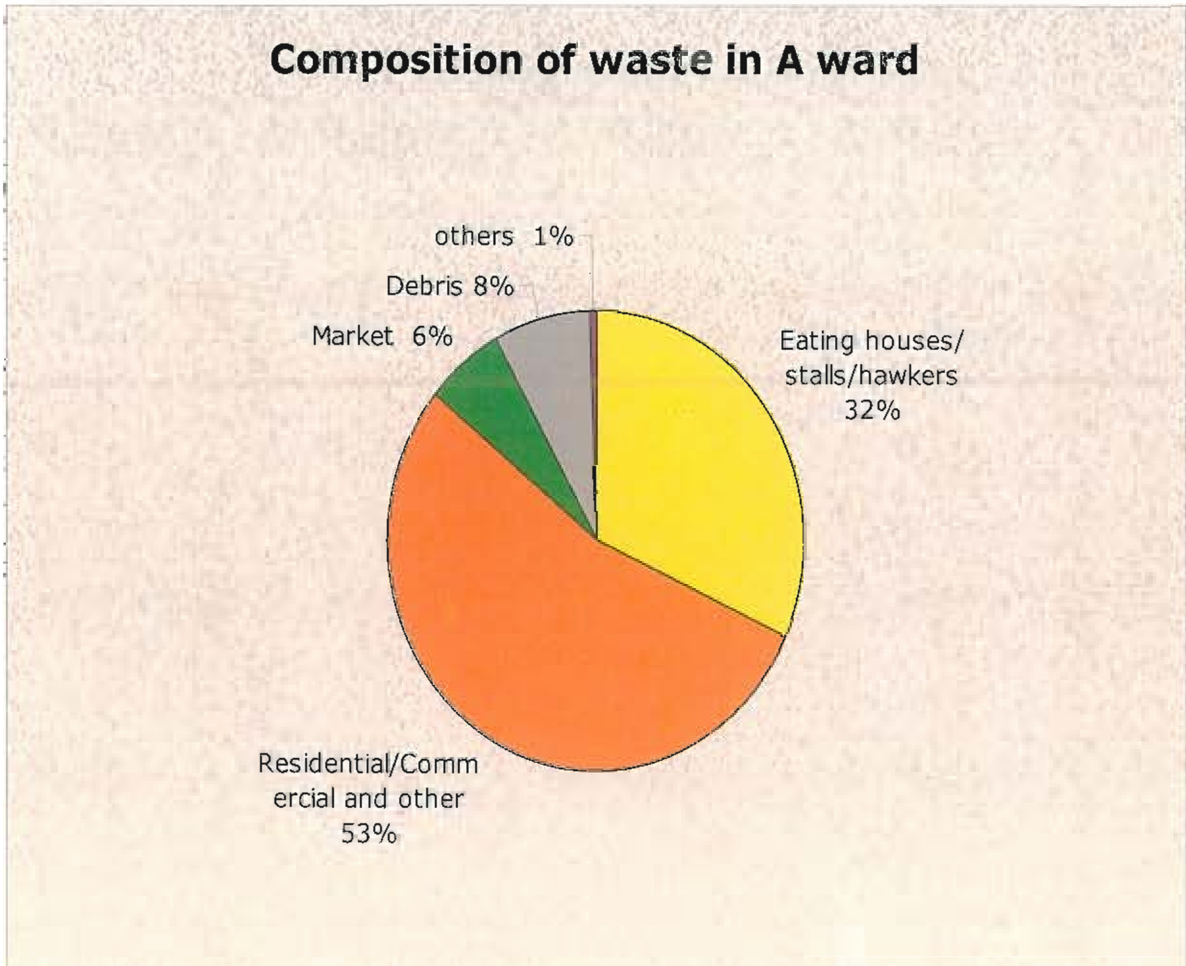
Wards A, B,C and D were selected for carrying out detailed study regarding generation of municipal solid waste due to following reasons:

- The distance from A, B and C wards to Deonar dumping ground is the largest as compared to other wards (apprx 20-25kms) which actually necessitates the need for localized processing of biodegradable Municipal solid waste.
- A ward is a commercial hub of City and gets a large floating population which comprises of all the strata of the society from all parts of Mumbai and encourages hawking, eating houses etc.
- Offices of most of the Central and state government as well as private companies are located in 'A' ward, thus bringing in substantial number of floating population everyday. The canteens of these organizations generate lot of wet waste, which is lifted by MCGM in a mixed form.

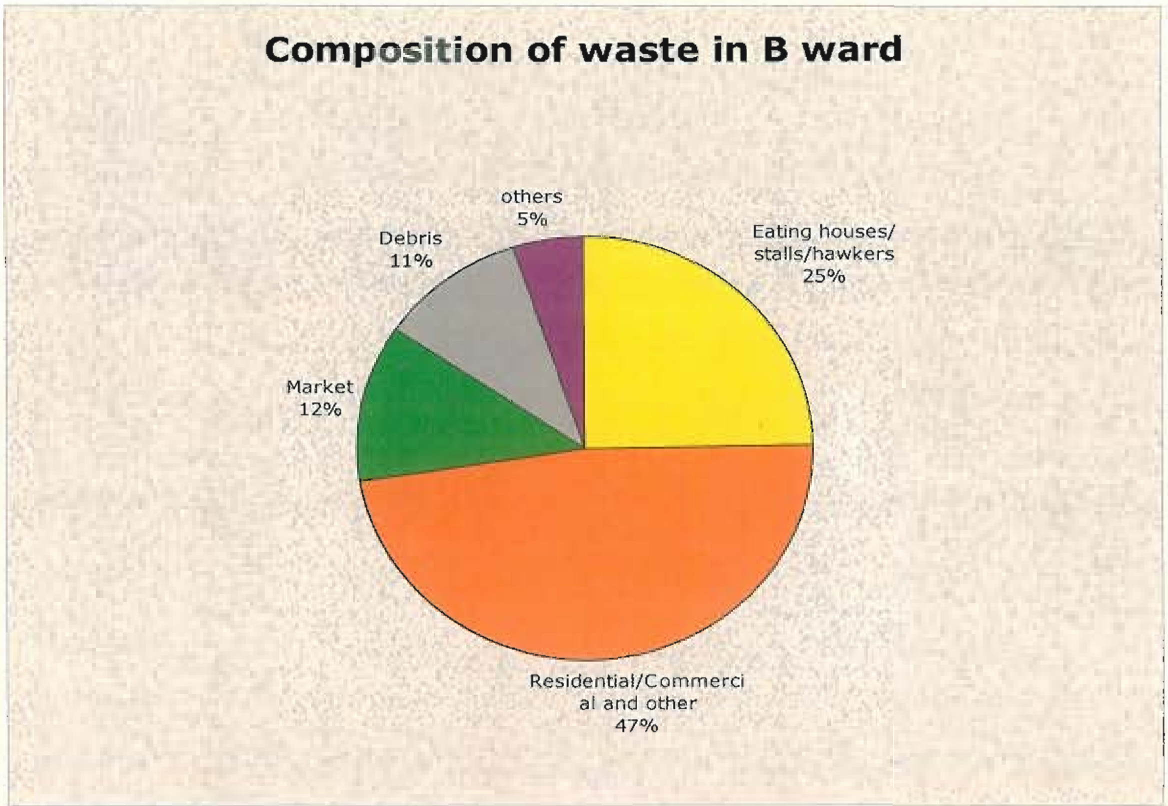
- Most of the wholesale markets of foodgrains, stationary, cloth etc. are located in B ward thus increasing the floating population in the ward. In fact the floating population in this ward accounts for more than the residential population per day
- C ward is somewhat similar to that of B ward. Both the wards are very small and are very much congested as compared to other wards in the limit of Municipal Corporation of Greater Mumbai.
- Large number of eating houses generating huge quantities of bio-degradable waste in all the three wards, which is considered to be rich input for any biomethanation plant.
- The three wards together represent both the rich as well as poor (Lower class) community, which could be considered as a representative of the entire Mumbai.
- **The wards have been finalized after suggestions made by the then Commissioner, MMRDA and the MMR Environment Committee.**

Composition of Waste at a few sample wards studied in this Report:

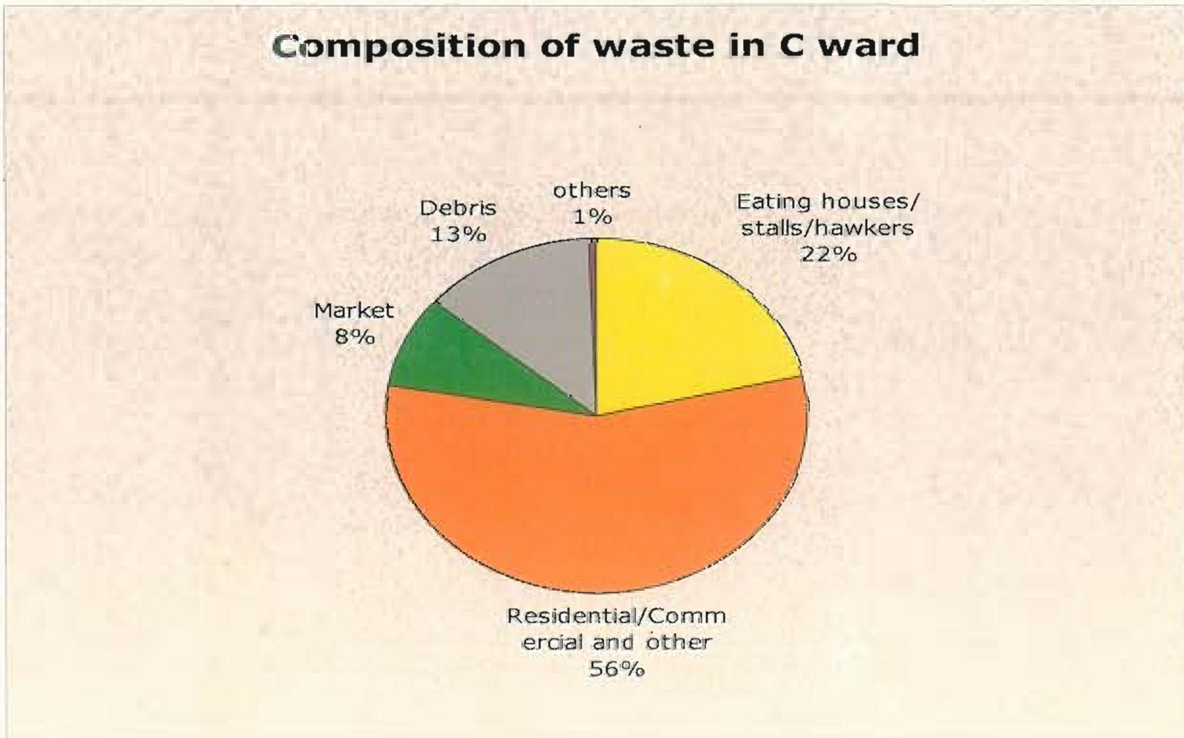
Estimated composition of waste based on the survey and vehicle trips in 'A' ward



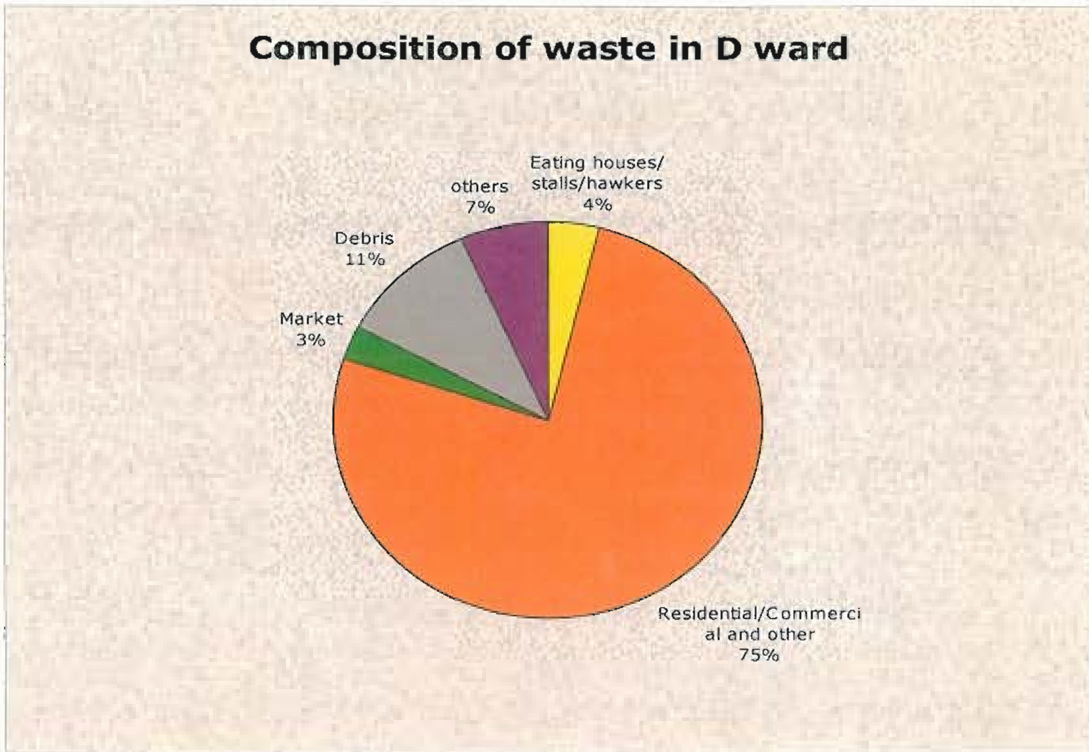
Estimated composition of waste based on the survey and vehicle trips in B ward



Estimated composition of waste in C ward based on survey and discussions with the Officers of Solid Waste Department of the ward.



Estimated composition of waste in D ward based on survey and discussions with the AHS and DyHS (SWM Dept).



(Unit: Tons per day)

No	Sources of Municipal Solid Waste in wards in South Mumbai	Weight Apprx	Weight Apprx	Weight Apprx	Weight Apprx
		A Ward	B Ward	C Ward	D Ward
1	Eating houses/ stalls/hawkers	127	35	65	15
2	Residential/Commercial and other	215	68	170	285
3	Market	25	17	25	10
4	Debris	30	15	40	40
5	Others	2	7	2	25
	TOTAL	**399**	**142**	**302**	**375**

Source: (from all the AHS of respective wards, DyHS, HS and SWM dept of MCGM - latest updates have been included – 24/08/06)

It can be seen from the above Four diagrams/table that eating-houses and markets constitute a relatively larger share of the total waste generated in a ward after residential waste. The waste generated from eating houses and markets is generally biodegradable and generated in bulk from limited number of sources. It gets mixed with other types of waste as at present MCGM does not have a separate collection system for this waste. Whereas residential waste though the overall quantity is large, it is generated from a large number of sources in a mixed form.

At present smaller quantities of mixed waste would involve disproportionately high amount of effort and cost to segregate and it would require a sustained communications, education supported by vigilance.

Hence we have decided to concentrate on the waste generated from hotels and restaurants and markets in the first phase. This segment presents an opportunity for the waste to be considered as a raw material with a value rather than a nuisance.

Though we have studied these wards in detail, our focus has been mostly on generation, collection, transportation and disposal of institutional wastes like Market Waste and Hotel Waste. Major waste generators in each of these three wards are Markets, Hotels and restaurants.

Comparative information on the wards in zone I

No	Ward	Unit	A Ward	B Ward	C Ward	D Ward	E Ward	Total
1	Area	Sq.km.	12.50	2.47	1.78	6.63	7.4	30.78
2	Population	Lacs	2.10	1.40	2.02	3.82	4.40	13.74
5	No. of eating houses	Number	656	237	296	431	863	2483
6	No. of food markets (only Municipal)	Number	4	2	3	2	6	17 Mun markets
7	Refuse (total mixed waste)	Tons/day	399	142	302	375	476	1694
8	Offal*	Tpd-zone I	---15---					
9	Market	Tpd-zone I	---45---					

Source: SWM department, MCGM
(latest updates as on 24/08/06 are mentioned in the table above)

Note: *The figure is based on the trips made by offal van in South Mumbai. The private chicken/ mutton shops and markets, which do not get separate lifting service by MCGM, dump their waste at the collection spots. That mixed waste is not counted here.

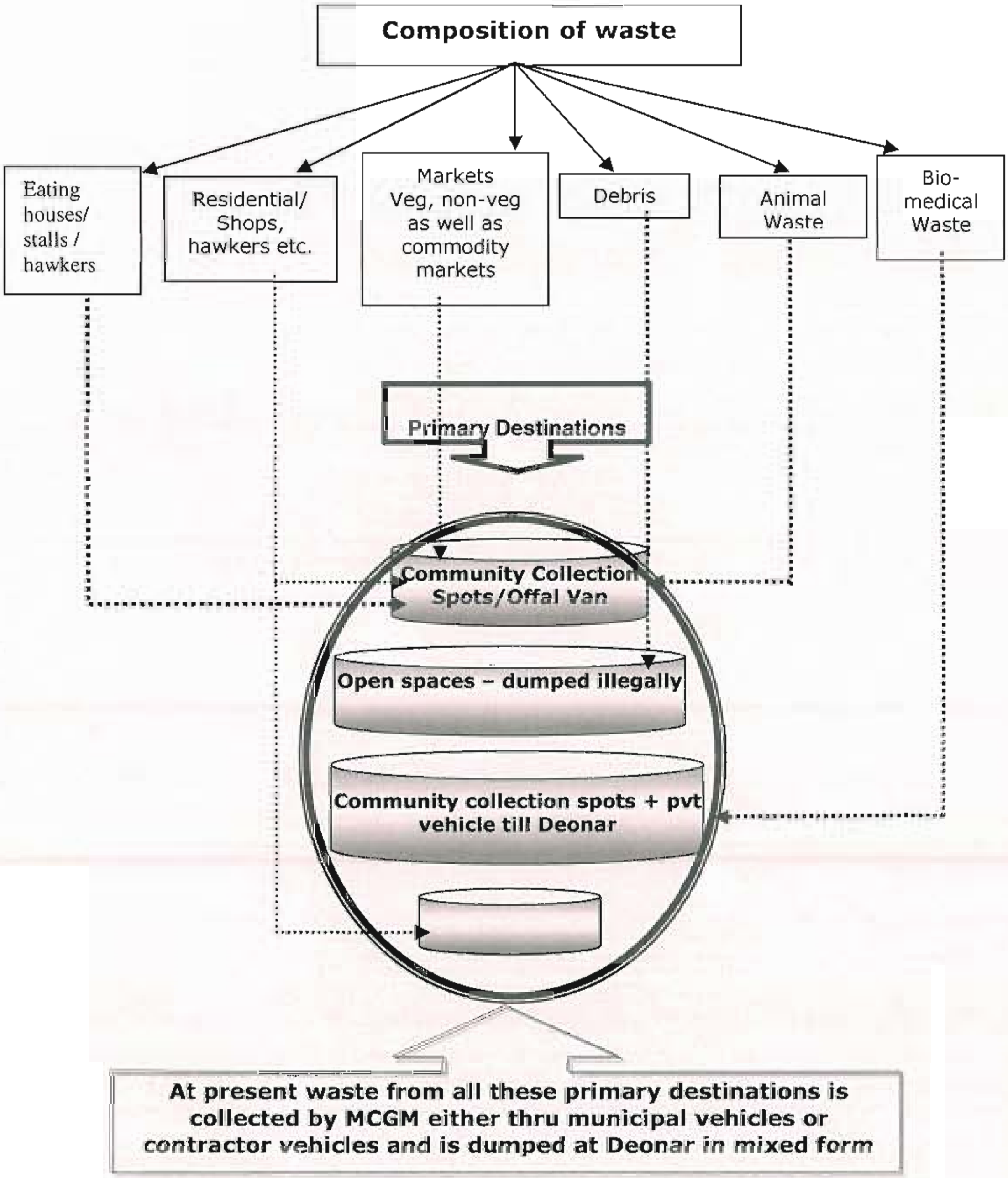
The total mixed waste is inclusive of the market waste but just to give an idea of the amount of market waste available in zone I, it is mentioned separately.

Separate sheets have been attached with the note as Annexure D- G giving details about the institutional waste – residential, market waste, eateries and nirmalya.

In order to understand how to collect and transport the waste in a segregated manner, MEDC decided to study the pattern of waste generation, collection systems and disposal of waste for A, B and C wards of Municipal Corporation of Greater Mumbai (MCGM).

Chapter No 3

Composition of Municipal Solid Waste and its Disposal in Mumbai



Existing Processes of Solid Waste Management in a ward

The Municipal Corporation of Greater Mumbai (MCGM) is formally responsible for the management of waste in the city. The prevailing approach has been one of collection and disposal that is, garbage is collected from communities by the municipal authorities and disposed off at the three main dumping sites that are currently servicing the city. Garbage collectors employed by various housing societies manually collect the waste generated at the household level and dump it in the garbage bin at specified street corners. There are around 5,800 community bins in the city. In case of South Mumbai, trucks collect garbage from the garbage bins and transport it to a transfer station, which is located in Mahalakshmi. A separate transport is arranged for transferring the garbage from Mahalakshmi to the northern part of Mumbai where the dumping grounds are situated. From all other parts of the city, garbage is sent directly to the dumping grounds. Nearly 95% of the waste generated in the city is disposed off in this manner. This largely manual operation involves 35,000 personnel employed by the MCGM and is collected by a fleet of 800 bigger vehicles, including vehicles hired from private contractors, that work in shifts each day. MCGM spends about Rs. 15-20 lakh per day on collecting and transporting garbage and debris with municipal and private vehicles making about 2,000 trips every day.

Current system at a municipal ward is geared to collect the garbage in whichever form it is available primarily from the collection points.

Source of Waste at the community collection point -

1. Hotels & restaurants
2. MCGM Section waste
3. Residential population who stay close by
4. Waste from unauthorized markets
5. Waste from hawkers
6. Waste from unauthorized slaughter shops
7. Debris generated from building demolitions/constructions or household/building renovations or debris generated from road digging

Municipal vehicles as well as private contractor vehicles collect and transport mixed waste from various collection points in a ward (there are 21 such points in B ward) to the dumping grounds. Today Solid Waste Management Department has 38000 staff,

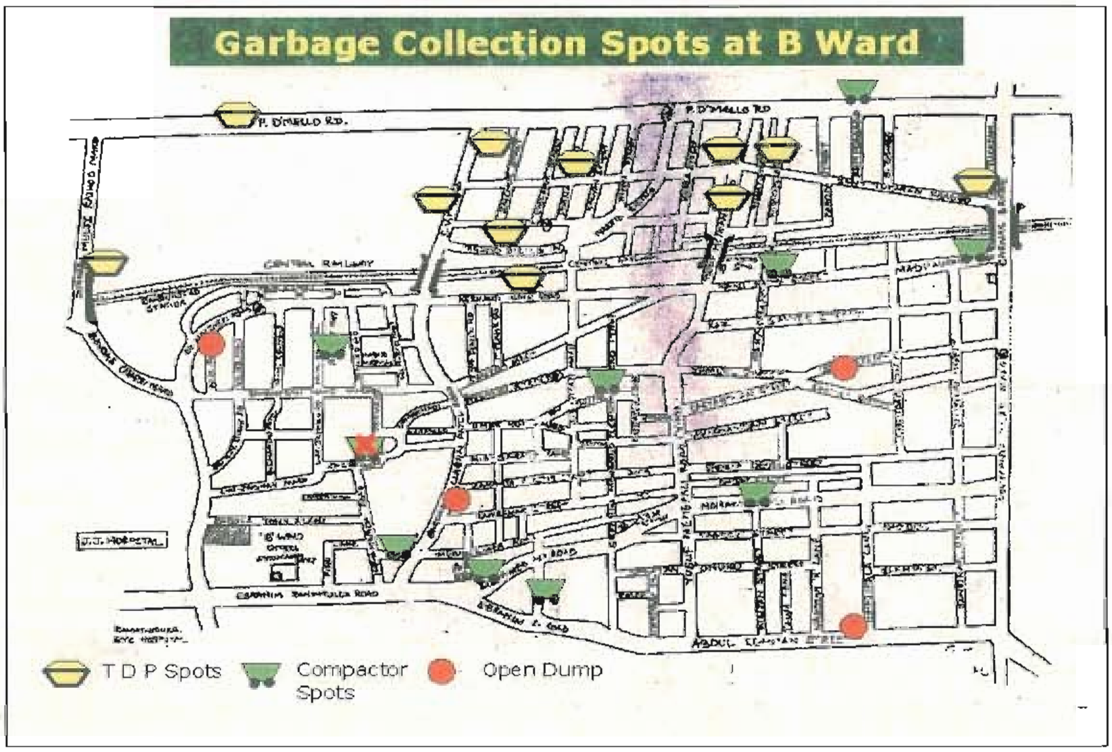
which is very large by any standards and it is necessary that we should optimize this number in the long run thru attrition and redeployment but without causing any loss of jobs.

Present System of Collection and disposal of Solid Waste in B Ward :

The ward has adopted 4 systems for the collection and disposal of waste generated in the ward.

1. **Compactor system (Privately managed by Do it Associates)** – These compactors can carry 8 tonnes of waste, which is not effectively compacted. Compactor attends 10 sheds and 3 open dumps out of which 4 sheds and 1 open dump are very critical with heavy generation of waste. **These compactors are old compactors and do not provide DIN standard bins lifting arrangements.**
2. **Tempo (Privately managed by M/s DCON India Pvt. Ltd.)** – Having a capacity of 1.5 tonnes waste (35 baskets with 85 ltr capacity each) 5 tempos – 2morning+2afternoon+1night
3. **TDP – (Municipal)** – Having 2.5 tonnes of waste capacity. TDPs are placed at 10 places in the ward having total number of 15 TDP containers served by 4 TDP vehicles
4. **Dumper lifting thru JCB (Municipal)** – Having a capacity of 8 m.t. 3 dumpers are provided twice a week

Community collection spots in B ward have been illustrated in the graph given below:



(Note: Visual mapping of the garbage collection spots has been worked out on the official map of the ward provided by the Asst Municipal Commissioner of B Ward)

The residential waste as well as the waste generated by the vendor gets dumped at the collection spots at different times of the day. The hotel waste, which is a relatively segregated wet waste, is also dumped at the collection spots and gets mixed with the other waste at the spot.

Quantity of waste lifted by Private contractor at B ward per day

No	Vehicles	Responsibility	Service Provided	No of collection spots	Capacity of Vehicles tpd	Qty of waste lifted (tpd)	Destinatn from ward
1	Compactors (5nos)	Private (Do it Associates)	11 time/day 3 shifts (5+4+2)	14	88	69*	Deonar (19.75km)
2	Tempo (3nos)	Private (M/s D CON India Ltd)	5 shifts per day X 3 trips/shift/vehicle (2+2+1)	As per program given by JOs	22.5	18 (apprx – 3.5 tonnes/ shift/vehicle	At C ward – BRC or TDP in the ward itself $
				Waste lifted by pvt contractor (tpd)	110	87	

Waste lifted by MCGM at B ward per day

No	Vehicles	Responsibility	Service Provided	No of collection spots	Capacity of Vehicles tpd	Qty of waste lifted (tpd)	Destinatn from ward
1	Dumper (3nos) (Lifting thru 1 JCB) – for Conservancy dept**	Municipal	Twice a week X 2 trips per dumper	As per program given by ward	13	10 (Not sure– no documentation at ward)	Deonar (19.75km)
2	TDP (15 containers and 5 TDP lifting vehicles)	Municipal	20 TDPs as per the TDP lifting program	10	50	45 (Sometimes tdps are lifted when they are not full)	Mahalaxmi Transfer station
				Waste lifted by Municipality	63	55	
				Grand total	173.5	142	

*Average as per ward record for the month of August to December 2005
** Excluding dumper details from maintenance dept
Breakdown of waste going to C ward station or within B ward itself is not possible as it varies in the range of 3+15 to 8+10.

Photos of some of the critical collection spots in B ward:



Present System of Collection and Disposal of Hotel Waste in B ward :

Hotel Waste

There are around 233 hotels in the ward registered with the ward office. Besides these, there are a large number of small movable eating joints such as tea stalls, coconut stalls, sugarcane juice stalls etc. (called as Tapryas). There are also a lot of stalls of non vegetarian eatable items such as kabab and meat stalls.

As per our survey and discussions with the ward authorities, the total generation of hotel waste in the ward is around 35 **tpd.** This includes waste generated by the tea stalls, sugarcane juice and coconut vendors as well as a large number of non-veg eatable stalls.

All the vendors dump their waste at the collection spots at different times of the day. The hotel waste which is a relatively segregated wet waste is also dumped at the collection spots and gets mixed with the other waste at the spot.

As per the suggestion of MEDC, MCGM has started a night tempo service for 27 hotels located in the vicinity of Memonwada collection spot. The total waste collected is around 2.5 to 3 tonnes.

Correlation between Trade Refuse Charge and Waste generated by a hotel.

MEDC carried out a detailed survey of around 100 hotels and eateries as well as small food vendors located in B ward. As per our survey and discussions with the ward authorities, the total generation of eating houses in the ward is around 35 tpd. This includes waste generated by the tea stalls, sugarcane juice and coconut vendors as well as a large number of non-veg eatable stalls.

MCGM collects Trade Refuge Charge (TRC) from the hotels vendors for undertaking disposal of waste generated by them. This TRC is charged on the basis of grade and area of the hotel rather than waste generation by them.

Correlation between Trade Refuse Charge and Waste generated by a hotel

MEDC has carried out survey of a large number of hotels located in B ward. We observe that there is no direct co-relation between the waste generated by a hotel and the TRC paid by it. Following table gives a comparison of the same:

No	Name of the Hotel	Grade	Area Sq.mt.	License Fees (Rs/annum)	TRC (Rs./annum)	Waste Generation (Kg/day)
1	Govinda's Shree Durga Bhavan	I	91	1345	12105	80
2	M/S Vishwaraj restaurant and Bar	I	36	820	7380	40
3	Chetan Restaurant & Bar	I	203	3025	27225	50
4	Hotel Parijat	I	68	1345	12105	40
5	Hotel Bumper	I	71	1345	12105	180
6	Ruchi fast Food	II	22	820	4920	10
7	Hotel Shalimar	III	480	3025	9075	1000
8	Café Almas	III	130	2130	6390	80
9	Bharat Lunch Home	III	74	1345	4035	10
10	Hotel Nityanand	III	174	2465	7395	50
11	Lime & Spice Restaurant	III	68	1345	4035	30

It can be seen from the above table that the TRC is charged in multiples of license fees which is directly based on the area of the hotel and the grade. The grade one hotels are generally bars and permit rooms which do peak business during evening hours. The waste generated by the restaurants with bars and permit rooms is much less as compared to that generated by the food restaurants. However the TRC charged for the bars and restaurants is much higher than that charged for the ordinary restaurants, which generated much, more quantity of waste.

TRC is also applicable to hawkers. Monthly TRC is three times the license fees and is deposited by the hawkers quarterly. (MCGM is now changing over to monthly deposit of TRC by hawkers). As per our study of ward records (registers maintained at the ward, not supposed to be taken outside the ward premises), on an average hawkers pay a TRC of Rs. 400-450 per month. This amounts to Rs. 3600 per annum. As compared to the TRC paid by the hotels, this TRC is very high when the waste generated is very less.

Since there is no separate collection system for collection and disposal of hotel waste which is relatively segregated and biodegradable and which could serve as a good raw material for a biomethanation or composting plant, gets mixed with all the other types of waste at the collection spots.

As per the suggestion of MEDC, MCGM has started a night tempo service for 27 hotels located in the vicinity of Memonwada collection spot. The total waste collected is around 2.5 to 3 tons.

Though the detailed survey was undertaken for B ward, similar observations recorded in our cursory survey of other wards.

Study of Market Waste in B ward

There are 4 markets in the ward –

- J B Shah Market (Municipal Market)
- Dongri Municipal Market (Municipal Market)
- Char Nal Market (Unauthorized market)
- Vegetable market at Lokmanya Tilak Marg near Crawford Junction (Unauthorized market).

Other commodity markets are situated on Narsi Natha street, Keshvji Naik Street, Nagdevi street and Abdul Rehman street. The commodity markets have more generation of dry waste which is picked up by the rag pickers at some of the collection spots especially at TDP spots.

J B Shah Market is a wholesale market and mainly has a sale of spices, food grains and fruits whereas Dongri market has a sale of food grain items, vegetables and also sizable amount of non-veg (chicken, mutton and fish). J B Shah Market is located besides Masjid Bunder Railway station which is mostly commercial and wholesale market area and Dongri market is located in an area near Sandhurst Rd station which is a combination of residential population and commercial activities. Only common situation in this is both the markets are cleaned by labour from Market dept. This entire market activity is not under the charge of ward authorities. Both these markets contribute a small share of waste at the collection spots named after the markets. Lot of waste is section waste and then the waste from hotels and hawkers in the surrounding areas. J.B. Shah Market has 120 shops out of which 38 are big store rooms (warehouses) whereas Dongri Market has 152 shops. The non-veg waste generated in Dongri Market is collected by an offal van, which collects the offal waste twice in a day.

Dongri Market

1. The market generates around 2 m^3 waste which is mixed in nature
2. This spot was created only for the market waste but it is used for dumping of BMC section waste, hotel waste from the hotels in the vicinity, non- veg waste from the mutton, chicken stalls (authorized/unauthorized) and residential waste
3. A shed has been constructed outside the market from the local corporator's fund but the surface is uneven
4. There are total 152 shops out of which 45 belong to fish vendors, 22 mutton shops and 10 chicken shops make it a market with more sale of non veg items
5. This shows that the market generates more of non-veg waste rather than the green vegetable waste
6. The sweeping and maintenance of the market is done by the market department and the ward doesn't have any control on the market
7. Eventhough the market is cleaned by the market labour, the waste other than nonveg waste is lifted by conservancy department from the community collection spot outside the market
8. An offal van comes to lift non veg waste twice a day
9. Generally 2 trolleys are kept on the spot outside the market
10. Private compactor attends the spot in 3 shifts – morning, afternoon and night

Many a times rag pickers are seen on the spot who segregate dry waste which has resale value – these rag pickers are mainly drug addicts and female rag pickers are hardly seen on the spot

Chapter No 4

Segmented Approach to Waste Collection

Based on our research on the waste generated in four wards which has been discussed in the earlier chapters, eateries and food, vegetable and animal product markets generate a lot of mostly bio-degradable waste in a concentrated fashion. Current waste handling system mixes such waste with dry and other waste (primarily debris) and transports all the mixed waste to Deonar and other dumping grounds. It is virtually impossible to obtain segregated waste from residential areas with the exception of a few isolated efforts in some of the residential colonies either as a result of individual effort or thru Advance Locality Management.

(A recent survey conducted by NGO Clean Sweep on behalf of All India Institute of Local Self Government indicated only 50 housing societies/lanes or a group of houses observe segregation in a serious and sustained manner. We believe that such effort can be significantly increased but such residential areas should be encouraged and incentivized for establishing vermin or ordinary bio compost pits within their own premises).

But high volume eateries whether 5 star or other high volume low priced eateries – Biryani and kabab joints, high turnover Udipi restaurants, party catering, and markets as well as unofficial slaughtering provides a good opportunity to obtain mostly segregated bio-degradable waste in a large quantities in a concentrated manner which can be handled as a raw material by bio-methanation plant.

In fact, for the MCGM, preventing 500 kg or more wet waste from one location will not only reduce the transportation load of bio degradable waste but also reduce the load of dry waste which would be then easy for the rag pickers or a contractor to pick it up easily in a dry manner with ease and less handling cost. Thus handling one ton of segregated waste is equal to collection and disposal of approximately two tons of waste in a more hygienic and environmentally correct manner.This would improve the earning of ragpickers (waste pickers). A good quantity of quality dry waste segregated in more hygienic manner will give justice to the unorganized sector of the rag pickers in terms of monetary gains from the scrap vendors and also will give them the basic human right to live and work in a hygienic environment. (A simple observation during our field survey has brought out that Plastic bottles fetch a price of around Rs. 9-10 per kg. But a cleaned plastc bottle fetches a price of Rs. 15 per kg. The caps separated from the plastic bottle fetch a price of Rs. 22-25 per kg.)

There is an urgent need to adopt institutional waste management system. Current situation is not very much encouraging to start immediate implementation of segregation at source and adopting waste processing activities. We hardly get to see any coordinated and sustained effort in the direction of advertisement campaigns, people participation, formation of ALMs in large number, fining practices etc. Therefore waste management at the household level will be a wishful thinking at present. But to start collection of segregated waste, high volume waste generators need to be targeted in the first phase. Eating houses, which serve more than 1000 meals per day should be brought under a common system, also markets needs to be attended separately.

We would like to recommend following segmented approach :

No	Waste Generators	Details
Segment I		
1	VIP Waste Generators	a) Hotels, restaurants, clubs, canteens and hospitals serving more than 1000 meals/day b) Marriage Halls
2	Markets selling food articles ***	a) Vegetable, Fruit and flower markets b) Non-veg Markets for fish, meat and Chicken c) Commodity Markets
3	Other Commercial market	
Segment II		
4	Residential Waste	a) Housing Complexes with more than 50 flats b) Smaller housing colonies with less than 50 dwellings
Segment III		

5	Lower segment	a) Chawls b) Slums
Segment IV		
6	Other waste at community collection spot	a) Non bio degradable and non recyclable
Segment V		
7	Debris	a) Building constructions/renovations

Segment I and II need attention in the first phase especially for a plan for bio degradable waste as it is comparatively easy to obtain mostly segregated waste in a sizeable volume in a concentrated manner. Further, these generators can be identified and can be made accountable. Besides, they can afford to pay for /provide management inputs as well possibly some space or some intermediate segregation processing and possibly captive use of gas at site (wherever possible) and captive use of manure (in some cases – especially clubs).

Thus volume, accountability and possible use of end product make this segment appropriate for localized plants for recycling of such waste. By training, making rules and provision of positive and negative incentives, it is possible that we can ensure start

and will have a potential to be a sustainable effort in the longer run. If we assume that there are 2000 housing societies in Mumbai with minimum 50 flats then the dwellings go upto 1 lac (with min 4 persons/dwelling = 400000 population). This will cover 3% of the total population in Mumbai (Pop of Mumbai - 1,20,00,000). This calculation further strengthens the 'segmented approach'. Segment I and II are easy to start with and remaining segments need lot of sustainable efforts.

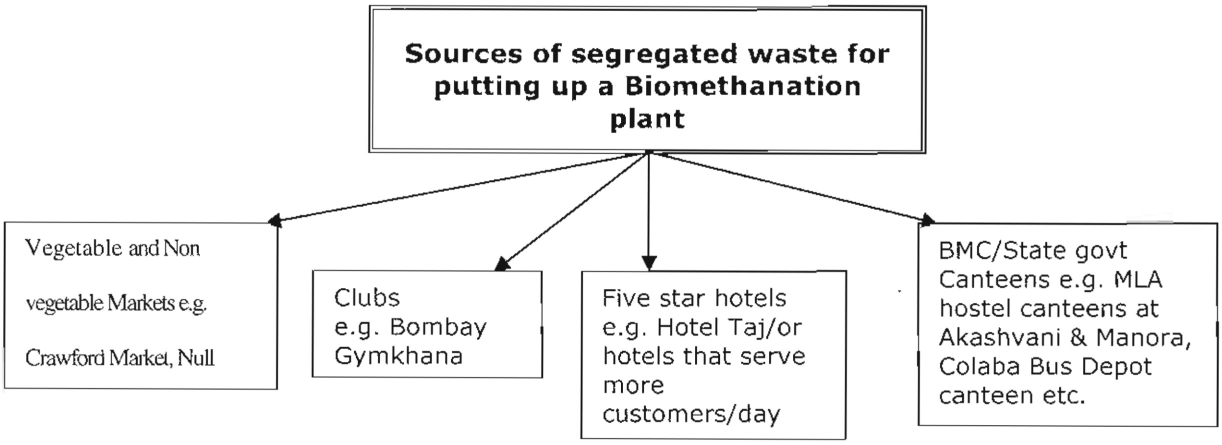
Segment I

Private High Volume waste generators: Private high volume waste generators include big institutional waste generators such as eateries where more than 1000 meals (equal to at least a value of Rs. One lakh) are served per day. The Principle of EXTENDED PRODUCER'S RESPONSIBILITY should be applied and such establishments should number approx under 2000 in Mumbai. They will have to absorb entire food waste either within their own premises in a manner/method approved by MCGM or should tie up with one of the approved waste recycling agency (using an approved method of conversion of food waste at a permitted place) within the city but the performance and cost responsibility has to be that of the establishment. All the institutions following such practices should be charged a nominal Trade Refuse Charge, whereas those who do not follow after adequate period should be subject to penal charge equal to approx Rs. 2/kg of waste.

Planning at the micro level

Proposed System for Collection of Hotel and Restaurant Waste in a segregated Manner

Sources of segregated waste



Hotels and Restaurants share a major portion of the total waste generated in any municipal ward. Our study on hotel waste (eating houses) reveals that this waste is mostly biodegradable and is relatively segregated. This gets mixed when dumped at common collection spots. 'A' ward has more number of five star hotels. Hotels such as Taj Mahal Hotel, Hotel President as well as major eating joints in B ward such as Shalimar and Delhi Darbar generate around One tonne of waste per day. These hotels also have private contractors to take care of their dry waste, which pays Hotel Taj around a lakh of rupees per month. The waste which is rich but doesn't pay anything in monetary terms gets neglected at all levels whether a five star hotel or some Udipi restaurant or a bhatarkhana. Food waste is an ideal raw material for a Biomethanation plant and hence should be collected in a segregated manner from the source of generation.

In some of the wards the conservancy department gives service to some of the hotels/restaurants but mostly this waste is not segregated waste. In A ward the hotel waste service provided by Conservancy Dept collects around 50 tons of waste per day. Which means if this waste comes in properly segregated manner then more than 25 tons of waste can be processed at the nearby location but the 'proper segregation' is the important factor in all this activity.

We would like to recommend following action plan for management of solid waste for high volume segments:

1. MCGM should make segregation of waste mandatory for Hotels and Restaurants
2. MCGM should provide a vehicle to collect this waste in segregated form
3. As far as possible the eating-houses and restaurants should be asked to manage their waste themselves. Land requirement should be fulfilled by MCGM but the ultimate responsibility of the waste management should be with the restaurant.
4. Defaulters should be fined heavily – Different departments of MCGM such as MOH, License, Conservancy etc. need to give coordinated effort
5. The grading of the hotels should be done also on the basis of the area and the number of customers catered by them rather than whether it is a only a bar or a normal restaurant.
6. The TRC should be charged on the basis of waste generated by the hotels than linked with the license fees. There could be a SWM cess for the waste generated by the hotels within the overall license fee.
7. Since MCGM is the licensing authority for the hotels/eating houses, the segregation of waste by hotels should be strictly enforced. Each hotel should be forced to install separate bins for wet and dry waste. These bins could be standardized to suite the direct lifting by the compactors.
8. The eating house wet waste should be collected directly in a segregated manner by MCGM and it should be dumped at common collection spots in the ward, where it will be further processed into composting in the first phase and biogas in the second phase.
9. The eating houses for which MCGM provides the door-to door service should be prohibited from dumping their waste on the collection spots. In case they have to dump the waste at the collection point, it should be with the prior permission from AHS (repeated requests should qualify the eating house for a fine. The timings must be adjusted with the compactor/tempo timings)

Incentives in the form of rebate in TRC to be provided by MCGM for giving segregated waste by the hotels.

Market waste:

As markets offer large volumes of mostly segregated waste per location, the same can be easily transported in a segregated manner and linked to a neighborhood privately operated Biomethanation/vermin compost plant. Depending upon the quantity of the waste it can be either used for composting or Biomethanation. Decentralized composting with public and NGOs participation, may be encouraged wherever possible, and centralized composting of the rest of the waste may be done. Microbial or Vermicomposting processes may also be adopted. A variety of composting options are available.

Municipal markets in Mumbai are a combination of sell of veg and non-veg food items. There are total 17 municipal markets in Zone I which account for more than 3000 shops and more than 20 tons of mostly biodegradable waste. The waste generated at these markets is relatively more segregated but under the current system it increases "the mix coefficient". Crawford Market with 1154 shops and Sant Gadgebaba Mandai i.e. the Byculla Market with 530 shops, are the huge markets in Zone I.

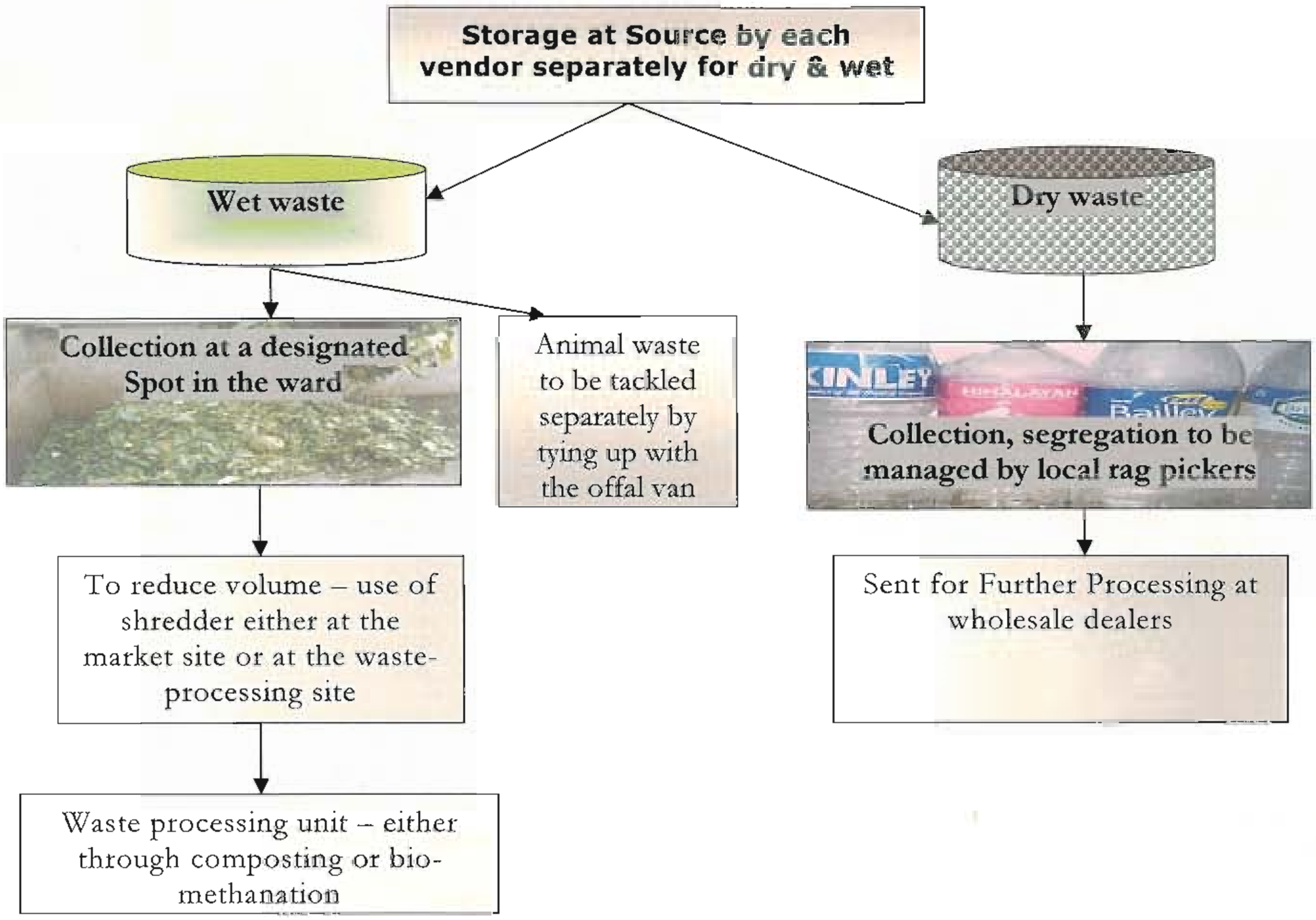
It was observed that, the garbage management activity at the Markets is carried out by Market Department, which does the sweeping and cleaning of the markets and, Conservancy Department, which does garbage lifting from the community collection spots outside the markets. Some markets where there is a sell of non-veg food items such as fish, chicken, meat etc., get a separate waste collection service by the offal van. And other vegetable markets dump their waste at the collection spots outside the markets.

The markets generate three types of wastes namely,

- Vegetable and Fruit waste,
- Non-veg waste generated from fish, meat, chicken and,
- Dry waste generated out of packaging

Out of the above 3 types first two are purely biodegradable and considered as a rich raw material (r.m.) for a Biomethanation plant. While municipal non-veg selling markets have a system for collection of Non-veg waste by offal van, which collects the animal waste and transports it to Deonar. Biomethanation plant set up at Deonar is built to take care of the animal waste generated at the Deonar Abattoir and waste collected by the offal van is dumped at the dumping ground. However, MCGM does not provide a system for collection of animal waste generated out of unauthorized slaughtering which eventually gets dumped at the community collection spots. MEDC would like to recommend following system for collection of market waste. Separate route for the market waste needs to be tracked. And non-veg waste and vegetable waste should be collected separately at least of the municipal markets and then same system can be adopted for the private markets or unauthorized markets.

Proposed System for Market Waste



Segment II

Housing Societies/colonies: Housing societies and colonies should be encouraged/compelled to have onsite processing of biodegradable waste either by composting or vermicomposting. In 'A' ward there are some big colonies such as Navy Nagar, Army, BPT etc. There are schools, markets, offices etc situated in these colonies. MCGM provides compactor service twice a day to the Navy Nagar colony. There are total 45 bins inside the colony, which accounts to more than 20 tons of mixed waste per day. These colonies have open spaces where waste processing can be done. It is also observed that BPT colonies are spread over in large areas some of them are at prime locations such Colaba. BPT mostly lifts the garbage in their premises thru private contractors but the dump the waste at Municipal Dumping grounds.

Segment III

Chawls, slums and house gallies: Dattak Vasti Yojna should be followed.

Segment IV

Community collection spot: Only non-recyclable and non-biodegradable waste should go to community collection spots. If segment I is tracked properly then the load on the community collection spots will be reduced to a great extent and then it will be easier to have segregation at the collection spot itself.

Segment V

Debris (Construction and Demolition Waste): Though Debris management is beyond the scope of this study , we have suggested a few recommendations for management of Debris as this forms a substantial part of waste collected at common collection spots and gets mixed with biodegradable waste.. MCGM has already developed and implanted a system for collection and disposal of large quantity of construction debris.

This category of waste comprises of waste generated as a result of new construction, renovation, demolition and reconstruction activities comprising of sand, gravel, concrete, stones, bricks etc. The management of construction and demolition waste is a major concern for Mumbai Municipal Corporation due to the increasing quantum of debris, continuing shortage of dumping sites and increase in transportation and disposal cost. Re-utilization or recycling is an important strategy not only for management of such waste but also to address the issues of depleting reserves of conventional natural aggregate and related environmental impacts. Recycled construction material and technology can play a significant role in the development of urban infrastructure.

In Mumbai, every day 2,000 tonnes of debris is generated officially, of which some part goes to the dumping ground for spreading over the organic garbage, as earth is expensive. The remaining debris is spread next to the roads, in the creeks, next to railway tracks and on open grounds. Every day, somewhere or the other, in some building, some renovation takes place, generating debris. This could be of houses or shops; it could be for repair of buildings or demolition of old buildings for reconstruction. This type of demolition waste can be used either in filling low-lying areas or for reclamation. Presently, though MCGM has a system for monitoring renovations and repairs, it is rarely followed strictly. The concerned housing societies give the permissions for the renovations / repairs; hence, no data is available on this. The only regulation, which has been imposed by the Corporation, is that the area where the repairs, renovations and new constructions have happened, needs to be cleaned up from all wastes, after the completion of work. There are truckers who earn a livelihood by collecting this debris and transporting it for disposal. However, disposing it off properly remains a concern, as there is very little space in Mumbai. It has to be carted over long distances, which increase transportation costs so significantly as to make the entire "business" unprofitable. So it is dumped clandestinely in the creeks, thus, destroying our valuable mangroves. As Mumbai has a coastal stretch of 603 sq. km, it has numerous creeks. These are channels of water which occupy marshy land during high tide. The salty water occupies the land during high tide and drains off during low tide. This nurtures plants called mangroves. These plants, in turn, have leaves which provide oxygen to the water for fishes to breed in the creeks. In many areas, like Versova, Gorai, Charkop and Mankhurd, the entire eco-system of the creek has been destroyed as waste is dumped surreptitiously.

Increasing prices of land and more construction activities are forcing the demolition of old structures and building new structures and creating more debris wastes. Debris, being very bulky in nature, requires more space, reducing the life span of the dumping ground. Therefore, municipalities, generally, refuse the entry of debris into dumping grounds other than what they need to cover the garbage. Finding few viable alternatives, people just dump the debris by roadsides. Over time, people start dumping organic waste on top of debris not only compounding the waste disposal problem but also creating a health hazard.

Debris Dumping depots for each ward will at least solve the problem of illegal dumping of debris on the roads, house gullies and footpaths. These depots should have separate places allocated for segregation of debris so that the type of debris suitable for making paver blocks or bricks can be collected directly and processed further. An NGO person /consultant may be appointed as a supervisor for this depot on contract basis who will be paid by MCGM and should be responsible for the debris management at the depot.

Chapter No 5

Some other Aspects of Effective Collection of Municipal Solid Waste:

Cost Recovery from users for waste management services and Incentivization

Fees structure for Solid waste management: Currently MCGM is not charging anything for residential properties other than TRC, which is being charged for eating-places. Solid waste management fees should be levied on all households in a range of Rs. 5/(for slums and chawls)- to Rs. 50/ in a graded manner (for flats) per month and out of this,

75% should be given back to the active ALM's, which segregate waste and absorb biodegradable waste themselves. In spite of operational difficulties, it is essential to make people aware that waste must be managed by citizen themselves in a certain manner!

The basic economic, legal and administrative issue needs to be understood and addressed. In south Mumbai for e.g. House gullies involve congested houses with smaller and older tenements with very low rentals (and hence negligible property tax which is used as a base for all the "addl levies") and a lack of reason or motivation for maintenance and cleanliness. Rents and property taxes have been frozen at ridiculously low levels – in fact – quite unrelated to even the incomes of residents.

This should be a policy for the entire city with a separate accounting and auditing and would be considered administratively difficult but it is worth the trouble as a sustainable solution for congested and crowded areas in Mumbai!

To make a real (even if small to begin with) and sustainable progress towards end-to-end handling of waste in a sustainable manner, some difficult but really worthwhile measures need to be adopted.

Education and Communication

MCGM should run a round the year educational and informative advertising campaign thru T.V. and print media primarily aimed at Non English speaking audience. The advertisement needs to be done primarily in Hindi, Marathi, Gujarati & Urdu. The ads should contain information, contests, ALM reporting and items with news value identifying heroes and weaknesses in identified areas. We should avoid slogans and personality cult. This extensive campaign can get major corporates as sponsors. A special interactive website devoted to SWM should also be an integral part of the communication program.

Equipment synchronization:

To avoid all the above-mentioned problems the Waste and transport equipments, bins, trolleys etc., should be synchronized. So that they work seamlessly and flawlessly and they should be uniform. For the transportation of waste, a system that synchronizes with both primary collections as well as waste at the collection spots may be introduced. Manual loading and multiple handling of waste may be dispensed with and

instead, hydraulic vehicles with higher capacity should be introduced for lifting the closed trolleys at the garbage collection spots.

Route Mapping – Designing GIS based garbage movement

Detailed route mapping should be undertaken when adopting a segmented approach towards waste management at a ward level. Route mapping of community collection spots in B ward has been illustrated on page on 16. This should be applied on a much bigger scale to implement the segmented approach towards waste management.

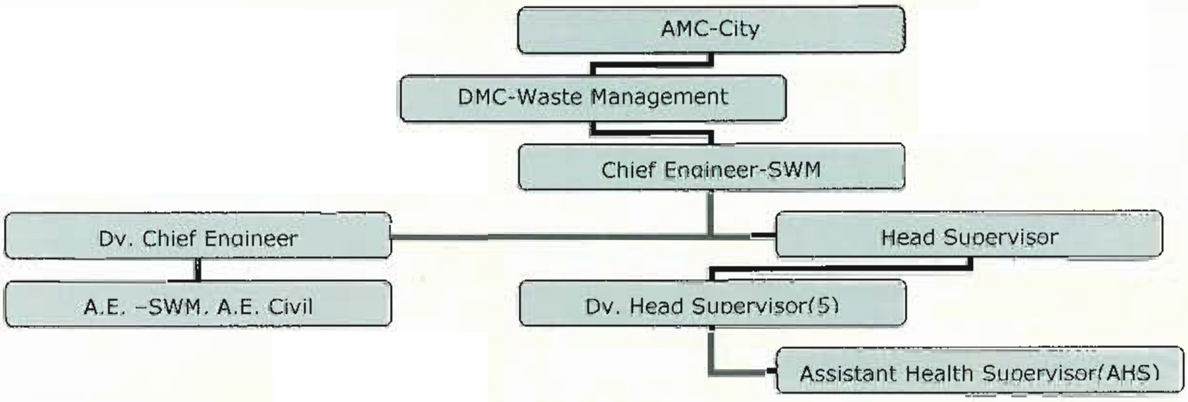
Special layer should be used in the GIS, which should show High volume waste generators such as:

1. Large eateries (serving more than 1000 meals/day)
2. Food Markets
3. Community collection spots
4. Open dumps

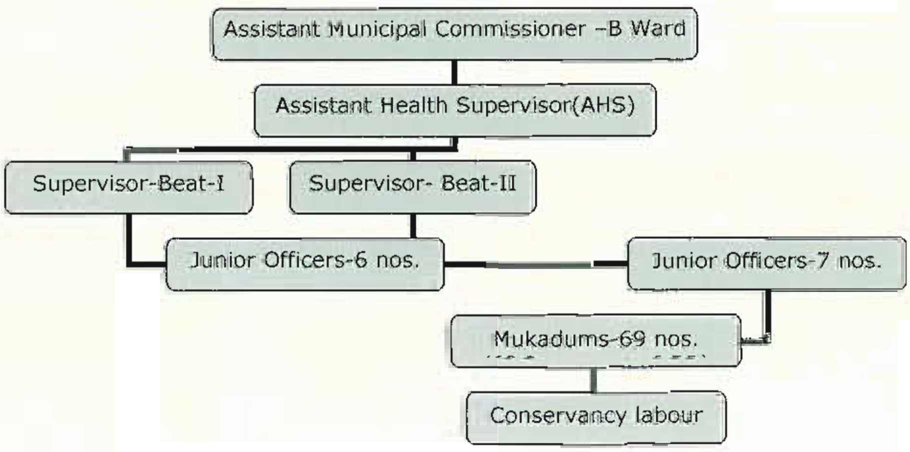
To track the garbage lifting movement of markets, eateries etc. route mapping should be designed considering the minute details of the ward.

Study existing processes, attitudes of people, municipal staff, equipment and how to achieve the desired efficiency and effectiveness thru education, communication, procedures and administrative measures to achieve an acceptable level of efficiency

Structure of SWM Department at MCGM:



Structure of the Conservancy Department at Ward Level – (B ward):



Municipal Staff

It can be seen from the above charts that the cleanliness of the ward is the responsibility of the conservancy department at a ward level but the functional reporting of the conservancy staff is to the Head office. All the decisions regarding the availability of the garbage refuse vehicles, policy decisions regarding indent of equipments, manpower recruitment and wardwise allocation, fund allocation for refurbishment of collection spots etc. are controlled at the head office level. The Asst Head Supervisor (AHS), who is the head of the conservancy department reports to Assistant Municipal Commissioner at the ward level for day-to-day functioning.

Conservancy manpower deployment in a ward

Two types of work is carried out by the conservancy department at ward level namely,

- ✓ i) Road Sweeping
- ✓ ii) Motor Loading- collecting garbage from MCGM community collection spots.

For MCGM properties, there is separate conservancy staff for sweeping, collection of garbage and cleaning of toilets etc. In south Mumbai there exists separate staff for cleaning house gallis.

Details about conservancy manpower in B ward :

There are two types of work carried out by the conservancy department at ward level namely, Road Sweeping and Motor Loading i.e. collecting the garbage at MCGM collection spots. Since B ward has a no. of MCGM properties, there is separate conservancy staff for sweeping, collection of garbage and cleaning of toilets etc. for these municipal properties. B ward also has special staff for cleaning house gallis.

Break up of Conservancy staff in the ward

	Motor Loading	Road Sweeping	Estates	House gallis	Total
Male	58	400	30	79	567
Female	0	146	11	0	157
Total	58	546	41	79	724

Motor Loading (ML Labour)

ML labour is assigned to the compactor and they work in three shifts. There are 7 loaders and one Mukadum with each compactor. The driver and the cleaner is provided by the contractor. The average education level of motor loading staff is upto 10th standard. The Mukadums generally are SSC passed and they have done sanitary inspector's course.

The permanent labour earns salaries in the range of Rs. 7000 to Rs. 10,000 per month. They also get other facilities such as Medical, LTA, PF, gratuity. Motor loaders get an additional allowance of Rs. 75 per month and the night shift staff gets an additional allowance of Rs. 10 per day.

As per our observations of the motor loading staff as well as with the reference of the attendance sheet, on an average atleast three labourers i.e. around 10% are absent from the duty everyday per shift. Hence on an average there are three DR labour for motor loading activity per shift.

Road Sweeping –

B ward has its own road sweeping staff of 404 labour of which 258 are male and 146 are female. The staff works in pairs and each pair covers an area of 2.47 sq. km. everyday. Hence each pair covers an area of **1200 sq. meters**. (Need to get this confirmed.)

B ward is the hub of commercial activity and the centre of wholesale markets in Mumbai. It has commercial areas like Masjid Bunder, Narsi Natha Street, Abdul Rehman street etc. The commercial activity starts by around 11 a.m. The road sweeping shift almost ends at 11 a.m. when the labour returns to the Chowkeys for muster signing and tea break. We have seen hardly any labour returning to work for second round of sweeping after 12 noon. **It will be very important to have a serious relook at the shift timings for B ward. The total labour of B ward can be split to work in two shifts. From 6.30 a.m. to 1 p.m. and a second shift from 2.30 p.m. to 10 p.m. should be introduced.**

B ward also uses NGO labour(20 nos.) for road sweeping activity for the cleaning in the second shift between 2 p.m. to 10 p.m. This labour is paid a compensation of Rs,. 140 per day and they use their own equipments for road sweeping.

In case the shift timings are altered as suggested above, MCGM can achieve a saving of Rs. 10 lacs per annum for the ward.

House Gullies

There are 79 people working for cleaning of house gallis which is permanent labour. There is only one shift and the shift timings are 6.30 a.m. to 1.30 p.m. The staff cleaning the house gallis has to work in inhuman conditions. Many house gullies have drainage leakages and a lot of waste. Some of the house gullies are very narrow making it very difficult for the labour to enter in them for cleanng. The sweepers cleaning the housegallis collect the waste in baskets which are hung to a wooden pole and are carried to the nearby collection spot by the two sweepers on their shoulders. Our discussions with the house galli labour has indicated that some of the staff has been doing this for over past 15 years. This labour is suffering from diseases like T.B. and Asthama.

Waste collected from the house gullies

At present the staff is neither trained, nor really expected to implement the technically correct methods of waste handling. . No check/accounting of quality and quantity of waste collected under the current system of dumping all waste at the community collection spot does not encourage efforts by class IV labour to adopt new ways and means for effective waste management. MCGM has now started providing manning at some Community collection spots, but the manpower is generally not present for the second and third shift of the day.

Current cleaning practices (Based on MEDC observations on A, B and C ward)

- Sweeping is done on all the roads in a ward – One time sweeping is followed in all the wards but at some major roads the sweeping is done in the second shift as well by Contract Labour/NGO Labour
- Municipal sweepers clean the house gullies at regular intervals although they are not able to clean each and every house gully everyday but they do clean them either alternately or twice a week but more than half the number of house gullies in a ward are cleaned everyday
- Municipal sweepers clean municipal properties such as BIT chawls as much as possible which are mostly found in the South Mumbai

- In some wards house to house collection has been started but in some wards like B ward this has not been introduced and may be difficult to introduce.
- Waste generated by eateries and food markets, which is mostly segregated and mostly biodegradable, is dumped at the community collection spots and under the current system it increases 'mixed co-efficient'.
- While the dept does the job of removing the garbage fairly competently under very difficult circumstances, there is no thought, and only few plans to improve the practices, introduce segregation at least in a limited scale.
- There is a lack of motivation and involvement and a feeling of insecurity insists among all employees in this dept – more than most other dept – (eg.the class IV labour results in failure of new experiments done in the field of solid waste management)

We all know that segregation of waste has been a subject of good intentions but it hasn't traveled much beyond lip service. No doubt, it is very critical but also very difficult at each stage. It needs serious experimentation in communication, motivation and incentivization, commitment and allocation of specific resources not only financial but of managerial attention!

Equipments

The vehicles used for collection and transportation of garbage

1. Close compactors - 7 tons capacity,
2. Dumpers 6 tons capacity
3. Tempo 1.5 tons capacity and,
4. TDPs (TATA Dumper Placers) 1.5–2 tons capacity

Status of Implements, Uniform and Safety Gears provided to the conservancy workers

The conservancy staff upto the level of Mukadum is provided with following safety gears and equipments :

No	Item	Frequency	Remarks
1	Gumboots	Once in two years	For house galli cleaners
2	Helmet	Once a year	For house galli cleaners
3.	Hand Gloves	Once a year	Cotton with PVC dots. Used by ML labour. Get wet and dirty and hence are not used by the labour.
4.	Masks	Once a month	Masks are generally worn by the conservancy staff.
5.	Shoes	Once in two years	Rarely used.

6.	Uniforms	2 pairs in two years	Rarely used by the labour.
7.	Raincoats	Once in two years	Raincoats are generally used by the labour. However female labour finds it difficult to wear existing raincoats. They prefer 2 pc. rain suites(with top and bottom in the form of a petticoat)

Our Observations :

The road sweeping staff uses brooms and brushes for road weeping and mopping, two HDPE hand burrows of 85 lit. each, hand cart and dust lifters. The male labour is provided with loose sticks and a bamboo. The labour makes its own brooms used for road sweeping.

The female labour which is generally engaged in road sweeping activity finds it very difficult to lift filled 85 lit. hand burrows and empty them in the TDPs or DIN standard GI Bins which have a height of 3.10 ft. and 3.11ft. resp. Many times the sweepers empty the waste outside the TDPs or GI bins thus leading to double handling. **We would therefore like to recommend use of 4 nos. of 60 lit. hand burrows instead of 2 nos. of HDPE hand burrows for road sweeping staff. The 120 lit. HDPE wheel burrows will be useful if the compactor has comb lifting arrangements**

Though the uniforms are provided to the male and female staff, we have observed that most of the staff does not wear uniforms. The reasons for this are :

1. The material for stitching two pairs of uniforms is provided to the male labour once in two years. Stitching charges of Rs. 150 are paid to the staff for two pairs. Since the stitching charges are very low, most of the labour does not stitch the uniforms.
2. The Maharashtrian Ladies are given 9 yard sarees whereas the Kathewadi ladies are given 6 yard sarees along with the petticoat. Since most of the female labour staff is young and does not wear 9 yard sarees, they prefer to use the sarees to stitch clothes for their children than wearing the uniforms.
3. Only two pairs of sarees as well as uniforms during the two year period does not last longer (lasts only for 6 months if worn everyday) as since the staff has to work in unclean environments, the uniforms need to be washed more often.
4. Most of the sweeping staff stays away from the work place. The staff comes from the places like Dahisar, Kurla, Bhandup and Ambernath. Since the shift timings are early morning and the ladies travel long distances, they do not wear the uniforms.

5. There is no changing room for female labour either in ward office or at chowkeys.

The Uniforms, Gloves, masks etc. are provided only to the permanent staff. The temporary labour (DR), though works in the same working conditions is not provided with any of the safety gears.

Current situation with respect to equipment usage

1. Lack of coordination between the MCGM labour and contract vehicles
2. Most of the times garbage bins/trolleys are old and in damaged condition
3. Baskets provided in the tempo are not user friendly and hence are not filled up to its optimum capacity
4. TDPs are placed on the road many times creating traffic jams
5. The garbage lifting movement creates sound and air pollution
6. Most of the times the garbage lifting creates traffic jams
7. Garbage lifting timings are not strictly followed
8. Segregation of waste is not possible at the collection spot
9. There is no provision of different bins for dry and wet waste
10. Manning is at a few collection spots is provided (only in the first shift) but for the rest of the day, those spots are left unattended and unmanaged.
11. No notice boards at the community collection spots which can inform public about the garbage lifting timings, fines etc.
12. No drainage outlet arrangements for the wet waste.

MEDC Recommendations

The motor loading staff works in inhuman conditions as generally most of the collection spots are overflowing with garbage. We therefore recommend following :

- It will be necessary to provide gumboots or ankle shoes, masks and handgloves to all the motor loading staff irrespective of permanent and DR. Also the Mukadums should ensure that these are worn by the labour.(MCGM has already decided to provide safety gears to all the conservancy staff based on MEDC recommendations).
- The cotton gloves provided to the labour get wet and dirty when used for raking garbage and hence are not used by them. It will be necessary to provide PVC/PU gloves which are easily washable and reused.(MCGM has procurred waterproof gloves in the new tender)

- Regular medical check-ups (atleast once in two years) should be carried out for the conservancy staff.
- Better systems for waste handling such as closed bins, mechanized lifting of bins etc. should be introduced and the labour should be trained properly for a smooth transition to the new systems.

Housegalli Labour : The housegalli labour works in utmost inhuman conditions. **The system of carrying the waste on shoulders should be immediately discontinued.** This should be replaced with 120 lit. wheel burrows which can be directly unloaded into the compactor.

Attitudes of people

- In many areas of Mumbai such as B ward, in chawls/one-two room tenements, the concept of dustbins in the house does not exist
- Due to extremely small rooms and prevalence of housegallis people tend to throw waste in the housegallis/backyards which cannot be swept
- People are habituated to throwing garbage out from windows
- No knowledge about the need and importance of segregation of waste
- Fine as a coercive measure for implementing Solid Waste Management 2000 rules is not used with importance, spirit and any communication campaign.
- Concept of local initiatives i.e. advance locality management does not exist (inclu chawls to apartments) No systematic and sustained outreach effort
- At many places door do door waste collection has not been introduced forcing people to throw garbage in their backyards or housegallis. In fact, it would be difficult to introduce door-to-door collection in areas dominated by housegullies.
- Hence unless there is a strong, sustained and multi pronged effort, we will not achieve segregation without which solid waste management cannot be effective in a very congested city like Mumbai.

Public awareness and attitude towards waste

MEDC representatives held a lot of discussions with the community in the identified wards. While the middle and upper middle class localities in A and D wards were aware of the concept of Advanced Locality management(ALM), this concept was totally non existent in B and C wards. We could observe efforts of waste segregation and composting in some of the residential complexes in A and D ward. MEDC initiated formation of ALM in B ward and a compost pit was set up in B ward which was appreciated by the local residents.

Due to non involvement of local community in the waste management in B and C ward, general level of cleanliness observed was very low.

Development of Business Model for setting up a biomethanation plant successfully:

Based on our study on generation of waste and evaluation of different technologies for biomethanation, we would like to give a business model for setting up a one to five tpd biomethanation project at a ward level, for processing of hotel and market waste. (for processing of biodegradable waste generated from the hotels and markets in the entire zone -I, a plant with higher capacity in the range of 20 to 25 tpd will have to be set up).

We have discussed below the model for setting up one TPD biomethanation plant.

Purpose : To set up facilities for processing one tpd of biodegradable waste into biogas to be used by the operator

Location : . Premises of Fire Brigade Colony located in B ward.

End product : Biogas generated from the biomethanation.

User of Gas : Shalimar Hotel (it is important to select a single user for consumption of gas as gas distribution will add to the cost).

Process : Anaerobic Digestion of biodegradable waste in a primary digestor.

Sources of waste : Our survey of the Memonwada collection spot, found out that Hotel Shalimar generates around 500 to 700 kg of wet waste everyday(most of which is biodegradable food waste) which is dumped at the Memonwada collection spot. This biodegradable hotel waste will be the ideal raw material for the biogas plant. In addition, we can ask the operator to collect additional waste (which to him is" a raw material ") from a designated /chosen area/segment such as some other eateries and/or markets so as to achieve a sustained level of the right mix to run the plant **efficiently.**

Advantages

A small Bio Gas Plant at such a location in 'B' ward would serve many purposes especially in validating various technical , physical and commercial parameters .

- It can demonstrate the basic viability of such small plants in a congested area .
- It can teach us what care needs to be taken to ensure sustained collection of segregated waste which needs to be supplied in steady small doses throughout the day and still the plant runs continuously ("*just in time concept in practice*" for inventory management - critical for the waste handling within the city).
- A critical element of this project is to ensure that the plant operator has the right (and responsibility) to collect the waste from the area agreed by him (as indicated above)

- When the plant operator is collecting the waste as a raw material, he will be automatically much concerned with the "quality" of waste, i.e. how segregated that is . It would be desirable to pay him appropriately (perhaps as much as Rs. 1/kg, based on transport cost and labour cost. Currently MCGM incurs Rs 2/kg)to ensure that his effort in segregating the waste in an incentivised manner.
- We should also examine how the NDs can work in support of the segregation in a defined back up area for this pilot bio gas plant
- It will help us to work out the technical and commercial modalities of collecting and selling the gas . It would be preferable that the plant operator himself is a user of the gas .

Basic Technical Parameters :

Technology	• Anaerobic Digestion. • Technology will be used for Biogas generation from biodegradable waste.
Raw material	• 1000kg/day of biodegradable hotel and Household waste.
Water input ratio	• 1:1 i.e. around 1000 lit.
Shredder / Mixer	• Electric consumption is 3 hp/30 mins
Water cum Recycle chamber	• Single-phase motor is used which is linked with the stirrer/agitator. • Pump – Electric consumption is 1hp/4hrs
Primary Digester and Secondary Digester	• Digester will be made of RCC which will be 2/3rd underground • Electric consumption is 2.5hp/4hrs.
Gas balloon (Gas Holder)	• Made up of Neoprene rubber • Balloon is UV protected. • Gas collected 43^3/day • Balloon will be protected in a shedThe composition of biogas produced at this plant is as follows: Methane (CH_4) 55% - 60% Carbon Dioxide (CO_2) 38% Hydrogen sulphide (H_2S)1-2% .
Blower (Compressor)	• Pressurize the gas from the gasholder to the receiver tank. • 2000 mm water column. • Electric consumption is 1hp/8hrs
Retention time	• 28 days i.e. • Primary digester takes 21 days and Secondary digester takes 7 days.
Sludge	• Sludge will be removed once a year

	• Approximately $4m^3$ = 4000 lts is removed • Sludge, which will be removed, can be used in as manure in gardens.
End Products	• Gas can be used directly by Shalimar Restaurant.
Space required	• 10 mts x 10 mts

Manpower requirement :

2 semiskilled workers working in each of two shifts for putting the waste in the shredder. One sweeper will be required to bring the waste to the processing site. Existing electrician or a mechanic available with the operator can be trained in the maintenance.

Financing :

The capital cost for setting up the plant can be shared between MCGM and Shalimar Hotel as it will be direct beneficiary of the project. It should be in the form of long term (8 years) interest free loan with one year moratorium even for repayment on the condition that the entire operating cost should be borne by the operator incl. use of the gas Price for some quantity as well as Trade Refuse fee and handling and transportation charge that he would be entitled for collecting the waste from the area/sources allotted to him could also be recovered as a repayment after first year.

Operating Cost for power and water to be borne by Shalimar Hotel.

Operations

The material to be processed will be brought to the plant site every afternoon around 1 p.m. The attendant will put the waste in the mixer. He can be a local person who will be trained. It will be important to get segregated waste to the site.

Infrastructure Required

Space : Around 100 sq.mt.

Power Consumption : 30 units per day

Water Consumption : 1000 lit. of water per day.

Cost for this to be incurred by the operator.

End use : The gas should be used by the kitchen of Shalimar restaurant which is located at the back side of the fire brigade colony.

Estimated Project Cost :

Cost item	Rs.
Biogas Plant on turnkey Basis*	8,50,000(Incl. Taxes)
Installation and Commissioning	50,000
Est. cost of Civil Works(Including piping)	2,00,000
capital cost (incl contingencies @10%	1100,000
Operating cost per annum	
Maintenance Cost (Electricity , Fuel etc.)	50,000
Manpower (@ Rs.3000 per month per 4persons)	144000
Contingencies @10% of operating cost	19400
Total Operating Cost per annum	2,13,400

*: Equipments will include following :

Shredder for Hotel waste, Primary Digester, Secondary Digester
Recycle Pump, Balloon Gas Holder, Biogas Compressor
Biogas Receiver Tank with burners, Control Panel
Instrumentation works.

Being a direct user of the gas, there is no need for an additional cost of Rs. 3.1 lacs for installation of a DG set for generation of 5Kw power).

Broader Cost- Benefit Analysis :

Generation of biogas per day	80-85 m3 equivalent to 40 kg of LPG per day)
Generation of biogas equivalent of LPG per annum	12,000 kg(for 300 days)
Cost of LPG per kg (at current rate- minimum)	Rs. 32
Value of gas generated pa	Rs.3,84,000
Savings per annum after subtracting annual operating cost	Rs.170,000
Repayment per year (after one year of moratorium) for 10 years	Rs. 100,000
A one tpd plant will save 2 tpd waste transported to dumping ground. However it is necessary to pay the operator for outside waste that he may bring (which is half the qty – say, one ton of mixed waste)	One extra ton of dry waste will be picked up by the rag pickers. MCGM will save transport of 500 kg of captive waste/day i.e. Rs. 250/day or Rs. 90,000/pa almost equal to interest on the capital cost of Rs. 10 laks

This will be a pilot project and operation should be closely monitored. It is important that the first operator finds the operation very profitable. This will encourage setting up of more such projects .

Basic Technical Parameters :

Technology	Anaerobic Digestion. Technology will be used for Biogas generation from biodegradable waste.
Raw material	1000kg/day of biodegradable hotel and Household waste.
Water input ratio	1:1 i.e. around 1000 lit.
Shredder / Mixer	Electric consumption is 3 hp/30 mins
Water cum Recycle chamber	Single-phase motor is used which is linked with the stirrer/agitator. Pump – Electric consumption is 1hp/4hrs
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Sludge	Sludge will be removed once a year Approximately $4m^3$ = 4000 lts is removed Sludge, which will be removed, can be used in as manure in gardens.
End Products	Gas can be used directly by Shalimar Restaurant.
Space required	10 mts x 10 mts

Manpower requirement :

2 semiskilled workers working in each of two shifts for putting the waste in the shredder. One sweeper will be required to bring the waste to the processing site. Existing electrician or a mechanic available with the operator can be trained in the maintenance.

Financing

The capital cost should be funded by MCGM or thru corporator or other external agency. It should be in the form of long term (8 years) interest free loan with one year moratorium even for repayment on the condition that the entire operating cost should be borne by the operator incl. use of the gas (free of cost for the first year and for some quantity after the first year.) Price for some quantity as well as Trade Refuse fee and handling and transportation charge that he would be entitled for collecting the waste from the area/sources allotted to him could also be recovered as a repayment after first year.

At the moment, we have provided indicative figures based on a quotation obtained from Mailhem Engineering . It should be possible to obtain a competitive quotation from them and other parties who can meet the specs and performance guarantees and the cost can come down to some extent . But it is useful to go by the figures that are available now as there is a reasonable assurance that the performance criteria are met for this plant .

Operating Cost for power and water to be borne by Shalimar Hotel.

Operator to be paid Rs 1/kg per kg. Which will take care of the cost of collection, segregation and manpower required for the plant operations.

Operations

The material to be processed will be brought to the plant site every afternoon around 1 p.m. The attendant will put the waste in the mixer. He can be a local person who will be trained by Mailhem. It will be important to get segregated waste to the site.

Infrastructure Required

Space : Around 100 sq.mt.

Power Consumption : 30 units per day

Water Consumption : 1000 lit. of water per day.

Cost for this to be incurred by the operator.

End use : The gas should be used by the kitchen of Shalimar restaurant which is located at the back side of the fire brigade colony.

Estimated Project Cost :

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A one tpd plant will save 2 tpd waste transported to dumping ground. However it is necessary to pay the operator for outside waste that he may bring (which is half the qty – say, one ton of mixed waste)	One extra ton of dry waste will be picked up by the rag pickers. MCGM will save transport of 500 kg of captive waste/day i.e. Rs. 250/day or Rs. 90,000/pa almost equal to interest on the capital cost of Rs. 10 laks

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