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

FINAL REPORT

(Annexures)

Presented to:

MMR Environment Improvement Society

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Annexure A :

The plants identified for studied:

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

ii. Vijayawada Municipal Council, Vijayawada, AP

iii. BARC, Mumbai

iv. Shatabdi Hospital, Govandi, Mumbai

v. Bharat Petroleum Corporation Ltd. Mumbai.

vi. Bajaj Auto Ltd. Nigadi, Pune.

vii. Kirlosker Oil Engneers Ltd. Khadki, Pune

viii. Mahindra & Mahindra Ltd, Mumbai.

ix. Marigold Complex, Kalyaninagar, Pune

x. Sadhu Vasvani Hospital, Koregaon Park, Pune

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

xii. Tata International Ltd, Dewas, MP

xiii. Shirdi Devasthan, Shirdi

xiv. Dakor Biogas plant, Dakor, Gujrat.

xv. Al-Kabeer , Hyderabad

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 generated in the market was collected on daily basis by a private agency, transferred to 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 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, Govt. of India, (MNES) have 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. 5.50 Crore including electricity transfer station.

Waste Collection :

The plant works on integrated solid waste management principle. There is a waste collection agency, which collects the specified waste and transfers it to the plant site which within periphery of 1 km. The waste collection contractor and CDMA have an agreement for waste collection.

The market is open for 24 hrs round the clock. The arrival of vegetables starts at 12 midnight from different parts of the state and nearby states and continues till 4 am. As soon as material is received activities like unloading, sorting, wholesale trading and loading takes place till 6 am. After 6 am, local small vendors start coming for purchasing till 9 am. After 9 am wholesale trading stops and retail trading starts, which continues whole day. Up to 9 am market complex is full of crowd so that waste collection can not be started. The shop owners simply throw the waste on the service lanes/roads 6 to 8 feet wide where no vehicle can go. Waste is collected in tricycle-mounted trolleys manually from these inner lanes and brought to the main road where it is stored at one place. Then with the help of JCB it is loaded in tractors/dumpers and transported to the plant site via Weigh Bridge where its weight is taken.

At present selected waste containing highly perishables, easily biodegradable material is processed, as plant is under stabilization process. High lignin content waste like banana leaves and stem, flower waste is not taken for time being. The waste used includes vegetables like cauliflower, cabbage, spinach, brinjal, cucumber, carrot, tomato, potato, gourd, pumpkin, fruits like banana, chikoo, pine-apple, papaya, etc.

The waste collection starts at 9 am in the morning and first vehicle reaches to plant at about 10 am. It takes about 12 hrs to remove all waste from market complex. The other waste, which is not used for biomethanation, is also collected and transferred to transfer station, which is near to plant. From transfer station the waste is loaded into bigger size/ capacity trucks, covered with tarpaulin sheet and transported to the dumping site of Corporation of Chennai.

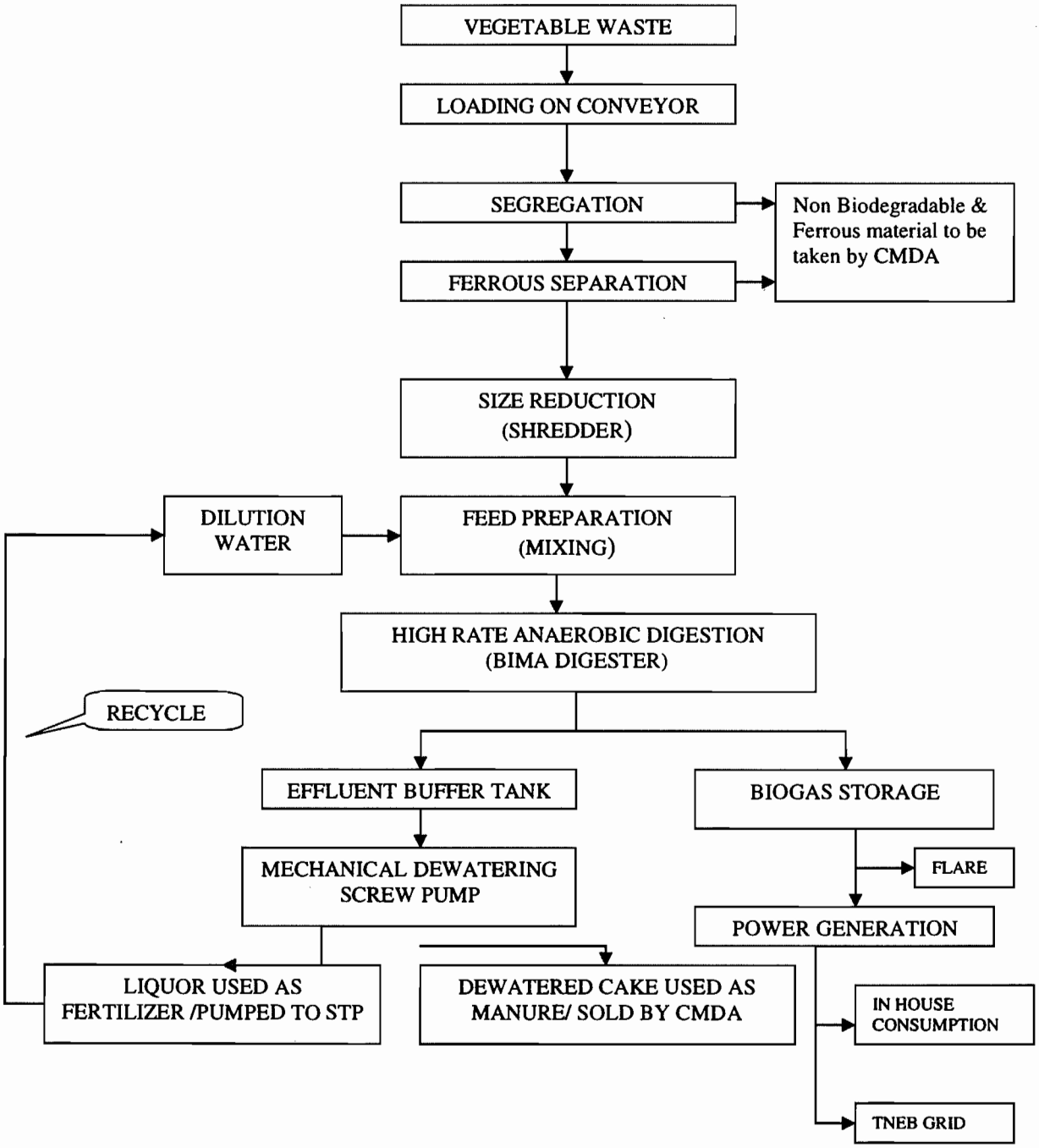
The work of waste collection is supervised by the Junior Engineer (Technical-civil) of MMC, CMDA.

Waste Treatment :

The waste is treated in high rate biomethanation plant based on Biogas Induced Mixing Arrangement i.e. BIMA Technology developed and patented by M/s ENTEC, Austria. The following are main stages involved in the waste treatment process.

1. Waste receipt, loading on conveyor and segregation of non-biodegradable material.
2. Size reduction - shredder.
3. Feed preparation - agitator/mixer.
4. Maceration.
5. High rate anaerobic digestion through BIMA digester.
6. Biological desulphuration.
7. Biogas storage- gasholder.
8. Power generation- generator.
9. Dewatering of digested substrate- screw press.
10. Odor control system.

Process Flow Diagram:



Biomethanation Plant at Koyambedu Wholesale Market Complex, Chennai

Waste receipt, loading on conveyor and segregation of non-biodegradable material:

The waste collected from market area after weighing is received in receiving platform, which is a under ground open tank. This waste is 99 % segregated and free of plastic, paper, cloths and stones etc.
From receiving area waste is lifted with the help of mechanical handling system called 'GRAB' of 0.8 m^3 capacity with traveling electric hoist and feed to hopper of the conveyor belt and transferred through conveyor to the shredder for size reduction.

When waste moves on conveyor it is manually sorted /segregated for removal of plastic, cloths, wood, stone, which are non biodegradable & banana leafs/stem by persons standing on platform side of conveyor.
Magnetic separator is provided parallel to conveyor in hanging position so that ferrous materials like nails, pins, which are removed manually, stored and taken out of plant.

Size reduction:

The sorted waste moving on conveyor belt, falls into the shredder at the other end of conveyor. The shredder cut the waste into uniform size of 20-40 mm. it is capable of handling 4 T/hr. the shredded material directly falls into the feed preparation tank below. This is a first stage size reduction.

Feed preparation:

The fresh shredded vegetable waste falls into one of the two feed preparation tanks through a distribution trough. Depending upon the type of waste i.e. leaf waste, pumpkins, fruits quantity of water/ liquor from screw pump is added to the waste. The waste is blended/ mixed to provide uniform characteristics. The solids concentration of 10% is maintained. Turbine type agitator is provided in each feed preparation tank. When one tank is full of waste other is used feed preparation and the blended waste from first tank is pumped to BIMA digester via macerator.

Maceration :

The well-mixed homogeneous slurry from feed preparation tank is pumped to high rate BIMA digester through cutter pump & macerator by screw pump. The cutter pump reduces waste to 15-20 mm size whereas macerator further reduces it to 10-14 mm. the main purpose is to shred the fibrous waste which have escaped from shredder.

High Rate Anaerobic Digestion through BIMA Digester:

The well-mixed homogeneous waste is pumped into a high rate anaerobic digester called BIMA digester with the help of screw pump. Screw pump is used because it handles waste with high solid concentration.

The digester consists of main chamber, central core and upper chamber. The waste is fed to central core where it is hydrolyzed, then to main chamber where the contents are mixed & digested.

Biogas is stored in the upper chamber. From central core, material spreads over digested, mixed substrate at the top of main chamber. The effluent is taken out through pipes from the bottom of main chamber.

As the name suggest BIMA, Biogas Induced Mixing Arrangement, the mixing of decomposing substrate and incoming feed in the digester is carried out by blowing biogas from upper chamber to main chamber with the help of blowers installed on the top of digester. This operation of continuous mixing for 20 minutes is carried out at every 4 hrs interval automatically.

The temperature inside the BIMA digester is maintained at 35^{0}c by heat exchanger arrangement.

There are no moving parts inside the digester. The main advantage of digester is the ability to handle high concentration of solids and the process of mixing without any mechanical devices.

The discharge from digester is collected in buffer effluent tank. The temperature and pH inside the monitor are monitored continuously.

Biological desulphurization:

Biogas composition consists of methane, carbon dioxide, hydrogen sulfide and moisture. H_2S has to be removed before biogas is used as fuel in gas engine otherwise it will corrode the engine and reduce the efficiency of engine and hamper the performance. The permissible limit of H_2S is 500 ppm up to which gas can be used for engine.

M/s. ENTEC has developed a biological desulphurization system in built in BIMA digester. This consists of a group of facultative bacteria to oxidize H_2S, which adhered to the walls of BIMA digester separating the upper and main chamber. There is online monitoring system to monitor H_2S levels.

Biogas Storage:

The biogas produced in the BIMA digester is then collected in the gasholder. A 550 m^3 capacity gas holder made of non corrodible polyester material is housed in GI sheet protection silo. This is a dry type membrane gasholder developed by M/s ENTEC of Austria. The function of gasholder is to buffer the difference between the rate of production and rate of consumption of biogas.

Power Generation:

The biogas, after removal of H_2S is used as fuel to produce electricity. A 230 KW gas engine is installed for generation of electricity. The engine runs on biogas only. The engine consumes about 100-m3 of biogas per hour. The gas is withdrawn from gasholder and blown to engine with the help of blowers.

With fully operated plant, generator will run for 20 hours a day i.e. 5hr work & 1 hr rest, producing 4000 units' per day. At present generator is run for 10 hrs in two shifts of 5 hr only. Power generation started on 4.9.2005.

The net power generated after in-house consumption is exported toTNEB (Tamilnadu Electricity Board) grid.The engine is of Deutz German make.

Biogas Flare:

In case of maintenance of gas engine, the excess gas beyond the storage capacity of holder is burnt out in the flare. The flare provided is an automatic type with auto start arrangement, i.e., auto ignition with spark plug.

Dewatering of Digested Sludge:

The discharge from BIMA digester is collected in an effluent buffer tank. Dewatering is carried out in a screw press of capacity 6 m3/hr. The digested sludge is then pumped to screw press by screw pump. It is a continuous type of mechanical dewatering equipment. It works like juice machine separating solids and liquid apart. The liquor from screw press is used as dilution water for feed preparation, liquid fertilizer or pumped to nearby Sewage Treatment Plant STP. The dewatered sludge is then sun dried and sold by CMDA as manure.

Odor Control:

Because of highly putrecible nature of waste, the odor problem is observed at following places. 1) Receiving area, 2) Conveyor, 3) Shredder, 4) Feed preparation tank and 5) screw press. Suction points of PVC pipe are taken out from the above sources and connected to common pipe. A blower will draw air from these points and transfer to the treatment unit called 'Bio-filter (wood chips are kept wet by sprinkling water). Bio-filter is a tank filled with wood chips, which are kept wet by sprinkling water. The odorous air is passed from bottom of the bio-filter unit through conduits/ channels. The microbes grown on media absorb the bad odor in the air sucked from the odor producing areas and the clean air is let into atmosphere.

Laboratory facility

To check the quality of raw material small laboratory setup is provided in the premises. Analytical balance, oven and muffle furnace are availaboratoryle in the laboratory. Parameters like Total solids (TS), Volatile solids (VS) and Moisture content (MC) are checked in the laboratory.

Salient 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.

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.

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.

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.

Waste Collection

The plant of capacity 20TPD is designed to treat 16 TPD of vegetable market waste and 4TPD of slaughterhouse waste. The vegetable waste from different markets in the city is collected by VMC in hydraulic container loaded vehicle and transported to the plant and unloaded. The VMC is bound to give vegetable waste only and other garbage.

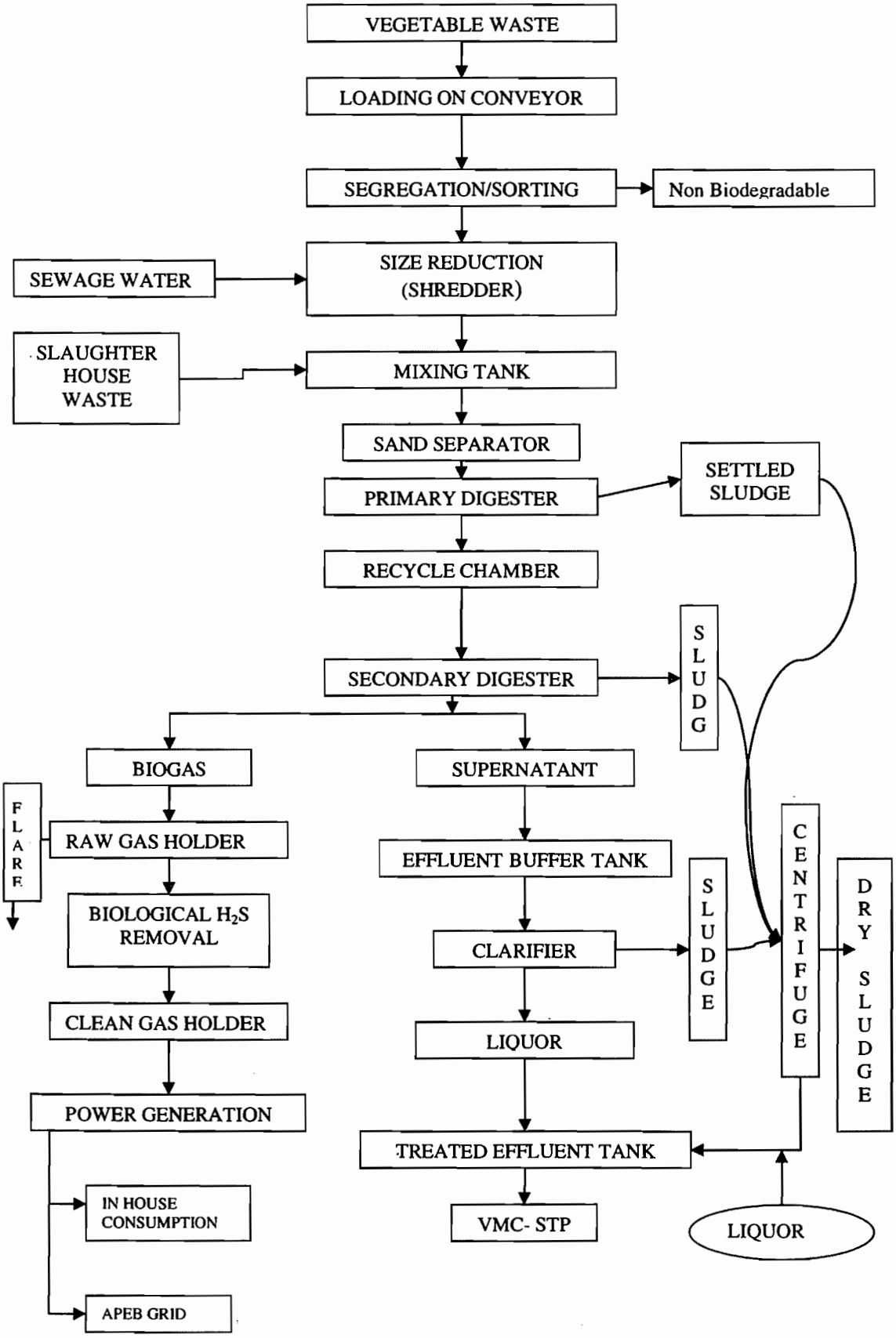
The slaughter house waste consisting of undigested food from intestines of slaughtered animal waste, etc. is collected in special vehicle (Airtech) by VMC from slaughter house/tabela and brought to the site where it is unloaded in mixing tank.

The work of waste collection and supply is a responsibility of VMC only.

Waste Treatment

The waste is treated in two-stage or biphasic biomethanation plant. The operation include stages/units

1. Waste receipt and segregation of non-biodegradable.
2. Size reduction.
3. Mixing.
4. Sand separation.
5. Primary digester.
6. Recycle chamber.
7. Secondary digester.
8. Biological desulphurization.
9. Power generation.
10. Biogas flare.
11. Clarifier.
12. Dewatering of sludge by centrifuge.
13. Treated effluent storage and disposal.
14. Control panel.


VEGETABLE WASTE
LOADING ON CONVEYOR
SEGREGATION/SORTING
Non Biodegradable
SEWAGE WATER
SIZE REDUCTION (SHREDDER)
SLAUGHTER HOUSE WASTE
MIXING TANK
SAND SEPARATOR
PRIMARY DIGESTER
SETTLED SLUDGE
RECYCLE CHAMBER
SECONDARY DIGESTER
SLUDG
BIOGAS
SUPERNATANT
FLARE
RAW GAS HOLDER
EFFLUENT BUFFER TANK
BIOLOGICAL H_2S REMOVAL
CLARIFIER
SLUDGE
CENTRIFUGE
DRY SLUDGE
CLEAN GAS HOLDER
LIQUOR
POWER GENERATION
TREATED EFFLUENT TANK
IN HOUSE CONSUMPTION
VMC- STP
LIQUOR
APEB GRID

Flow sheet of the Biomethanation plant

1. Waste receipt and segregation of non-biodegradable

The vegetable waste collected from market area is unloaded on receiving platform. The platform is at higher level with ramp for vehicle movement. From the receiving area the waste is pushed on conveyor belt by shovel manually. The person pushing waste also takes out large sized unwanted things from the waste. At the another end of the conveyor belt, persons standing on either side, segregates for removal of plastic, clothes, wood, stones, glass, metal, banana leaves/stems, etc. which are non biodegradable. At the other end waste falls in a chute, this takes this waste to the shredder/pulveriser.

The slaughterhouse waste consisting of undigested food from intestines, animal droppings, urine, etc. is collected in Airtech? vehicles and brought to the plant. Vegetable and slaughterhouse waste is mixed in the 4:1 ratio. When slaughterhouse waste is mixed with vegetable waste gives higher production of biogas than only vegetable waste. The waste is stored in hopper bottom tank when received in large quantity other wise in mixing tank. When the slaughterhouse waste is not availaboratoryle the sewage sludge from nearby STP is taken for mixing with vegetable waste.

2. Size reduction

The segregated waste moving on conveyor belt falls into chute and goes to shredder. Here before entering to shredder, water is added to waste. The waste to water ratio by weight is maintained at 1:1. The water used for mixing is sewage water and not fresh water. The shredder is a hammer mill which breaks the waste into pieces of 10-20 mm size. The addition of water helps in free flowing of waste to mixing tank. The shredder is capable of handling 2T/hr of waste. One mixer type shredder provided as standby.

3. Mixing tank

This is a square shaped, under ground, open tank constructed in masonry. The fresh shredded waste with water is collected in this tank where it is allowed to mix with the slaughter house waste is added in this tank and allowed to mix with vegetable waste. From tank, the mixing waste is pumped to primary digester via sand separator. Mixing tank is provided with 2 solid handling pumps.

4. Sand separator

This is a cyclone type sand separator in which the heavy sand particles settle under gravity at the bottom. The drain valve is opened after certain interval to remove sand collected at bottom. From the sand separator waste goes to primary digester.

5. Primary digester

It is a round shaped under ground tank of 300m^3 capacity constructed in masonry. The top is fixed roof type made up of mild steel angle structure and fiber reinforced plastic sheets. To prevent the corrosion of mild steel, it is lined with FRP. The agitator is provided on the top for mixing purpose. Manhole is provided for emergency maintenance on top of roof. The waste material coming from sand separator is fed at bottom and move upward. After its retention in the tank, it flows into the launder provided on periphery of digester from where it goes to recycle tank by gravity.

Scum chamber is provided to remove scum from digester. The scum collected is either recycled back to primary digester or disposed off. Tank is connected to drain chamber at bottom to remove settled digested sludge. The valve in drain chamber is opened and sludge is allowed to flow in chamber where sludge quality is checked physically. If sludge is found digested sufficiently, it is then only removed by sludge pumps and taken to overhead tank in centrifuge room, where solids are separated from liquid.

6. Recycle chamber

This is a square shaped, under ground, open tank constructed in masonry. The overflow from primary digester is collected in this tank. Two pumps are provided one for pumping the material to secondary digester and other for recycling. The waste material coming from primary digester is stored in this tank and then pumped to secondary digester. Also waste material is recycled to primary digester.

7. Secondary digester

It is a circular shaped under ground tank of 1000m^3 capacity constructed in masonry. The waste material from recycle tank is pumped at bottom and moves upward. After retention time is over supernatant flows into the launder provided on periphery of digester from where it is goes to effluent buffer tank by gravity and the digested sludge settles down. The digested sludge is then sent to drain chamber.

The digester is equipped with automatic electric sensors to give flow of waste, temperature, pH, Pressure, etc. To collect gas outlet is provided on roof top.

The combined hydraulic retention time of primary and secondary digester is said to be 30 days. The temperature inside the digester is ranges 30 to 40^{0}c. To collect gas outlet is provided on roof top.

8. Biogas storage

It is estimated that 1600 M^3 of biogas will be produced when plant operates at full capacity. There are three neoprene rubber balloons of 100 m^3 capacity each for storage of biogas. Two are used for raw biogas and one for clean biogas storage. The balloons are housed in room to protect from rodents and any casualty. The rooms are always locked and under supervision. The balloons are guided by four rods to move vertically when filled with gas. Rope and pulley type counter weight level indicator is mounted on outside of the wall to know the gas quantity in the balloon.

9. Biological desulphurization

Biogas composition consists of methane (60-65%), carbon dioxide (30-35%), hydrogen sulfide (0.5-0.6%) and moisture. H_2S has to be removed before biogas is used as fuel in gas engine.

/s. Mailhem has used biological desulphurization method for removal of H_2S. This consists of closed cylindrical vessel in which media containing a group of facultative bacteria to oxidize H_2S is kept. The raw biogas under pressure is allowed to pass through this vessel where it comes in contact with sulphur reducing bacteria thereby reducing the H_2S concentration in the biogas. H_2S is reduced from 0.5-0.6% to 0.05-0.1%. The nutrients are added to the vessel to enhance the growth of bacteria. The clean gas after H_2S removal is stored in balloon no. 3 from where it is used for power generation.

10. Power generation

The biogas, after removal of H_2S is used as fuel to produce electricity. A 150 kWh gas engine is installed for generation of electricity. The engine runs on biogas only. The engine generates about 1.8-1.9 units/ m^{3}of biogas. The gas is withdrawn from clean gas holder and to receiver tank with the help of blower from where supplied to engine under constant pressure.

The engine is of Libbherr, Switzerland make and AC generator of Stanford, made in Germany. The net power generated after in-house consumption is fed to APEB grid.

11. Biogas flare

When gas engine is taken out of operation for maintenance, the excess gas beyond the storage capacity of holder is burnt out in the flare. The flare provided is an automatic type with auto start arrangement, auto ignition with spark plug.

12. Clarifier

Cylindrical with conical bottom mild steel clarifier is provided to clarify the supernatant from secondary digester. The supernatant from digester flows to effluent buffer tank by gravity. Then it is pumped to clarifier where heavy solids settle down by gravity overflow is taken to the holding tank. The sludge from clarifier is passed through centrifuge to separate solids from liquid.

13. Dewatering of sludge by centrifuge

For dewatering of digested sludge removed from bottoms of primary and secondary digesters mechanical centrifuge is installed. The sludge from drain chamber is pumped to over head tank provided in centrifuge room and then it flows by gravity to centrifuge machine. The liquor from centrifuge machine is collected in holding tank and then pumped to nearby STP for further treatment. The dewatered cakes are dried in open pit and then sold as manure

14. Treated effluent storage and disposal

The liquor separated in clarifier and that from centrifuge is stored in another tank called holding tank. This is a square shape, open, under ground tank constructed in masonry. The effluent from this tank is pumped to nearby VMC's sewage treatment plant for further treatment.

15. Control panel

There are three control panels provided in the plant.

First control panel is in the office cum control room. This gives online information about various parameter like slurry flow rate, raw gas flow rate, clean gas flow rate, temperature in primary and secondary digester, raw gas and clean gas levels in the balloons, pH in the digesters, air flow rate and pressure in the digesters. This also controls the operations of generator.

Second panel is in the ground floor of laboratory room. This controls the operation of conveyor belt, shredder, sand separator and pumps in the mixing tank.

Third is in the centrifuge room which control the operations of centrifuge, pumps in recycle tank and treated effluent tank.

Laboratory:

To check the quality of raw material and that of biogas produced small laboratory setup is provided in the premises. Following parameters are checked in the laboratory

1. Total solids (TS)
2. Volatile solids (VS)
3. Moisture content (MC)
4. % concentration of CO_2 and CH_4 in the composition of biogas
5. % of H_2S in the biogas
6. pH

Following equipments/ apparatus are provided in the laboratory

1. Hot air oven
2. Muffle furnace
3. BOD incubator
4. Orsat apparatus
5. Tutoiler apparatus

Tests for TS, VS and MC on raw fresh vegetable waste and carbon dioxide, methane and hydrogen sulfide on raw and clean gas are carried out daily in the morning.

We observed the tests on gas. The results obtained are like CO_2 = 30.2%, CH_4 = 69.8% and H_2S = 0.12%.

Silent 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.

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.

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 at most sincerity and precise planning. It is therefore our responsibility that we return this debt appropriately to maintain the positive balance. The basic concept of the project "Nisargruna" is acknowledgement of nature's loan and proper

repayment. Five Nisargruna plants have been installed at BARC, Anushaktinagar, Govandi, Deonar and Kunjali 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.

Type 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, tires/ rubber, hazardous and chemical industries waste etc.

Silent Features of the Plant

Major components of BARC's a Nisargruna plant include

- Mixture/Pulper with 5 HP motor(s) for crushing solid waste,
- Pre-mix tank,
- Pre-digester tank,
- Air compressor,
- Slow water heater or solar panels,
- Main digestion tank,
- Gas delivery system,
- Manure pits, a tank for recycling water,
- Water pump, slurry pump and a gas utilization system.

Principle & Operation:

The waste is homogenized in a mixer using water. This slurry enters the pre- digester tank where aerobic thermophilic bacteria proliferate and convert part of this waste into organic acids like acetic acid, butyric acid, prop ionic acid and formic acid. The compressed air is supplied to maintain aerobic conditions and hot water is injected to maintain thermophilic conditions. The waste has given retention time of four days in the pre digestion tank. After four days waste enters the main digester where methanogenous bacteria convert the volatile acids into methane and carbon dioxide. HRT in digester is said to be 15 days.

The Three steps involved in Nisargruna for Biogas production are:

Nisargjyoti microbes consist of a large group of complex and differently acting microbe species, notably methane-producing bacteria. The whole Nisargjyoti formation process can be divided into three steps: hydrolysis, acidification, and methane formation. Various types of bacteria are involved in these processes.

Hydrolysis

In the first step (hydrolysis), the organic matter is enzymolyzed externally by extra cellular enzymes (cellulase, amylase, protease and lipase) of microorganisms in the pre-digester tank. Converting solid waste into liquid form in the mixer stimulates this step. Bacteria start decomposing the long chains of the complex carbohydrates, proteins and lipids into shorter parts. Proteins are split into peptides and amino acids. Simple carbohydrates and proteins are degraded completely.

Acidification

Acid-producing bacteria involved in the second step convert the intermediates of fermenting bacteria into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2) in the pre-digester. These bacteria, of the genus bacillus, are aerobic and facultatively anaerobic, and can grow under acidic conditions. An air compressor maintains aerobic conditions in the pre-digester. To produce acetic acid, the bacteria use the oxygen dissolved in the solution or bonded-oxygen. Hereby, the acid-producing bacteria reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. The pH of the raw slurry falls from 7.5 to about 4.5 to5.5 in the pre-digester

Methane formation

Methane-producing bacteria, involved in the third step, decompose compounds with a low molecular weight. Under natural conditions, methane-producing microorganisms occur to the extent that anaerobic conditions are provided, for instance under water (in marine sediments), in ruminant stomachs and in marshes. They are anaerobic and very sensitive to environmental changes. In contrast to acidogenic and acetogenic bacteria, methanogenic bacteria belong to the archaebacteria group, a group of bacteria with a very heterogeneous morphology and a number of common biochemical and molecular-biological properties that distinguish them from all other bacterial genera. It is advisable to circulate the generated

biogas back into the system using a small compressor. This would enhance the reduction of carbon dioxide to methane and enrichment of methane fraction in the biogas.

The separation of two stages (Aerobic and Anaerobic) in methane production helps in improving the purity of methane gas, thereby increasing its fuel efficiency. However, the average composition round the year would depend on how effectively pre-digester temperatures can be maintained. The biogas is a mixture of methane (70-75%), carbon dioxide (10-15%) and water vapor (5-10%). It is taken through a GI pipeline to utility points. Drains for condensed water vapor are provided online. The biogas burns with a blue flame and is ideal for cooking. Alternately, it can be used to produce electricity in a dual fuel biogas-diesel engine.

Gas generation and its use:

The plant at present is getting only 2 TPD of waste per day hence under capacity. The gas production claimed is about $100m^3$-120 m^3 per TPD of waste processed. The gas produced is used in the BARC canteen for cooking purpose.

Sludge generation (Organic manure):

At full capacity 500 kg of dry sludge is generated daily. This will be used as manure for gardens. Chemical analysis of organic manure i.e. in terms of NPK value was found out to be good enough for the growth of the crops. This manure would have maximum benefit when used in slurry form. However, transportation may be a problem, hence it may be air dried and used. An important character of this manure is that it is weed free. The weed seeds present in vegetable matter and other waste materials are killed in pre-digester due o higher temperature and acidic conditions.

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.

Comment: 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 to 120 m^3/T of waste processed which seems very high and unrealistic. There is no arrangement for measuring the actual gas production.
- There is no laboratory facility to monitor the plant.
- The biogas produced is used to in the duel fuel engine to produce the electricity which is used in the hospital. Excess biogas is left in the atmosphere without flaring.
- 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 is not with all the amenities but the latest designed plants of this technology are further modified.

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

Capacity: 5 TPD

Location: Govandi, Mumbai

Type of waste: Canteen Waste

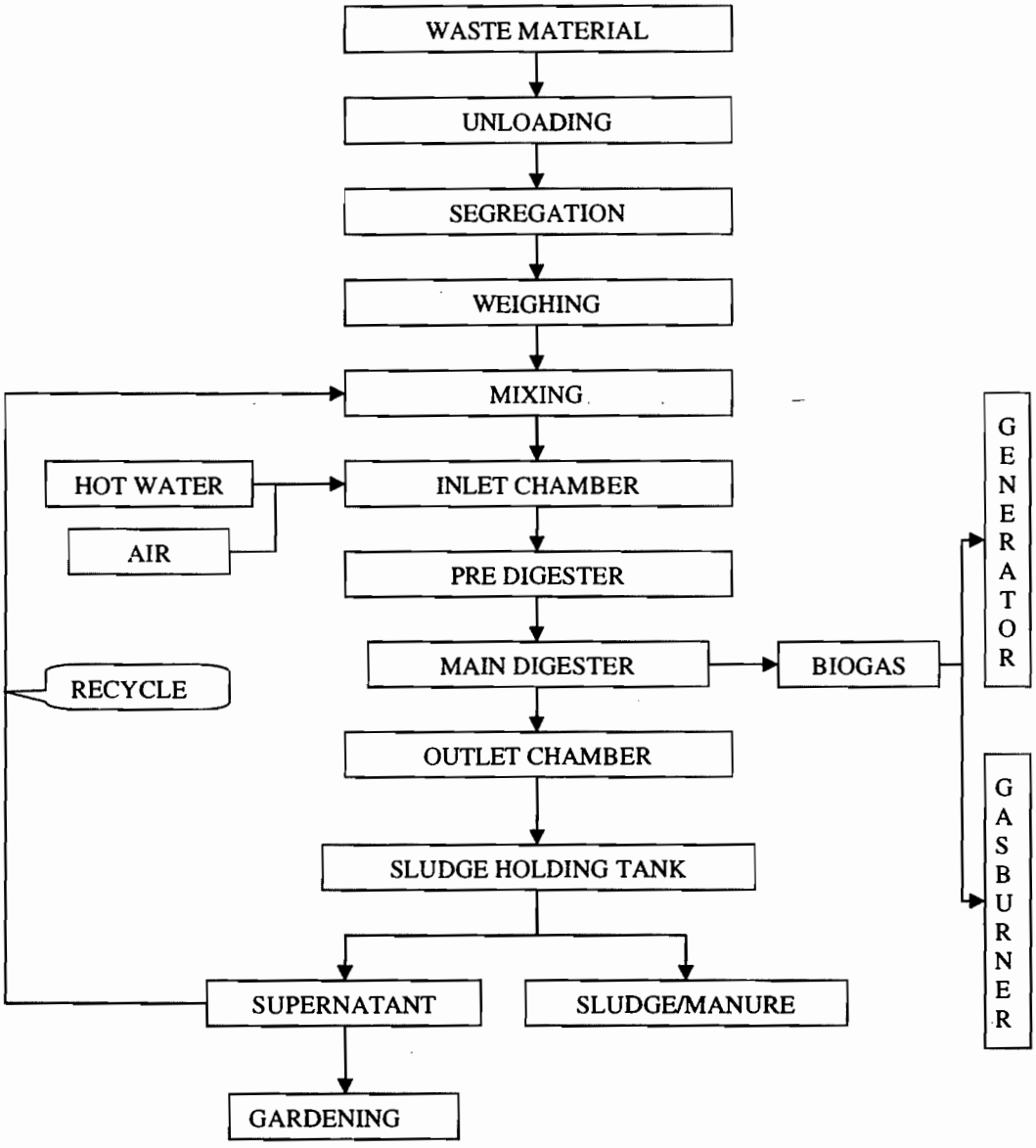
Municipal Corporation of Greater Mumbai (MCGM), has installed biogas plant of capacity 5 T/day based on BARC technology in 2001 and commissioned in June 2003. The waste processed is cooked hotel waste and vegetable market waste.

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 tri partite 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

Silent Features of the Plant

1. Shed
2. Unloading platforms/segregation area
3. Mixer platform/Segregation area
4. Mixer
5. Weigh balance
6. Inlet chamber
7. Pre digester
8. Main digester
9. Gas holder - floating roof
10. Outlet chamber
11. Sludge holding tank
12. Compressor
13. Solar water heater/ gas burner
14. Slurry pump
15. Water pump
16. Duel fuel generator

Process Flow Diagram



Nisargruna Biogas Plant at Shatabdi Hospital

1. Shed

This area is for movement and temporary storage of materials. This measures about 5.3m X 8m and is covered with plastic roof. Flooring is concreted and is at ground level.

2. Unloading platforms/Segregation area

There are two unloading platforms, one at height of 1.15m measuring 3.10m x 3.75m and other at height of 0.50m having 7.50m x 3.90m area. The waste from tempo is unloaded on these platforms easily. The waste is segregated on these platforms.

3. Mixer platform/ segregation area

This is at height of 1.70m. The size of platform is 3.90mx 3.75m. The mixer is installed on this platform. Extra space on platform is used for segregation and storage of segregated waste filled up in plastic buckets.

4. Mixer

It is made up of 0.50 mm thick mild steel plate having 1.20 m diameter and 1.20 m depth. Stain less steel blade about 0.40m in dia. is fixed on central shaft which is rotated with the help of 7.5 hp motor mounted on top of mixer.

While mixing first water is taken in mixer about 25-35 cm above bottom and about 10 cm above blade. Then waste is added about 5-6 buckets measuring 30-35 kg each depending on waste source. Waste to water ratio is maintained about 1:1. Mixer is loaded manually by lifting buckets by two persons at a height of about 0.90 m. motor is started and mixed for a period of 10 minutes till constituent slurry is formed. It does not shred or cuts the waste completely but mixes homogeneously. After mixing operation is over, HDPE valve provided at bottom is opened and waste is allowed to fall into inlet chamber. Then next batch is loaded. The discharge from main digester is recycled which is used for mixing purpose. Fresh water is not used for mixing but used for cleaning at the end of days work.

5. Weigh balance

Platform balance of capacity 100 kg is used for measuring waste and manure bags.

6. Inlet chamber

Y shape inlet chamber is provided. 13 holes/openings of 100 mm dia. are provided near the pre digester wall through which mixed material enters the digester. The slurry is retained in inlet chamber

till it is filled completely. Then alternate holes are opened at a time to maintain proper distribution of waste in pre digester. At the end of days work inlet chamber is cleaned with fresh water. The depth of chamber is 60cm.

7. Pre digester

Circular, constructed in brick masonry having capacity of 40 m^3, diameter 4.0 m and depth 3.20 m is provided. It is divided into two parts by wall having opening at bottom of wall. The waste from inlet chamber enters pre digester via 13 holes provided at top. It is designed for 4 days retention period. The waste in pre digester undergoes hydrolysis and acidification processes with the help of aerobic – thermophilic micro organisms. To maintain thermophilic range of temperature hot water from solar water heater or heated on gas burner is poured in pre digester. To maintain aerobic conditions air is supplied with the help of compressor. The compressor is run 2 hrs in morning and 2 hrs in evening. The discharge from pre digester flows to main digester under gravity through open channel. The light weight fibrous material floats in first part of pre digester which needs pushing down manually.

8. Main digester

The main digester circular in shape, is made up of brick masonry. It is having 80 m^3 capacity, diameter 5.1 m and depth 3.90 m. additional capacity or buffer is maintained by rising outlet pipe. The discharge from digester is stored in holding tanks where it is allowed to settle. Supernatant is recycled for mixing and gardening purpose. Settled sludge is used as manure after drying. Bio gas generated is stored in floating roof type gas holder and used in duel fuel generator for electricity generation. Also bio gas is used in gas burner for heating water.

9. Gas holder - floating roof

Mild steel floating roof is used as gas holder having volume of about 25 m^3. It floats in water bath which maintains water seal also. The weight of gas holder is 800 kg. for 10 mbar pressure required for generator, the weight is increased by 1.5 TPD. 4 mm thick mild steel plate is used for fabrication.

10. Outlet chamber

It is 1m x 1m x 1m deep brick masonry chamber from which PVC pipe of 150mm dia. is taken out. The pipe opens at two levels thus providing additional capacity in digester.

11. Sludge holding tank

Total 5 tanks (under ground) are constructed in brick masonry for sludge holding. There is no filter bed inside tank. The discharge is taken in each tank on alternate day and allowed to settle. The supernatant is pumped in another tank which is used for mixing with waste material and for gardening. The settled sludge is taken out, dried and used/sold as manure.

12. Compressor

There are two compressors used for aeration of pre digester, to maintain aerobic conditions in digester. It is run for about 4 hrs in a day.

Compressor-1: 1hp, rpm-1440, capacity- 4.5cft, working pressure-5 kg/cm^2

Compressor-2: 0.5hp, rpm-940, capacity-2.5cft, working pressure-2.sss5 kg/cm^2

13. Solar water heater/ gas burner

It is used for heating water which is poured into the pre digester for maintaining thermophilic temperature range. Gas burner run on biogas is also used to heat up water. Hot water from gas burner is manually poured in pre digester. At present solar water is under repairs.

14. Slurry pump

It is used for transfer of supernatant water from sludge holding tank to mixer for mixing with MSW and for gardening. It is run for at least 2 hrs in a day.

Motor: Kirlosker make

2 hp, 1.5 kW, 415 v, efficiency = 77%, rpm- 2830

Pump:

Head range = 9-18 m, Total head = 13.5 m, Discharge = 4.5 lps

Efficiency = 45%, rpm = 2830, size = 40 x 40 mm, kW/hp = 1.5/2.0

15. Water pump

It is used for fresh water supply and transfer of supernatant from on tank to another. It is run for at least 2 hrs in a day.

Motor: Crompton Greaves make

1 hp, 0.75 kW, 225 v, rpm- 1425

Pump:

Head range = 18-45 m, Discharge = 2800/880 lph

rpm = 1425, size = 20 x 20 mm, kW/hp = 0.75/1.0

16. Duel fuel generator

Kirlosker make duel fuel A.C.Generator of the following specification is installed for generation of electricity. Power generated is supplied to hospital. Generated is run for about 6-8 hrs daily.

Engine	:	No. 21.1042/0400314
		RPM = 1500, bhp = 12, kW = 8.8
A.C. Generator	:	IS- 4728
		Frame 4 DM 180/2, KVA = 10, rpm = 1500, volts = 445, Amp=13.3
Fuel consumption	:	Only diesel, 1 lit = 1 hr
		Duel fuel, 1lit diesel + biogas = 8- 9 hrs

Generator needs biogas at 10 mbar pressure for which additional weight of 1500 kg is placed on gas holder in addition of 800 kg self weight. The biogas consumption observed in one hour was 3.55 m^3 measured on gas meter.

Observations made during the study

- 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 in Chembur area weighs 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 smell badly.
- The bucket is lifted by two persons and emptied in the mixer.

- There should be some mechanical lifting and loading arrangement so that laboratory 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 filled completed and then emptied in pre digester by opening alternate holes provided for the same.
- 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.
  - It is observed that if the level is not dropped before loading the main digester then digester over flows. In this situation the scum gets mixed with water in water seal and comes out giving ugly appearance.
- 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.
  - It is observed that generator consumes about 3.55 m3 of biogas in 1 hr.
  - The generator is run only for 6-8 hrs in a day.
  - Excess biogas is being flared as it contains green house gases like CH4 and CO2.
- 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 blacish.
  - The BOD was observed to be less than 100/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 and their salary
  - Supervisor 1 no

- Plant operator 1 no
- Asst. plant operator 1 no
- Helper 3 no
- Watchman 1 no

TOTAL 7 no

- Rate of biogas generation, methane content and calorific value needs to be assessed.
- House keeping was good.
- Greenery developed around plant.

Commenst: Shatabdi hospital

- Because of Biphasic digestion, percentage of methane is higher as compared to other technologies and also the hydraulic retention time is reduced (HRT) is reduced.
- 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 needs modification.
- Digestion would be much faster if the input material is in the form of paste hence designs of the mixer needs to be modified.
- Input and output chambers can be further modified.
- This being a Pilot 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, hence the separate comparison is not given.

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

Capacity: 1 TPD

Location: Mahul Refinery, Chembur, Mumbai.

Type of waste: Canteen Waste

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 has 500 flats. The waste generated from these flats 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.

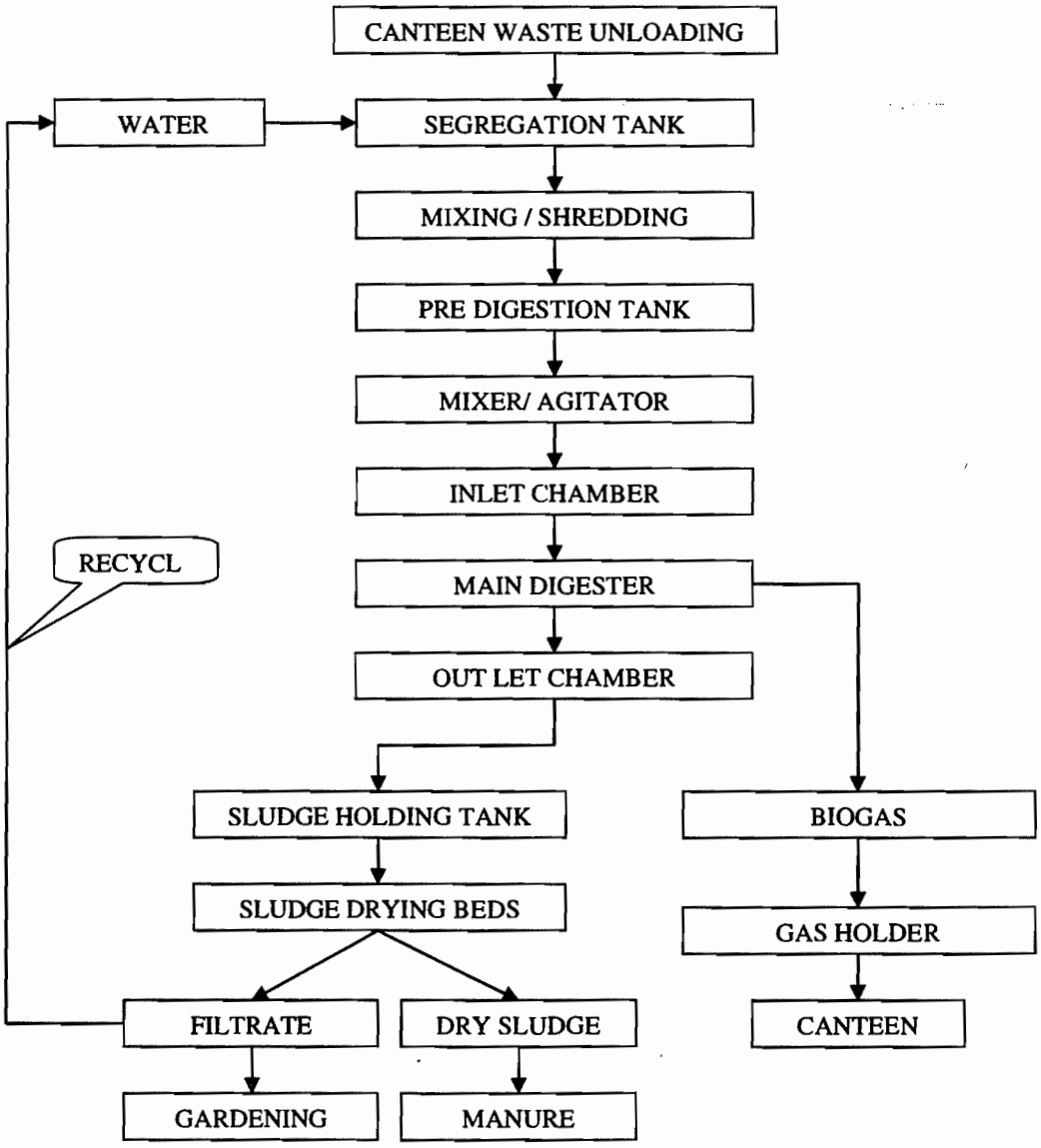
M/s. Aryan Associates, a Baroda based firm has installed biogas plat for 1TPD intake capacity producing 85-100m^3 of gas per day in 2001.The plant costing Rs. 29 lacs (excluding land & infrastructure) is spread over an area of 900 sq. M.

Silent Features of the Plant

- Unloading platform - 1 m high brick masonry with ramp.
- Mixing/ segregation tank - 2 nos. brick masonry tank
- Mixer / crusher - 2 HP, 2 Nos.
- Pre digestion tank - 2 nos. brick masonry.
- Mixer/ agitator - 2 HP, 2 Nos.
- Inlet chamber - brick masonry
- Main digester - Masonry digester 7 m in dia. and 5 m deep.
- Gas holder - M.S. Floating roof weighing 4 TPD
- Outlet chamber - Brick masonry.
- Sludge holding tank - under ground tank
- Sludge Drying Beds - 4 Units

- Water storage tank - under ground closed roof tank
- Water pump - 1.5 HP, 2 Nos.

Process Flow Diagram



Bharat Petroleum Corporation Ltd. Mumbai

Plant Operation

The waste generated and segregated at source is collected twice a day. Once in the morning at 9 am & secondly in the noon at 4 pm after lunch hour is over. The waste is collected in HDPE drums having capacity of 50 Kg. The drums are kept in each canteen. These are transported to the site through jeeps. In the morning 5-8 drums and in the noon 12-15 drums are collected. The vehicle is parked on the ramp near the unloading platform.

The drums are manually lifted & kept on platform. The waste is taken out from drums in mixing tanks. The water taps are opened while mixing. The manual search is done to remove unwanted things like plastics, spoons, bones, etc. Water to waste ratio is kept @ 1:1for making proper slurry. Finally the segregated waste after removing bones is mixed with water & is poured in mixer manually with the help of buckets/pans for crushing into small pieces. The crusher is like domestic grinder made up of stainless steel body & crushing blades operated by 2HP motor.

The grinded mix is kept in crusher vessel for half an hour for the purpose of pre digestion where acidification starts. Then it is drained in other tank from where it is taken to another mixer to make it a homogenous mix. Finally it is taken to inlet chamber from where fed to main digester for biological treatment, where biogas is produced.

The digester is 7 m in diameter and 5 m deep. The walls are constructed in masonry with water seal arrangement and a floating roof made of mild steel weighing 4 Tones. The floating roof is provided with central guiding pole for it's up & down movement and lifting arrangement for removal during the maintenance. Temperature inside the digester is generally 35-38^{0}c. Initially the hydraulic retention time (HRT) was of 40 days, now it is between 15-20 days.

Gas generation and its use

The gas produced @ 85-100 m^3/day is used for preparation of tea, as it is having low calorific value 4500Kcal/M^3 compared to LPG. It is not used for food preparation which needs more heat. The gas contains 55-60% methane.

About 100 m^3 of gas is hold in MS roof under its own weight pressure. Excess gas is bubbled out from water seal provided.

Sludge generation

The slurry flows out continuously. It comes first to outlet chamber & then to slurry sump. In slurry sump it is held for a day where mixed gas is allowed to vent off and then taken to sludge drying beds (SDB). There are 4 SDB units. One bed is used for one week and then left for sun drying. Sludge is removed weekly from alternate beds.

The filtrate is collected in water storage tank which is recycled for mixing the waste initially and for gardening. The dry sludge, good manure, is used in gardens.

Operation & maintenance

Operation & maintenance is carried out by M/s. Aryan Associates for which contract for 15 years is awarded to them at the cost of Rs. 47000/- per month at 4% increase per year. They are having staff of 1 engineer, 1 supervisor, 5 labor & vehicle for transportation of waste on site.

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.

Comment: BPCL Plant

- There is no laboratory for monitoring of plant performance.
- Segregation should be done on loading platform instead of carring 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. Nigadi 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 cooters 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.

It is having two canteens. One is for officers and other for general workers. Both canteen 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 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.

The plant provided consists of the following units/machinery.

1) Loading table - Mild steel lined with glass fibers to avoid corrosion.

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

3) Inlet chamber - Brick masonry.

4) Feeding pump - 1 HP

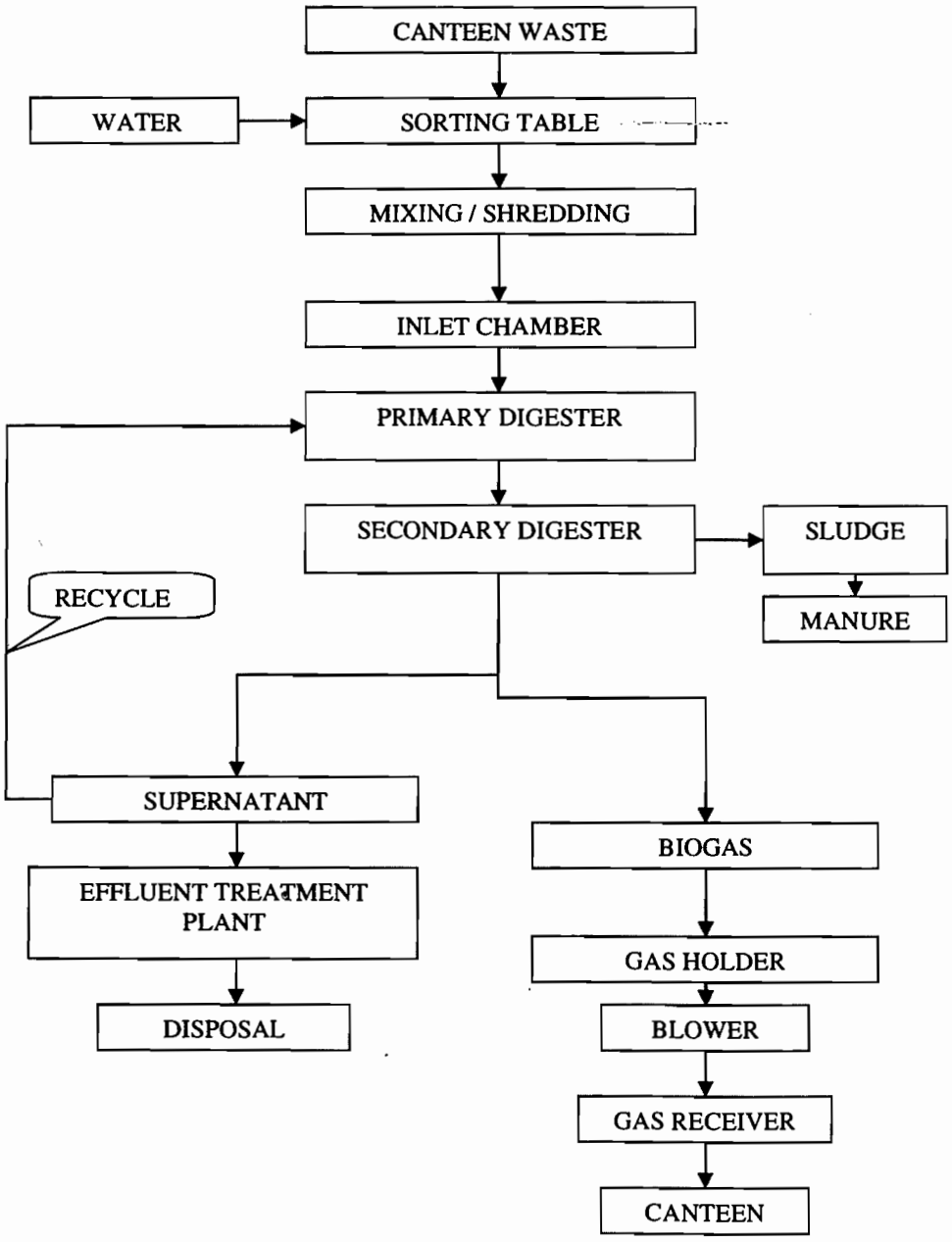
5) Primary digester with stirrer - Mild steel, 0.5 HP, 5 rpm

6) Secondary digester - Mild steel

7) Gas holder - Neoprene rubber balloon.

8) Gas compressor - 1 HP with MS gas receiver tank.

9) Outlet - Brick masonry.


CANTEEN WASTE
WATER
SORTING TABLE
MIXING / SHREDDING
INLET CHAMBER
PRIMARY DIGESTER
SECONDARY DIGESTER
SLUDGE
MANURE
RECYCLE
SUPERNATANT
EFFLUENT TREATMENT PLANT
DISPOSAL
BIOGAS
GAS HOLDER
BLOWER
GAS RECEIVER
CANTEEN

Bajaj Auto Ltd. Nigadi, Pune.

Plant Operation

Both the canteens open in the morning at about 9 am for tea and breakfast. The waste is generated after the lunch i.e. 2 pm. Therefore the waste is brought to site at 2.30 pm in trolley loaded with buckets containing waste. The waste is about 90% segregated. Some times it includes plastic bags, packaging material spoons, nails which need to be removed before grinding/shredding.

The plant operator unloads the waste from bucket on table. Opens the tap of water & feed the waste to shredder manually, at the same time he picks up unwanted things from waste. To settle heavy objects like screws, nails, spoons a groove is provided in the table. The shredder is provided with tungsten carbide blade which cuts hard material like bones, nails or spoons, etc. This takes hardly 30-40 min. to complete operation. The waste to water ratio is generally 1:1 thereby it forms slurry which is taken to inlet chamber from where pumped to the bottom of the primary digester.

Primary digester is made up of M.S. 3.2 m in dia. & 4.2 m liquid depth. Top is welded / fixed. The stirrer & baffles are provided for mixing the waste thoroughly. The motor of stirrer is fixed on top of digester roof. Baffles are provided on inner side of wall. Some specially designed modules are provided inside which helps in settling of particles. The supernatant is connected to secondary digester at bottom. The blac/darker water coming out of secondary digester is good indicator of efficient / successful working of unit. This water is partially recycled to primary digester and remaining is taken to ETP for further treatment. The detention period in primary digester is 21 days and secondary digester is 7 days.

Gas generation and its use

From 500 kg of waste per day about $43m^3$ of biogas is generated. The yield varies from season to season depending upon ambient temperature & substrate quality fed to the digester. The gas contains 55-60% methane, 1% H_2S remaining CO_2 and little moisture. The gas is stored in neoprene rubber balloon at NTP conditions. From the balloon the gas is passed in M.S. vessel / gas receiver with the help of blower / compressor to maintain pressure of 2000 mm of water column, so that burners get gas at constant flow.

The gas is conveyed/carried through HDPE pipes painted in yellow colour to the canteen situated at second floor. The pipes are provided with moisture traps to remove moisture. The gas is used in canteen for cooking food of about 125 persons daily.

The experiments are going on to operate LPG fired geyser (water heater) on this gas. It is observed that the gas does not light with lighter, but it needs flame/ match box for lighting. Calorific value of gas is about 4800 K-Cal/Kg.

Sludge generation

The generation of sludge is very less. It is only 4000 lit/yr which is 12% slurry. It is removed once in a year and used as manure in the gardens.

Power consumption

Shredder	- 3hp, 30 min	- 1.125 units
Pump	- 1 hp, 4 hrs.	- 3.00 units
Stirrer	- 0.5 hp, 4 hrs.	- 1.50 units
Compressor	- 1 hp, 8 hrs.	- 6.0 units
	Total	**- 11.625 units**

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.

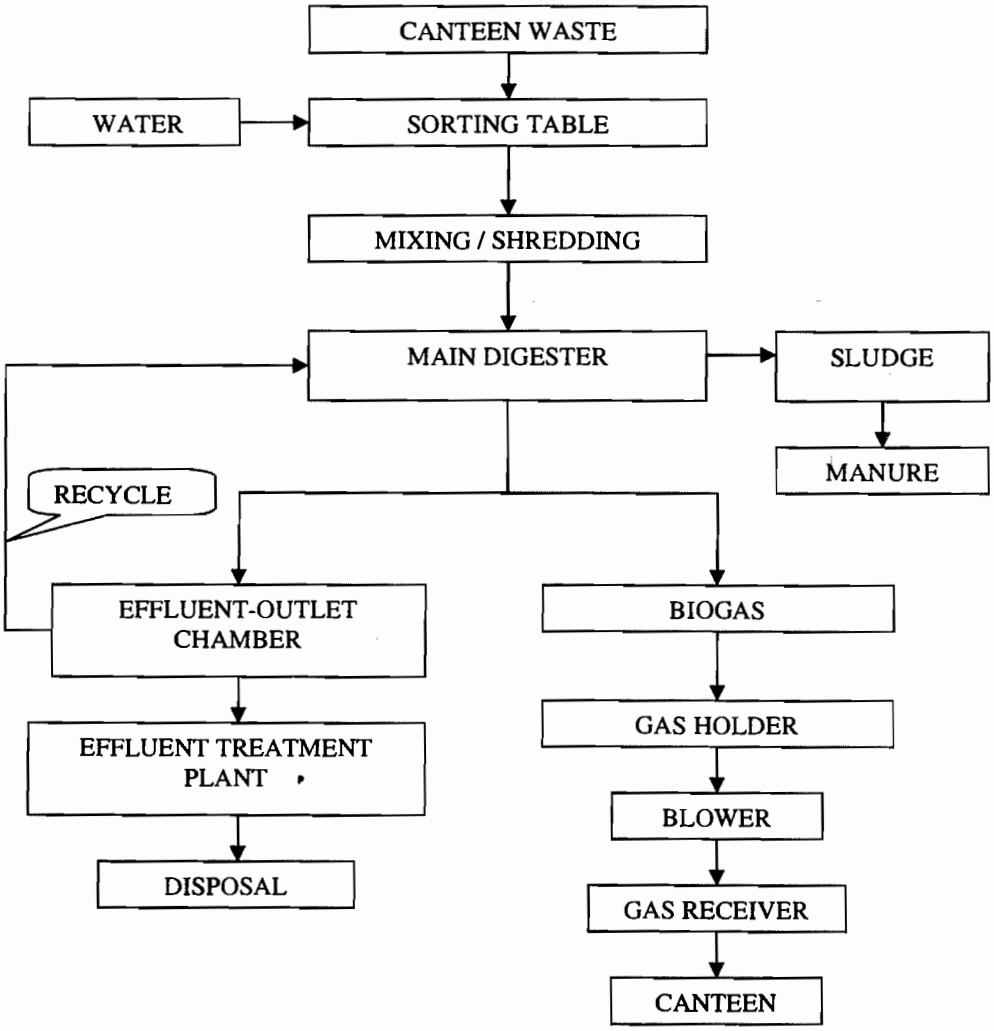
M/s. Mailhem engineers Pvt. Ltd. Pune has installed biogas plant 9 month ago. The plant total cost is Rs. 4.5 lacs plant Rs. 3.5 lacs + civil works Rs. 1.0 lacs]. The space required is very less(20' X 40').

Company is having 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 of the Plant

1) Loading table - Mild steel lined with glass fibers to avoid corrosion. Size 2'X 4'.
2) Shredder/cutter - 3 HP motor, Tungsten Carbide Cutter, 1 TPD/hr capacity.
3) Inlet chamber - Brick masonry.
4) Digester with stirrer - under ground RCC, 0.25 HP
5) Gas holder - Neoprene rubber balloon with level indicator of rope pulley type.
6) Gas compressor - 1 HP with MS gas receiver tank and pressure gauge meter.
7) Outlet / recycle chamber - Brick chamber.

8) Recycle pump/sludge pump - 1 HP



Kirloskar Oil Engines Ltd. Khadki, Pune

Plant operation

The canteen which opens in the morning is located on first floor near plant. The loading table is placed near the kitchen on first floor. The waste is collected in bucket (only one) provided. As soon as bucket is full, the operator unloads on table, opens tap of water and starts grinding operation. The process is intermittent as when bucket is full, waste is fed to digester.

From the grinder, the slurry type material flows through pipe (about 3 inch dia. And 100 feet long) under gravity to inlet chamber & then to digester. The inlet chamber is masonry pit covered M.S. plate. The water to food ratio used is 1:1 for making slurry. We can see slurry from inlet chamber.

The digester is provided under ground which is helpful in maintaining temperature inside. Also the slurry can be fed by gravity reducing electricity consumption. It is circular in plan having 3.8m dia. and 2.5m depth. The top is of M.S. welded on RCC wall. On top stirrer motor is mounted and closed opening is provided for removal of sludge and maintenance inside.

Outlet chamber is constructed in masonry & is covered with M.S. plate. The submersible pump is installed in the outlet chamber for recycling of effluents back into inlet. Recycle ratio is 1/10.

Gas generation and its use

From 300kg of waste 24 m^3 of is produced. It is used in canteen for making tea. It savesone 19.2 kg of Rs. 696/- LPG cylinder per day. The gas is stored in neoprene rubber balloon kept in locked room. The rope & pulley type level indicator is provided on wall of room. From where one can easily see and knows quantity of gas available Venting arrangement is provided to balloon. Gas compressor and receiver is provided to maintain the pressure at burners. The compressor is automatic, as pressure drops below required it operates.

Sludge generation

The generation of sludge is very less. It is removed once in a year and used as manure in the gardens. The submersible pump is used for removal of sludge from digester at the time of cleaning.

Power consumption

Electricity consumption is only 8units/day.

Shredder	- 3hp, 30 min	- 1.125 units
Stirrer	- 0.25 hp, 4 hrs.	- 0.75 units
Compressor	- 1 hp, 8 hrs.	- 6.0 units
	Total	- 7.875 units

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.

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

Capacity: 0.80 TPD

Location: Kandivli (E), Mumbai

Type of waste: Canteen Waste

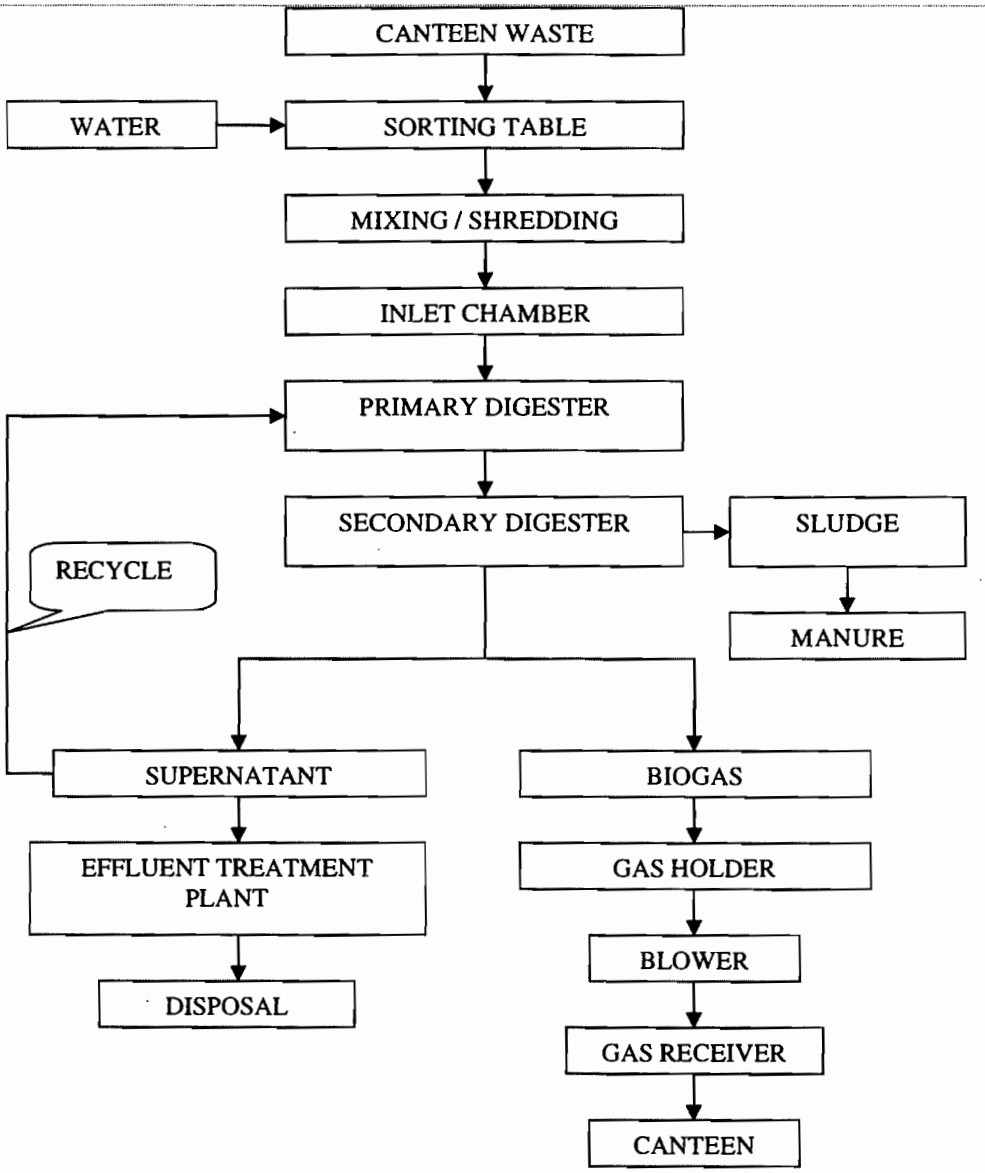
Mahindra & Mahindra Ltd. (Auto Div) is located at, Kandivli (E), Mumbai on western express highway. The industry engaged in manufacturing of jeeps.

It is having one common canteen for officers and general workers. Canteen generate 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 is between 7- 8 lacs.

Silent Features of the Plant

1. Loading table - Mild steel lined with glass fibers to avoid corrosion.
2. Shredder/cutter - 3 HP motor, Tungsten Carbide Cutter, 1 TPD/hr. capacity.
3. Inlet cum recycle chamber - Brick masonry (2mx1mx1m ht).
4. Feeding pump - KSB centrifugal slurry pump
5. Primary digester - capacity 35 m^3, 5mm thick MS with FRP lining of 1mm .
6. Stirrer assembly - 2 stage cyclo reduction gear box & a motor of0.5 HP
7. Secondary digester - capacity 9 m^3, 3mm thick MS with FRP lining of 1 mm thick.
8. Gas holder - 40 m^3 capacity Neoprene rubber balloon.
9. Biogas blower - Roots type 2HP with MS gas receiver tank of 1 m^3 a capacity.



Mahindra & Mahindra Ltd. (Auto Div)

Plant Operation

The factory works in 3 shifts and hence the canteen is open for 24 hrs. But the maximum waste is generated in first shift between 10 am to 4 pm. The waste is generated after lunchtime i.e. 2 pm. The plant is situated near the canteen. The waste from dish washing area is directly fed to the shredder. The waste is about 90% segregated. Some times it includes plastic bags, packaging material spoons, nails which need to be removed before grinding/shredding.

To settle heavy objects like screws, nails, spoons a groove is provided in the table. The shredder is provided with tungsten carbide blade which cuts hard material like bones, nails or spoons, etc. This takes

hardly 30-40 min. to complete operation. The waste to water ratio is generally 1:1 thereby it forms slurry which is taken to inlet chamber from where pumped to the bottom of the primary digester. The waste is brought down to the digester by Gravity and hence no power is required.

Primary digester is made of M.S. having 36m3 capacity. Top is welded / fixed /The stirrer & baffles are provided for mixing the waste thoroughly. The motor of stirrer is fixed on top of digester roof. Baffles are provided on inner side of wall. Some specially designed modules are provided inside which helps in settling of particles. The supernatant is connected to secondary digester at bottom. The blac/darker water coming out of secondary digester is good indicator of efficient /successful working of unit. This water is partially recycled to primary digester and remaining is taken to ETP for further treatment.

Gas generation and its use

From 800 kg of waste per day about $80m^3$ of gas equivalent of 32 kg of LPG is generated. The yield varies from season to season depending upon ambient temperature & substrate quality fed to the digester. The gas is stored in neoprene rubber balloon at NTP conditions. From the balloon the gas is passed in M.S. Vessel / gas receiver with the help of blower / compressor to maintain pressure, so that burners get gas at constant flow.

The gas is conveyed/carried through HDPE pipes painted in yellow colour to the canteen situated at ground floor. The pipes are provided with moisture traps to remove moisture. The gas is used in canteen for heating milk, tea and rice cookers.

Sludge generation

The generation of sludge is very less. The digested slurry is used for gardening.

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

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. The plant consists of the following units/equipments.

1. Loading table - Mild steel lined with glass fibers to avoid corrosion. Size 2'X 4'.
2. Shredder/cutter - 3 HP motor, Tungsten Carbide Cutter, 1 TPD/hr. capacity.
3. Primary digester with stirrer – 0.25 HP
4. Distribution chamber.
5. Secondary digesters (2 nos.)
6. Outlet / recycle chamber.
7. Recycle pump/sludge pump.
8. Vent / flare.

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 has 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 2'X 2'.

2) Shredder/cutter - 1 HP motor, Tungsten Carbide Cutter,

3) Primary Digester -9'x4'x8' deep.

4) Secondary digester - 16'x4'x8, deep.

5) Outlet chamber.

6) 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

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 2'X 2'.
2) Shredder/cutter - 1 HP motor, Tungsten Carbide Cutter,
3) Digester -1.5m x 1.8m x1.2m deep.
4) Outlet chamber.
5) Vent / flare.

Gas is not used being very less produced. It is vented/ flared out in the atmosphere. The plant is operated by watchmen/sweeper of the society.

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

Capacity: 2.0 TPD

Location: Devas

Type of waste: Canteen Waste

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 is 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

Silent Features of the Plant

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

Power consumption - 60 kWh/day

The biogas contains 65 – 70 % Methane (CH_4).

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: Canteen Waste

Shirdi,I, is a small temple townwhich s well known for the Saibaba Temple. There are regular devotees visiting Shirdi. The floating population in Shirdion any day is from 2500 to 50000 and on holidays and special occasions it is in few lacs.. Being small village, in order to provide facilities to the devotees,the Devathan committee decided to construct 'dharamshala', the lodging for visitors. The Dharmashala has 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 the Devasthan Committee decided to set up a biogas plant on human excreta and generate electricity.

M/s. Sulabh International has installed the biogas plant which wascommissioned in 1997. MNES, GOI and MEDA have funded the plant. The plant has 3 digesters of 35m^3 capacity treating 105 m^3 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

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. 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 cow dun is easily availabe for biogas plant. There are 3 digesters of 40 T capacities. The digested slurry is used for vermin composting where manure is produced.

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 (Cow dung)

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 buffalo per day. This is a 100% export oriented mechanized slaughtering unit. The slaughter house processes generate 1400 m^3 of liquid and 60 tonnes 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 tonnes of bio manure and reduces the green house gas emission to the atmosphere.

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 condition s with international collaboration. The gas engine is installed to generate electricity from the biogas generated from liquid and solid waste treatment plant. It is also used for generating steam to use in the meat processing unit as well as to maintain the temperature for operating 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 Feature 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 high rate Biomethanation reactor with biogas induced mixing arrangement.
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
Process control	Automatic microprocessor based programmable logic control (PLC) system
Power required for the solid waste biomethanation plant	420 KWh/day
Electrical equivalent of biogas produced	5500 KWh/day
Bio manure generated	7 tonnes/day
Type of gas holder and volume	Membrane type $500m^3$
Biogas composition	CH_4-60-65%, CO_2-35-40%, H_2S-0.5%

Composting techniques

The two principal methods of composting may be classified as agitated and static. In the agitated method, the material to be composted is agitated periodically to introduce oxygen, to control the temperature, and to mix the material to obtain a more uniform product. In the static method, the material to be composted remains static and air is blown through the composting material. The most common agitated and static methods of composting are known as windrow and static pile methods, respectively. Proprietary composting systems in which the composting operations are carried out in the reactor of some type are known as in-vessel composting system.

Windrow composting

It is one the oldest method of composting, in its simplest form a windrow compost system can be constructed by forming the organic material to be composted into windrows 8-10 feet high by20-25 feet wide at the base. A minimal system could use a front-end loader to turn the windrow once per year. Which such a minimal system would work, it could take up to 3 to 5 years for complete degradation. Also such system would probably emit objectionable odors, as a part of the windrow will likely be anaerobic.A high rate windrow composting system employs windrows with smaller cross section, typically 6-7 ft high by 14-16 ft wide. The actual dimension of the windrow will depend on the type of the equipment that will be used to turn the composting wastes. Before the windrows are formed the organic material is shredded and screened to approximately 25 to 50 mm and the moisture content is adjusted to 50-60%. High rate systems are turned up to twice per week while temp is maintained at or slightly above 55^{0}C, turning of windrows is often accompanied by release of offensive odors. Complete composting can be accomplished in 3 to 4 weeks. After the turning period the compost allowed to cure for additional 3 to 4 weeks without curing. During the curing period fungi and actinomycetes further reduce the residual decomposable organic materials.

Aerated static pile composting

The U.S. Department of Agriculture Agricultural Research Service Experimental Station at Beltsville, Maryland; thus the process sometimes known as Beltsville or ARS process developed the aerated static pile composting process. Originally developed for the aerobic composting of the wastewater

sludge, the process can be used to compost a wide variety of organic waste including yard waste or separated MSW.

The aerated static pile system consists of a grid of aeration or exhaust piping over the processed organic fraction of MSW is placed. Typical pile heights are about 7 to 8 ft. a layer of screened compost is often placed on the top of the newly formed pile for insulation or odor control.

Each pile is usually provided with an individual blower for more effective aeration control. Disposable corrugated plastic drainage pipe is used commonly for air supply. Air is introduced to provide the oxygen required for biological conversion and to control the temp within the pile. Blower operation is typically controlled by a timer or in some systems by microcomputer to match a specific temperature profile. The material is composted for the period of 3 to 4 weeks. The material is then cured for period of 4 weeks or longer. For improved process and odor control all or significant portions in the system in the newer facilities are covered or enclosed.

In- vessel Composting Systems

In vessel composting is accomplished inside an enclosed container or vessel. Everyimaginable type of vessel has been used as a reactor in these systems including vertical towers, horizontal rectangular and circular tanks and circular rotating tanks. In vessel composting systems can be divided in to two major categories; plug flow and dynamic (agitated bed). In plug flow systems the relationship between particles in the composting mass stays the same through out the process, and the system operates on the first in first out principle. In the dynamic system the composting material is mixed mechanically during the processing.

Mechanic systems are designed to minimize the odors and process time by controlling environmental conditions such as airflow, temperature, and oxygen concentration.The popularity of in vessel system has increased in recent years. Reasons for this are process and odor control, faster throughput; lower laboratory costs and smaller area requirements. The detention time for in vessel systems varies from 1 to 2 weeks but virtually all systems employ a 4 to 12 weeks curing period after the active composting period.

Aerobic Composting: The plants under study:

1. Vijayawada Municipal Council, Vijayawada, AP
2. CCI, Mumbai
3. M/s Excel Industries; Mumbai.
4. Bio Composting, 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 is commissioned in 1996 for Vijayawada Municipal Council (VMC). The Vijayawada city having population of 15 lacs generate 400 T 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 was **Rs. 3 crs at the time of installation**. The investment is made by M/s. Excel Industries Ltd. There is no finance from VMC or MNES. The technology and execution of work is done by M/s Excel Industries Ltd. The VMC supplies 125 T of mixed heterogeneous waste daily through its hydraulic dumpers. It is a non segregated waste as if lifted from the dust bins.

The collection and transportation of waste to the plant site is VMC's responsibility. After waste is arrived on site, treatment starts. The treatment is carried out in two steps

1) Biological process and 2) Mechanical process after which compost manure is recovered.

From rejects of screening recyclaboratoryles are recovered by rag pickers. Non-recyclaboratoryles are disposed off for land filling in low-lying areas within 5 km radius area by industry. Industry pays royalty of Rs. 50 per t of finished product. Also they pay land lease rent of Rs. 2.92 lacs per annum to the VMC.

At Vijayawada plant, technology adopted by Excel is controlled by aerobic composting. In aerobic composting 1) rapid decomposition normally completed within 4-6 weeks and (2) during this period high temperature are attained leading to speedy destruction of pathogens, insect eggs and weed seed. Factors that controls the rate of successful composting are

1. Moisture content (50 to 60 %) and Temperature (65-70^{0}c) maintenance.
2. Regular turning of heap to ensure uniform moisture content, inoculants content and proper aeration.
3. Carbon Nitrogen ratio (20 to 25)

Composting process:

The process carried out Vijayawada plant involves the following stages.

1. Waste sanitization.
2. Controlled aerobic composting.
3. Mechanical screening of digested compost.

Waste Sanitization Process:

Solid waste either at collection point or plant site is treated by spraying a biological inoculum. Treatment material developed by company is known as 'Sanitreat' is a mixture of biological enzymes and herbal extracts. Within couple of hours after the spray, solid waste becomes free from foul smell and hazardous pathogens. The treated waste can be safely handled for further processing without creating health hazard to the public in general and the workers in particular.

Controlled Aerobic Composting:

The process consists of two stages namely Biological process for decomposition of organic matter and mechanical process for screening the decomposed organic matter.

a) Biological process:

The solid waste is collected and on site regularly by VMC. As soon as waste is arrived on site, it is inoculated. The inoculum is sprayed on the garbage and mixed thoroughly. The treated garbage will be stacked in the form of windrows. Here one windrow consists of seven days waste. These windrows are turned once in a week for proper aeration so that the aerobic process continues uninterrupted.

Progress of composting is monitored by measuring the inside temperature of the heap and

level of moisture. The water is sprinkled on heaps as per requirement. The temperature has to be between 65-70^{0}c & moisture content should be 50-60%. Composting will be completed in 30-45 days. When brackish brown colour is obtained and waste becomes odorless, it is said that process of composting is complete.

The temperature inside the heap goes on decreasing after every turning of heap. It is like after

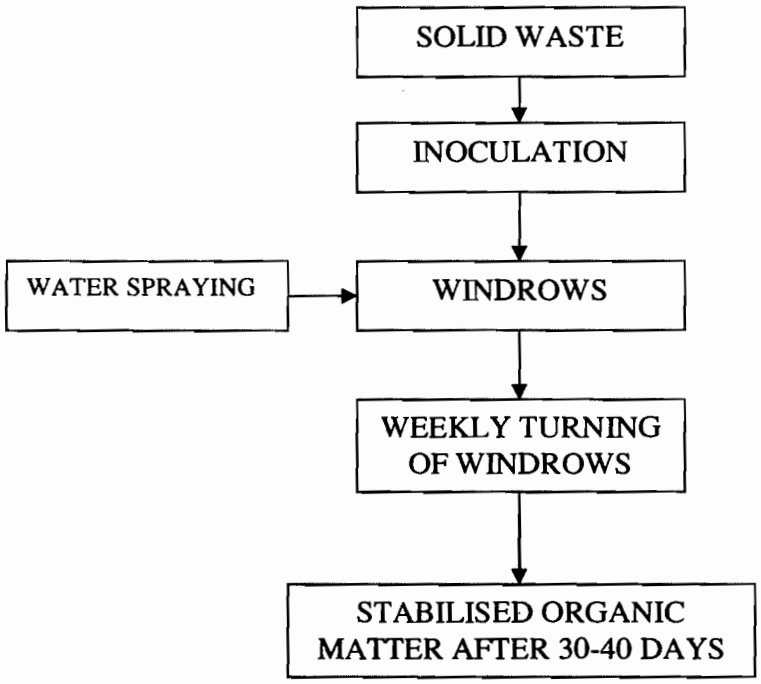
1st Turning 65 – 70^{0}c

2nd Turning 60 – 65^{0}c

3rd Turning 55 – 60^{0}c

4th Turning below 50^{0}c

Biological Process Flow Diagram



Total dose of bioculum consists of 1 kg per tonne of waste treated. It is given in three stages i.e. in the beginning, before first turning and before second turning. Total water requirement during complete process is about 200 lit per tonne of waste treated.

The inoculum is prepared by using the mixture of bacteria, cow dung and water. The biological inoculum used for composting known as Excel develops 'Bioculum'. It is a mixture of cultures of microorganisms (mesophillic & themophillic) specifically developed for accelerated aerobic composting of organic waste. It consists of cultures of bacteria, fungi and actinomycites aiong with

enzymes, which facilitates bioconversion of organic waste into bio-stabilized compost speedily. It is free from any toxic or hazardous material.

Mechanical process

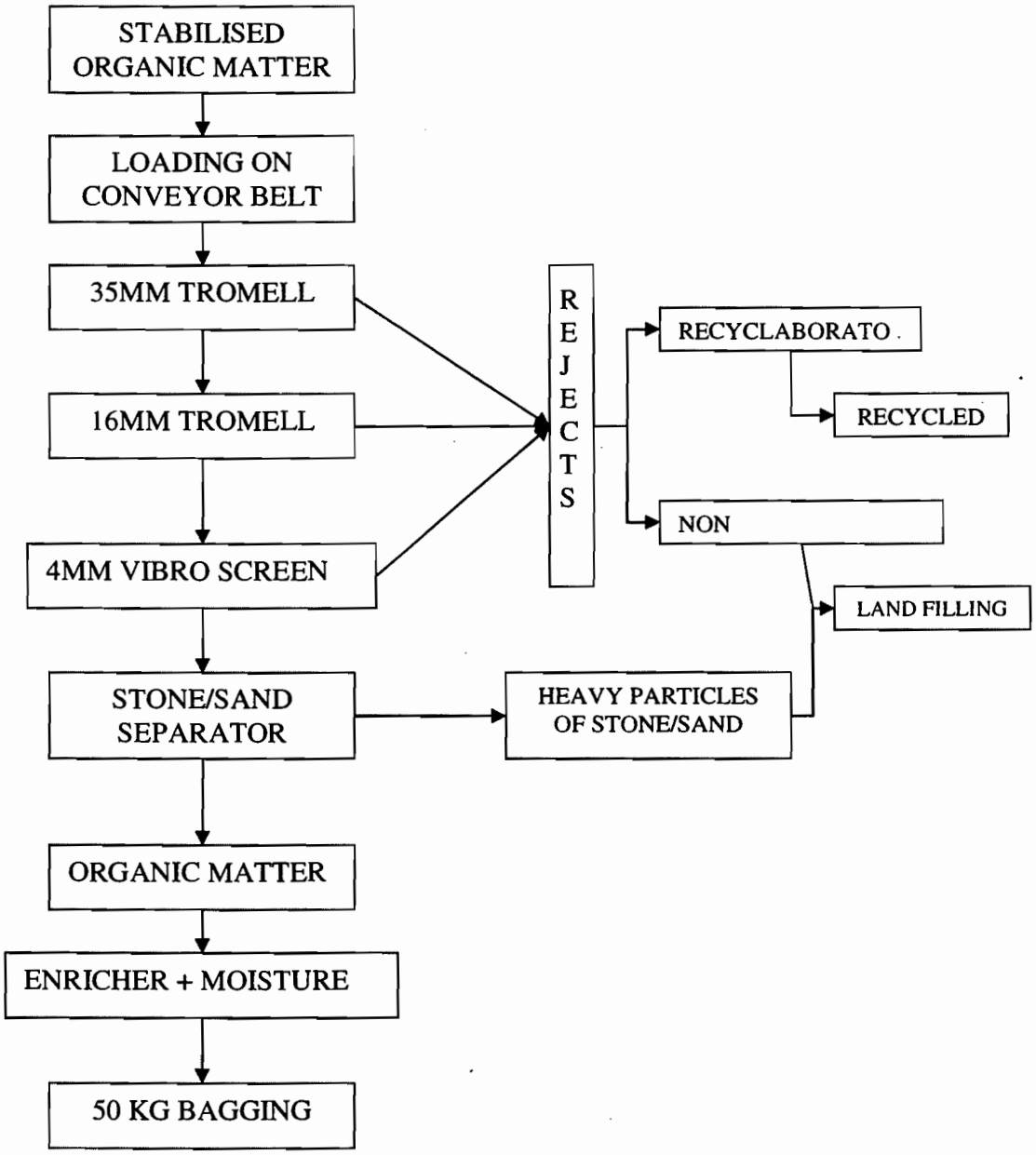
It is essential for screening out the digested organic matter in the form of powder from all impurities. The digested compost is highly heterogeneous having impurities of varies shapes, size and texture. Hence screening has to be done in different stages. Suitable machines are installed at different stages.

At Vijayawada plant mechanical process adopted is as under.

The completely composted material is lifted by front end loader JCB and unloaded onbelt conveyor. The conveyor discharges it into first rotary screen called tromill of size 35mm. Here the material more than 35mm size goes for rejection and smaller to further screening. The material screened in 35mm is fed to second rotary screen of size 16mm by bucket elevator. Here over size material is rejected and other is taken for further screening. The rejected material at 1st and 2nd tromill consists of some recyclables, which are picked by rag pickers. In third screen material is screened through 4mm size vibrating screen. Oversized is rejected while screened one is taken to stone/sand separator. In this air is forced from bottom, which separates lighter particles from heavier one. The heavier stone/sand particles are rejected. Lighter, organic matter taken to finished product area. In mechanical process section complete material is handled on conveyor belt and bucket elevators.

In the finished product section packaging is done in the 50 kg bags. Before packing enrichers as per customers' requirements are added and water is added to maintain the moisture upto 25%. The enricher includes microbes like azetobactor, Rhyzobium and micro nutrients like sulpher, gypsum, etc.

Mechanical Process flow diagram



Silent Features of the Plant

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.	- 2 HP(1 HP each)
6)	Out going conveyor	- 3 HP
		34 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
			23 HP

Total (A+B) - 57 HP

+ Bore well, Office light, Street light, etc Approximately 75-80 HP

Connected load - 85 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 laboratory	- 30
Total	- 40

Laboratory facility:

Small quality control laboratory is setup in the premises. Following tests are carried out in the laboratory.

1. Moisture content
2. Total organic matter
3. Total organic carbon
4. Nitrogen
5. Phosphorus

6. Potassium
7. pH
8. Bulk density

Observations:

125 TPD aerobic composting plant is commissioned in 1996. Plant is working at full capacity.

- 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 recyclaboratoryle 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 is 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.

Details:	Waste type	: canteen/ hotel waste
	Waste generation	: 200 kg / day
	OWC machine	: 100 kg capacity
	Processing shed	: 21 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.

Excel industries ; Jogeshvari

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.

3. Organic Waste Converter (OWC) developed by Excel Industries Ltd., Envir ; 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 is also engaged in composting of MSW since long back. 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.

Now they have developed a compact machine called 'Organic Waste Converter' (OWC). 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 maintained 25kg waste: 2.5

kg saw dust/ paper: 2.5 kg dry manure. Also bio-culture 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 availaboratoryle 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

x 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 m^2	60 m^2	150 m^2

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.

- More yields can be obtained if segregated waste is processed.

- Working schedule of the plant is disturbed in monsoon season.

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: The plants Studied:

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
8. Vermigold, Dadar

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.

The food waste conversion into compost is based on aerobic process and is entirely different from conventional vermin composting process. Bacteria and earthworm activity stabilize the waste into manure within 7 days. Manure is harvested every 6 months and used in gardening and farming.

The plant consists of pits made up of brick masonry walls of size17m long, 4m wide and 0.6md deep. The plant is situated in the company premises. In the pit first 10 cm layer of hard organic material is given over which another 10 cm layer of decomposed cow dung or mulch is spread. On this layer cocoon of Pheretima Elongata earth worm species is given at the rate of about 16 kg per sq. m. area. Thin layer of Murum is spread on this and covered with rice straw. The watering is done daily. After two months of earthworms will be developed from the cocoons. At this stage actual feeding of waste is started. Initially small quantity of waste is added i.e. about 5 kg per sq. m. area. Daily waste is

spread in one pit. After seven days it is again fed with waste. In second turn the waste is applied at full capacity around 16 kg per sq.m. area.. After every feed murum is sprinkled on it. It is required for earthworms for churning. It also absorbs extra water. After murum is laid the pit is covered with thin layer of rice straw to control the temp and to hide the waste from the flies and the birds. On this water is sprinkled daily at the rate of 5 lit/sq,m. .

Every day only one trench is loaded, in a week period. In the next week again theloading of the trenches starts from the very first trench. This loading process is continued for about 6 months after that the loading of that particular trench is stopped and the decomposed material will be allowed to stabilize for about 15 days. So after 6 months the manure so prepared will be harvested and then screened through screens and then packed and marketed. Waste screenings are taken to dumping ground for disposal.

About 15-18% yield of manure is observed. There is no operation and maintenance cost is given but 10% manure is used by M/s. TATA Motors and 90% is sold out by contracting firm. The manure so collected is used as soil conditioner for gardening and farming.

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 - Laboratorys - 5 nos. ; Supervisor - 1 no.

G) Water and electricity - given by TATA Motors.

Tata Motor Vermi Compost

4.5TPD vermi compost plant is commissioned in two stages i.e. first stage for treatment of 1.5 TPD waste per day commissioned 3 years back and second phase of 3.0 TPD per day capacity was commissioned in Jan'2005. 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 enricher to use in the farms. The plant is maintained properly and was in operation during the visit.

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.

The food waste conversion into compost is based on aerobic process and is entirelydifferent from conventional vermin composting process. The waste is stabilized into manure within 7 days by bacteria and earthworm activity. Manure is harvested every 6 months and used in gardening and farming.

The plant consists of pits made up of cuddapa stone walls of size 4m wide, 0.6md deep and suitable length to suit topography. The plant is situated at the foot of mountain near to PCMC dumping ground. In the pit first 10 cm layer of hard organic material is given over which another 10 cm layer of decomposed cow dung or mulch is spread. On this layer cocoons of Pheretima Elongata earth worm species is given at the rate of about 16 kg per sq. m. area. Thin layer of Murum is spread on this and covered with rice straw. The watering is done daily. After two months of earth worms will be developed from the cocoons. At this stage actual feeding of waste is started. Initially

small quantity of waste is added i.e. about 5 kg per sq. m. area. Daily waste is spread in one pit. After seven days it is again fed with waste. In second turn the waste is applied at full capacity around 16 kg per sq.m. area. After every feed murum is sprinkled on it. It is required for earth worms for churning. It also absorbs extra water. After murum is laid the pit is covered with thin layer of rice straw to control the temp and to hide the waste from the flies and the birds. On this water is sprinkled daily at the rate of 5 lit/sq,m. .

Every day only one trench is loaded, in a week period. In the next week again the loading of the trenches starts from the very first trench. This loading process is continued for about 6 months after that the loading of that particular trench is stopped and the decomposed material will be allowed to stabilize for about 15 days. So after 6 months the manure so prepared will be harvested and then screened through screens and then packed and marketed. Waste screenings are taken to dumping ground for disposal.About 15-18% yield of manure is observed. There is no operation and maintenance cost is given but 10% manure is used by P.C.M.C. and 90% is sold out by contracting firm. The manure so collected is used as soil conditioner for gardening and farming.

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	- Laboratorys - 6 nos. ; Supervisor - 1 no.
G) Water and electricity	- given by PCMC.

Obsevation:

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 enricher 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.

3. Orchid Ecotel Hotel

This Hotel is locagted 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 kg/month - 40320 kg/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

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 - depednign upon 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.

5. Pan India Paryatan Ltd. – Esselworld

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

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 MSWb 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 vermin composting area required is 374 Sq.M./TPD of MSWb waste of 1 TPD plant.

Analysis of Compost, Vermi Compost and Digester Sludge

Sample Location	pH	Moisture	NO_3-N	P	K
Shatabdi Hospital Biogas digester sludge)	7.48	41.83 %	1.47%	1.92 %	1.0 %
Makarand Society ;Vermi Compost	7.25	8.95 %	1.33%	0.08 %	0.25%
Colaboratorya Pumping St. (Vermi compost)	7.86	20.45 %	0.83%	0.35 %	0.85%
CCI, Churchgate (OWC compost)	8.42	48.65 %	1.16%	0.45 %	2.18%
Chennai biogas plant (Biogas digester sludge)	7.48	35.28%	2.20%	1.92%	2.40%
Mailhem Vijayawada (Biogas digester sludge)	7.55	30.42%	1.48%	1.76%	1.56%
Excel industries Vijayawada(compost plant)	7.35	23.85	1.21%	0.72%	0.78%
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:

S. 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 digester	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%

Annexure B:

Design of Digester for Treatment of 1 MT Canteen Waste

1. Loading platform and grinder:

Loading platform and grinder area 3m * 3m

Shredder capacity = 1 MT/ hr, 2.25kWh (3 HP) motor

2. Digester:

Assume 80% moisture in the canteen waste, remaining 20% will be solids.

Water is mixed in the ratio 1:1 by weight.

In 1 tonne waste, 80% water 20% solids i.e.200kg

In 2 tonne mixture 200 kg solid at 8% concentration

Assume 8% solids in the mix i.e. 80 kg/m3

$$\text{Volume of mix} = \frac{200\text{kg}}{1.02*80\text{kg/m3}} = 2.45\ \text{m3}$$

Assume detention time (DT) = 30 days.

Volume of digester = 2.45 * 30

= 73.5 m3 + 20.4 m3 for 10 days sludge storage

≈ 94 m3 Assume liquid depth = 4 m

$$\text{Plan area} = \frac{94}{4} = 23.5\ \text{m2}$$

To find diameter

$$\frac{\pi D2}{4} = 23.5$$

$$D = \sqrt{23.5 * 4 / \pi}$$

= 5.47 m ≈ 5.50 m

Provide fixed roof type digester having 5.50m dia. and 5m total depth.

(Additional 1m depth for supernatant, scum and as free board) provide bottom slope of 1:10

3. Gas generation and storage:

Assume volatile matter = 80 %

Volatile matter = 0.8 * 200

= 160 kg

Assume 60% destruction of volatile matter.

Volatile matter destroyed = 0.60 * 160 = 96 kg.

Volume of digester gas = 0.8 * 96 = 76.80 ≈ 77 m3/day

(0.8 m3/kg VSS destroyed/day @ 77 m3/ MT of waste)(60% CH4 @ 200 mm of water)

Providing 40 % storage capacity of daily gas production

Volume of gas holder required = 0.40 * 77

= 30.80 m3

Provide neoprene rubber balloon of 3.5 m diameter and 3.2 m height for gas storage.

Area for gas storage 4.5m * 4.5m * 4m (height)

4. Quantity of sludge:

Fixed solids 20 % = 0.20 * 200 = 40 kg

Volatile matter = 160 kg / day

Assume 60% destruction of volatile matter

Volatile solids remained = 160 * 0.4 = 64 kg

Total solids = 40 +64 = 104 kg

Assume 5% solids in digested sludge

$$\text{Volume of sludge} = \frac{104 \text{ kg}}{1.02 * 50 \text{ kg/m3}} = 2.04 \text{ m3 / day}$$

5. Quantity of supernatant:

Quantity of supernatant per day = Volume of feed sludge – Volume of digested sludge

= 2.45 –2.04

≈ 0.40 m3

The supernatant is recycled for making feed sludge. Additional water quantity required will be 1 m3 – 0.40 m3 =0.60 m3/day. This can be obtained from nearby sewers. Before using the sewage screening is essential.

6. Sludge drying beds:

Assume 10 days drying period.

Depth of sludge = 30 cm

$$\text{Area of S.D.B.} = \frac{2.04 m^3/d * 10 \text{ days}}{0.30}$$

$= 68 m^2$

Provide 1 bed of 12m * 5.7 m

Provide 3 * 3 m2 for dry sludge storage.

7. Power required for mixing:

Power required for mixing in the digester will be in the range of 5-8 watt per m3 of tank volume. (CPHEEO manual)

Power required =8 watts/m3 of tank volume

= 8 * 94

=752 watts

=752 *3/1000

=2.256kWh ≈ 3 kWh.

8. Office and laboratory:

Area = 3m * 3m

9. Open space:

For parking and movement of vehicles

Assumptions made in the design:

80% moisture in the canteen waste, remaining 20% will be solids.

Volatile matter 20 %

Biogas generation = 0.8 m3/kg VSS destroyed/day @ 77 m3/ MT of waste.

Biogas contains 60% CH4 @ 200 mm of water

Fixed solids 20 %

60% destruction of volatile matter

5% solids in digested sludge

10 days sludge drying period.

Power required for mixing in digester=8 watts/m3 of tank volume

Summary:

Item	Dimensions	Power	Remarks
Loading platform with grinder	3m * 3m	2.25kw*1hr	Suitable unloading ramp. Grinding to 10 mm size
Digester with mixer	5.50m dia, 5m deep	3.0kw*2hr	Fixed roof type. To brake scum & for mixing
Gas storage	4.5m * 4.5m * 4m (height)		Rubber balloon in closed room.
Sludge drying bed and slurry pump	1 beds of 12m*5.7 m		10 days drying cycle. 10 lps discharge.
Sludge storage	3m * 3 m		For 1 month manure.
Office cum lab.	3m * 3 m	5.0kWh	
Open space	Approximately 140m2		For parking and movement of vehicles

Actual unit area = 140 sq.m.

Open space = 140 sq.m.

Total = 280 sq. m

Plot size = 20m * 14m

Power requirement = 13.05 ~15 kWh

Design of Digester for Treatment of 5 MT Canteen Waste & vegetable market waste

1. Loading platform and grinder:

Loading platform and grinder area 5m * 3m

Shredder capacity = 2nos, 1 MT/ hr, 3.75 kWh (5 HP)

2. Mixing tank:

Volume of tank = Total volume of mix per day / 2

2

= 12.25 / 2 = 6.125 m3

Assume, Depth: Diameter = 1.5:1

$$\frac{\pi D^2}{4} \times 1.5\,D = 6.125$$

$$D^3 = \frac{6.125 * 4}{\pi * 1.5}$$

D = 1.73m

Depth = 2.6m

Assume power for mixing as 26 watts / m3

= 26 * 6.125

= 160 watts

Mixing period = 2 x 1/2 hr

= 1 hr

$$\text{Required power} = \frac{160 \times 1}{1000} = 0.16 \text{ kWh}$$

Provide one motor of 2 HP

Power provided = 2 X 0.746 X 1

= 1.5kWh

> 0.16kWh

3. Digester:

Assume 80% moisture in the canteen waste, remaining 20% will be solids.

Water is mixed in the ratio 1:1 by weight.

In 5 tonne waste, 80% water 20% solids i.e.1000kg

In 10 tonne mixture 1000 kg solid at 8% concentration

Assume 8% solids in the mix i.e. 80 kg/m3 (Range 7- 10%)

$$\text{Volume of mix} = \frac{1000\text{kg}}{1.02*80\text{kg/m3}} = 12.25\ \text{m3}$$

Assume detention time (DT) = 30 days.

Volume of digester = 12.25 * 30

= 368 m3 + 20.4 m3 for 2 days sludge storage

≈ 390 m3

Assume liquid depth = 5.50 m

$$\text{Plan area} = \frac{390}{5.50} = 70.90\ \text{m2}$$

To find diameter

$$\frac{\pi D2}{4} = 70.90$$

$$D = \sqrt{70.90 * 4 / \pi}$$

= 9.50 m

Provide fixed roof type digester having 9.50 m dia. and 7.0m total depth. (Additional 1.50m depth for supernatant, scum and as free board) Provide bottom slope of 1: 10

4. Gas generation and storage:

Assume volatile matter 80 %

Volatile matter = 0.80 * 1000

= 800 kg

Assume 60% destruction of volatile matter.

Volatile matter destroyed = 0.60 * 800 = 480 kg.

Volume of digester gas = 0.8 * 480 = 384 m3/day

(0.8 m3/kg VSS destroyed/day @ 77 m3/ MT of waste)(60% CH4 @ 200 mm of water)

Providing 30 % storage capacity of daily gas production.

Volume of gas holder required = 0.30 * 384

= 115.20 m3

Provide 2 neoprene rubber balloons of 4m dia and 4.6 m high for gas storage.

Area for gas storage 6m * 12m * 5.50m (height)

5. Quantity of sludge:

Fixed solids 20 % = 0.2 * 1000 = 200 kg

Volatile matter = 800 kg / day

Assume 60% destruction of volatile matter

Volatile solids remained = 800 * 0.4 = 320 kg

Total solids = 200 + 320 = 520 kg

Assume 5% solids in digested sludge

$$\text{Volume of sludge} = \frac{520 \text{ kg}}{1.02 * 50 \text{ kg/m3}} = 10.20 \text{ m3 / day}$$

6. Quantity of supernatant:

Quantity of supernatant per day = Volume of feed sludge – Volume of digested sludge

= 12.25-10.20

= 2.05m3

The supernatant is recycled for making feed sludge. Additional water quantity required will be 5 m3 – 2.0 m3 =3.0 m3/day. This can be obtained from nearby sewers. Before using the sewage screening is essential.

7. Sludge drying beds:

Assume 10 days drying period.

Depth of sludge = 30 cm

$$\text{Area of S.D.B.} = \frac{10.2\text{m3/d} * 5 \text{ days}}{0.30}$$

= 170m2

Provide 3 beds of 30m * 6 m

Provide 5m * 3 m area for dry sludge storage.

Sludge removal pump = 5 lps, 2.25 kWh

8. Power required for mixing:

Power required for mixing in the digester will be in the range of 5-8 watt per m3 of tank volume. (CPHEEO manual)

Power required =8 watts/m3 of tank volume

= 8 * 390

=3120 watts

= 3120 * 3/1000

=9.36kWh ~ 10kWh.

9. Office and laboratory:

Area = 5m * 3m

10. Store room:

Area = 5m * 3m

11. Open space:

For parking and movement of vehicles.

Assumptions made in the design:

80% moisture in the canteen waste, remaining 20% will be solids.

Volatile matter 80 %

Biogas generation = 0.8 m3/kg VSS destroyed/day @ 77 m3/ MT of waste.

Biogas contains 60% CH4 @ 200 mm of water

Fixed solids 20 %

60% destruction of volatile matter

5% solids in digested sludge

Sludge removal after every 5 days.

10 days sludge drying period.

Power required for mixing in digester = 8 watts/m^3 of tank volume

Summary:

Item	Dimensions	Power	Remarks
Loading platform with grinder	5m * 3m	3.75kw*5hr	Suitable unloading ramp. Grinding to 10 mm size
Mixing tank stirrer	1.73m dia, 2.6m deep	1.50kw*1hr	
Digester with agitatator	9.50m dia, 7.0 m deep	10kWh	Fixed roof type.To brake scum and for mixing
Gas storage	6m * 12m * 5.50m (height)	-	Neoprene Rubber balloon in closed room.
Sludge drying bed and slurry pump	3 beds of 30m*6 m	2.25kw*1hr	10 days drying cycle. 10 lps discharge.
Sludge dewatering machine	4m * 4 m	3.75kw*1hr	
Sludge air/sun drying area	10m * 5m	-	
Sludge storage	5m * 3m	-	For 1 month production
Office cum lab.	5m * 3m	9.60kWh	
Store room	5m * 3m		For spares, chemicals
Engine room	5m * 5m		
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

Design of Digester for Treatment of 15 TPD Canteen Waste & vegetable market waste

1. Loading platform and grinder:

Loading platform and grinder area 5m x 5m

Shredder capacity = 3 TPD/ hr, 5.595 kWh (7.5 HP)

2. Mixing tank:

Volume of tank = Total volume of mix per day / 2

= 36.76 / 2 = 18.38 m^3

Assume, Depth: Diameter = 1.5:1

$$\frac{\pi D^2}{4} \times 1.5\,D = 18.38$$

$$D^3 = \frac{18.38 \times 4}{\pi \times 1.5}$$

D = 2.50m

Depth = 3.75m

Assume power for mixing as 26 watts / m^3

= 26 x 18.38

= 478 watts

mixing period = 2 x 1/2 hr

= 1 hr

$$\text{Required power} = \frac{478 \times 1}{1000} = 0.478\text{kWh}$$

Provide one motor of 2 HP

Power provided = 2 X 0.746 X 1

= 1.5kWh

> 0.478kWh

3. Digester:

Assume 80% moisture in the canteen waste, remaining 20% will be solids.
Water is mixed in the ratio 1:1 by weight.
In 15 tonne waste, 80% water 20% solids i.e.3000kg
In 30 tonne mixture 3000 kg solid at 8% concentration
Assume 8% solids in the mix i.e. 80 kg/m^3 (Range 7- 10%)

$$\text{Volume of mix} = \frac{3000\text{kg}}{1.02 \times 80\text{kg/m}^3} = 36.76\ m^3$$

Assume detention time (DT) = 30 days.
Volume of digester = 36.76 x 30
= 1102.8 m^3 + 61.20 m^3 for 2 days sludge storage
≈ 1164 m^3
Assume liquid depth = 10 m

$$\text{Plan area} = \frac{1164}{10} = 116.4\ m^2$$

To find diameter

$$\frac{\pi D^2}{4} = 116.4$$

$$D = \sqrt{116.4 \times 4 / \pi}$$

$$= 12.20\ m$$

Provide fixed roof type digester having 12.20 m dia. and 11.5m total depth.
(Additional 1.50m depth for supernatant, scum and as free board) Provide bottom slope of 1: 10

4. Gas generation and storage:

Assume volatile matter 80 %

Volatile matter = 0.80 x 3000 = 2400 kg

Assume 60% destruction of volatile matter.

Volatile matter destroyed = 0.60 x 2400 = 1440 kg.

Volume of digester gas = 0.8 x 1440 = 1152 m^3/day

($0.8\ m^3$/kg VSS destroyed/day @ $77\ m^3$/ TPD of waste)(60% CH_4 @ 200 mm of water)

Providing 25 % storage capacity of daily gas production

Volume of gas holder required = 0.25x 1152 = $288\ m^3$

Provide 2 neoprene rubber balloons of 5m dia and 7.5 m high for gas storage.

Area for gas storage 7m x 14m x 8.0m (height)

5. Quantity of sludge:

Fixed solids 20 % = 0.2 x 3000 = 600 kg

Volatile matter = 2400 kg / day

Assume 60% destruction of volatile matter

Volatile solids remained = 2400 x 0.4 = 960 kg

Total solids = 600 + 960 = 1560 kg

Assume 5% solids in digested sludge

$$\text{Volume of sludge} = \frac{1560\ kg}{1.02 \times 50\ kg/m^3} = 30.60\ m^3 / day$$

6. Quantity of supernatant:

Quantity of supernatant per day = Volume of feed sludge – Volume of digested Sludge

$$= 36.76\text{-}30.60$$

$$= 6.16 m^3$$

The supernatant is recycled for making feed sludge. Additional water quantity required will be $15\ m^3 - 6.16\ m^3 = 8.84\ m^3$/day. This can be obtained from nearby sewers. Before using the sewage screening is essential.

7. Sludge drying beds:

Assume 10 days drying period.

Depth of sludge = 30 cm

$$\text{Area of S.D.B.} = \frac{30.60 m^3/d \times 5\ days}{0.30}$$

$$= 510 m^2$$

Provide 3 beds of 30m x 17 m

Provide 5m x 5 m area for dry sludge storage.

Sludge removal pump = 20 lps, 3.75 kWh

8. **Power required for mixing:**

Power required for mixing in the digester will be in the range of 5-8 watt per m^3 of tank volume. (CPHEEO manual)

Power required =8 watts/m^3 of tank volume

= 8 x 1164

=9312 watts/day

= 9312 x 3/1000

=27.94kWh ~ 28kWh.

9. **Office and laboratory:**

Area = 5m x 5m

10. **Store room:**

Area = 5m x 5m

11. **Open space:**

For parking and movement of vehicles

Summary:

Item	Dimensions	Power	Remarks
Loading platform with grinder	5m x 5m	5.60 kW x 5 h	Suitable unloading ramp. Grinding to 10 mm size
Mixing tank	2.5m dia, 3.75m deep	1.50 kW x 1 h	
Digester with mixer	12.2m dia, 11.50 m deep	28 kWh	Fixed roof type. To brake scum & for mixing
Gas storage area	7m x 14m x 8m (height)	-	Neoprene Rubber balloon in close room.
Sludge drying bed and slurry pump	3 beds of 30mx17 m	3.73 kWh	10 days drying cycle. 20 lps discharge.
Sludge dewatering machine	4m x 4 m	7.5 kW x 2 hr	
Sludge air/sun drying area	10m x 10m	-	
Dry Sludge storage	5m x 5m	-	For 1 month manure.

Office cum laboratory.	5m x 5m	18.0 kWh	
Store room	5m x 5m	-	For spares, chemicals
Engine room	5m x 5m	-	-
Open space	Approximately 461m^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

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.

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

Plant and Machinery required for mechanical composting plant:

Waste Handling Section

Excavators/ loaders, tractor, trolleys and motor vehicle

Preparatory Section

Chain drag conveyor, Trommel screens, Chain belt conveyors, Bucket elevator/conveyor.

Finishing Section

Drag conveyor feeder, Vibro-screen, Chain belt conveyors, Movable conveyor, Crusher, Hammer mill, Grinder, packing system.

Laboratory Section

Instruments for analysis of finished product (manure), for its nutrient contents like N, P, K and quality control assessment.

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 %

Design of Vermi Compost Treatment plant for 1 TPD MSWb

Quantity of waste treated per day = 1TPD

Assume density of waste = 800 kg/m^3

Volume of 1 TPD waste = 1.25 m^3

Assume width of vermi pit = 2 m

Total depth of pit = 0.7 m

Effective depth = 0.4 m

$$\text{Length of pit required} = \frac{1.25}{2 \times 0.4} = 1.5625 \text{ m per day}$$

One Pit capacity is taken as 7 days

Length of pit = 1.5625 x 7

= 10.94m ≈ 11m

Pit size = 2m x 11m x 0.7m

Assume composting period of 6 weeks.

There fore provide 6 + 1stand by = 7 pits

Keep distance between two pits as 1m

Provide 3m wide road.

Provide segregation platform of size = 2m x 3m.

Provide 4m x 4m office cum store area.

Approximately, 17 m x 22 m = 374 sq.m. Area is required

Design of Vermi Compost Treatment plant for 5 TPD MSWb

Quantity of waste treated per day = 5TPD
Assume density of waste = 800 kg/m^3
Volume of 5 TPD waste = 6.25 m^3
Assume width of vermi pit = 2 m
Total depth of pit = 0.7 m
Effective depth = 0.4 m

$$\text{Length of pit required} = \frac{6.25}{2 \times 0.4} = 7.8175 \text{ m per day}$$

One Pit capacity is taken as 7 days
Length of pit = 7.8175 x 7
= 54.6875m ≈ 55m
One Pit size = 2m x 11m x 0.7m
No of pits for one week = 55/11=5nos.
Assume composting period of 6 weeks
Therefore provide 30 + 5 (stand by) = 35 pits
Keep distance between two pits as 1m
Provide 3m wide road.
Provide segregation platform of size = 3m x 3m.
Provide 4m x 4m office area.
Provide screening cum store area = 5m x 15m = 75 sq.m.
Approximately, 34 m x 50m = 1700 sq.m. Area is required

Abstract of Vermi composting for 1 TPD and 5 TPD

Capacity	1 TPD	5 TPD
Number of Pits required	7 Pits	35 Pits
Area required for Pits	154 sq.mt	770 sq.mt
Segregation Platform	1 no. (6 sq.mts)	3 no. (18 sq.mts)
Office cum store room	16 Sq. mts	96 sq.mts
Labour room	9 Sq. mts	16 sq.mts
Total Area Required	374 sq .mt	1700 Sq.mts
Power required	5 kWh	9 KWh
Water required	2 m^3/day	10 m^3/day
Manure Yield	15 – 17%	15 – 17%
Project cost	5 lacs	22 lacs

Annexure C:

Cost Analysis for Biomethanation please refer to the chapter of Economic, feasibility and Business model at a ward level in Mumbai

Cost Analysis

Aerobic Composting

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

Cost analysis of 150 TPD:

1. Power 100 HP x 0.746 x 16 hrs (2 shifts) = 1200 KwH x Rs. 4 per unit
   = Rs. 4800/-day
   = Rs. 1, 44,000/month
   = Rs. 17, 28,000/- per Annum
2. Staff (labour to Engineer) = 55 x 6000 (average) = Rs. 3,30,000/month
   = Rs. 39, 60,000 /-Annum
3. Culture = 1Kg /ton = 150 kg /day = 150 x Rs 60/ kg = Rs.9000/day
   = Rs. 2, 70,000/month
   = Rs. 32, 40,000 /-Annum
4. Water requirement = 200 lit/ton = 30 m^3/day Bore well water or sewage can be used.

Total = 1,44,000 + 3,30,000 + 2,70,000 = 7,44,000/month = Rs. 89,28,000 /-Annum

Add 10% for repair, spares etc., 8,18,400 / month = Rs. 8, 93,000 /-Annum

Operation and maintenance cost per annum = Rs. 98, 20,800 = 9.82 million

= 9 to 10 million/annum

Operation and maintenance cost per ton = Rs 183/T

Manure Yield – assuming 50% destruction of organic matter, 35 % rejects and 15% yield and @ Rs. 3000/Ton

= 15 x 150 x 365 = 8212 T/annum

100

= 8212 x Rs. 3000/T

= Rs. 246, 63,000 /-Annum

= 24.66 million Net Earning in Lac Rs./ Annum = 148.10

Aerobic Composting 300 TPD

1. Power 150 HP x 0.746 x 16 hrs (2 shifts) = 1800 KwH x Rs. 4 per unit
   = Rs. 7200/day
   = Rs. 2, 16,000/month
   = Rs. 25, 92,000/- per Annum
2. Staff (labour to Engineer) = 80 x 6000 (average) = Rs. 4,80,000/ month
   = Rs. 57, 60,000/- per Annum
3. Culture = 1Kg/ton = 300 kgs/day = 300 x Rs 60/- kg = Rs.18,000/day
   = Rs. 5, 40,000/month
   = Rs. 64, 80,000/Annum
4. Water requirement = 200 lit/ton = 60 m^3/day
5. Bore well water or sewage can be used.

Total = 2, 16,000 + 4, 80,000 + 5, 40,000 = 12, 36,000/- = Rs. 148, 32,000/Annum

Add 10 % for repair, spares etc., 14, 83,200/- Annum

Operation and maintenance cost per annum = Rs. 163, 15,000 = 16 – 17 million

Operation and maintenance cost per ton = Rs 155 / T

Manure Yield – assuming 50% destruction of organic matter, 35 % rejects and 15% yield and @ Rs. 3000/ton = (15 x 300 x 365)/100 = 16,425 T/annum

= 16425 x Rs. 3000 / T

= 49.275 million

Net Earnings Lac Rs. / Annum = Rs.329 .50 /- Annum

Vermi Composting

Abstract of Vermi composting for 1 TPD

Capacity	1 TPD	5 TPD
Number of Pits required	7 Pits	35 Pits
Area required for Pits	154 sq.mt	770 sq.mt
Segregation Platform	1 no. (6 sq.mts)	3 no. (18 sq.mts)
Office cum store room	16 Sq. mts	96 sq.mts
Labour room	9 Sq. mts	16 sq.mts
Total Area Required	374 sq .mt	1700 Sq.mts
Power required	5 kWh	9 KWh
Water required	2 m^3/day	10 m^3/day
Manure Yield	15 – 17%	15 – 17%
Project cost	5 lacs	22 lacs

Vermicomposting – 1 TPD

Area required – 375 sq.mt

1. Power for Lighting = 8 tubes x 40 watt x 12 hr = 3.84 KwH
   Water Pump = 1 HP x 0.746 x ½ hr = 0.373 KwH
   Power consumption per day = 3.84 + 0.373 = 4.213 KwH
   Power Consumption Per annum = 4.213 x 365 = 1537 KwH
   Cost of Power per annum = 1537 x Rs. 4/unit = Rs.6, 148/annum
2. Staff = 1 semiskilled, 1 labour and 1 security.
   Cost per month = 1 x 5000 + 1 x 3000 + 1 x 4000 = Rs. 12,000/month
   Cost/annum = 12000 x 12 = Rs. 1,44,000/annum
3. Cost of earthworms included in plant cost.
4. Water required per day @ 5 lit/sq.mt = 5 x 375 = 1.8 m^3/day = say 2m^3/day
   Bore well water can also be used.
5. Total Cost = 6148 + 1,44,000 = Rs. 1,50,148
   Add 2 % sundries Rs. 3002 for Operation and Maintainance
   Total cost = Rs. 1, 53,150 = 0.15 million/annum
   Operation and maintenance cost per ton = Rs.420/Ton
   Vermicompost Yield assuming 15%, manure @ Rs.5000/Ton
   0.15 x 1 x 365 x Rs 5000/Ton = Rs.2, 73,750 = 0.27 millions

Vermicomposting – 5 TPD

Area required – 2000 sq.mt

1. Power for Lighting = 15 tubes x 40 watt x 12 hr = 7.2 KwH

   Water Pump = 1 HP x 0.746 x 2 hr = 1.5 KwH

   Power consumption per day = 7.2 + 1.5 = 8.7 KwH

   Power Consumption Per annum = 8.7 x 365 = 3175 KwH

   Cost of Power per annum = 3175 x Rs. 4/unit = Rs.12, 702/annum

2. Staff = 1 supervisor, 6 labour and 2 security.

   Cost per month = 1 x 7000 + 6 x 3000 + 2 x 4000 = Rs. 33,000/month

   Cost/annum = 33,000 x 12 = Rs. 3, 96,000/annum

3. Cost of earthworms included in plant cost.

4. Water required per day @ 5 lit/sq.mt = 5 x 2000 =10 m^3/day = say 2m^3/day

   Bore well water can also be used.

5. Total Cost = 12,702 + 3,96,000 = Rs. 4,08,702

   Add 2 % sundries Rs. 8174 for Operation and Maintainance

   Total cost = Rs. 4, 17,000 = 0.41 million

   Operation and maintenance cost per ton = Rs.228/Ton

   Vermicompost Yield assuming 15%, manure @ Rs.5000/Ton

   0.15 x 5 x 365 x Rs 5000/Ton = Rs.13, 68,000 = 1.37 millions

Cost Analysis : Comparison of Studied Technologies

S N	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 Economic, feasibility and business model at a ward level chapter)	-	-	-	-	-	-
2	AerobicComposting						
	i) 150 TPD plant	266	40,000	35.00	98.208	246.300	148.100
	ii) 300 TPD plant	166	50,000	45.00	163.152	492.700	329.500
3	Vermi composting						
	i) 1 TPD plant	374	374	0.5	1.530	2.740	1.210
	ii) 5 TPD plant	340	1700	2.2	4.170	13.680	9.510

* With Mechanical dewatering of Sludge

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	1	Nil	2	Nil	
	ii) 5 TPD plant	2	1	3	1	
	iii) 15 TPD plant	5	2	19	1	One Engineer
2	Aerobic Composting					
	i) 150 TPD plant*	8	15	30	2	*One Engineer per shift
	ii) 300 TPD plant*	10	20	45	5	
3	Vermi composting					
	i) 1 TPD plant	1	1	1	-	-
	ii) 5 TPD plant	1	2	6	-	-

Abstract of cost analysis of biomethanation

(plz refer to the chapter of Economic, Feasibility and business model at a ward level in Mumbai)

The power consumption for 15 TPD plant is given on the basis of basic plant installation, because the primary is to dispose the solid waste and suppose if the plant needs some more highly mechanized instruments then power consumption would vary.

Abstract of cost analysis of aerobic composting

Capacity 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

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

Annexure D :

Info on some selected residential colonies in Colaba, Mumbai

No	Name	Families/ Flats	Mixed waste kgs/day	Wet waste	Current sys	Space for waste processing	Proposed Solution
1	Harbour Heights	207	550	137.5	MCGM-compactor	Yes	Composting
2	Fire Brigade Colony*	30	1000	300	MCGM-compactor	Yes	Biomethanation
3	Ocean View-BPT colony#	200	1000	320	BPT Compactor-Deonar	Yes	Bio methanation
4	Army Head Quarters#	200	1000	250	Army+MCGM**	Yes	Bio methanation
5	Navy Nagar#	200	1000	290	Navy+MCGM**	Yes	Bio methanation
6	Maker Tower	500	4000	1100	MCGM-Compactor	Yes	Excel
		1337	**8550**	**~ 2397.5**			

Note
#The number of flats are estimated and minimum number has been considered
* 30 families & 1000kgs of waste - because MCGM collection spot is situated in the colony compound which gets more than 1500kgs of waste

Working of waste generation in different segments studied

	Type	Total waste kgs/day	% of wet waste	Kgs/day wet waste quantity
1	Upper class Residential	8550	Actual observations	2398
2	Eateries	70000	70%	49000
3	Food Markets	42500	70%	29750
	Total Waste	**121050**		**81148**

These figures are based upon the actual observations and data collected from AHS on daily garbage collection systems

Annexure E :

Information on selected high volume waste generators in Mumbai

Eateries

No	Name	Location	Rooms	Waste kgs/ day	Current sys	Dry waste	Space at site for waste processing	Proposed
1	**Hotel Taj**	Colaba	540	4000	By MCGM but waste holding sys is scientific	Contracted	No	Biomethanation-BMC land & responsibility with hotel management
2	**Hotel Taj President**	Cuffe Parade	292	2000	By MCGM in an open truck/day	Contracted	No	Biomethanation-BMC land & responsibility with hotel management
3	**Hotel Pritam bar/restaurant/Lodge**	Dadar	60	1500	MCGM - Tempo/day	Contracted	No	Biomethanation-BMC land & responsibility with hotel management
4	**CCI Club with lawns**	Churchgate	-	800	Biocomposting Excel machine used	Contracted	Yes	-
5	**Bombay Gymkhana with lawns**	Fort	-	500	Composting effort failed - now MCGM compactor/day	Contracted	Yes	Bio composting
6	**Hotel Shalimar**	SVP Rd Dongri	-	600	MCGM-Collection Spot	Mixed-MCGM	No	Biomethanation
7	**Akashvani MLA hostel**	Mantralaya		600	MCGM compactor	Mixed-MCGM	Yes	Biomethanation-BMC land & reposibility with hotel management
8	**Vanita Samaj marriage hall**	Shivaji Park, Dadar	2 halls	500	MCGM Compactor 3 trolleys – seasonal waste	Mixed-MCGM	Yes	Biocomposting
9	**Sassoon Dock fishing docks**	Colaba	-	-	Dock - tempo sent to Deonar			Biomethanation
10	**Hotels attended by MCGM in A Ward**							
a)	Hotel Marine Plaza			2000	MCGM – Compactor			MCGM
b)	Ambassador Hotel			1875	MCGM – Compactor			
c)	Hotel West End			-	MCGM – Compactor			
d)	Grand Hotel			-	MCGM – Compactor			
e)	Taj Wellington			625	MCGM – Compactor	Segregation		
f)	Hotel Nataraj			1000	MCGM – Compactor	is not 100%		
g)	Other hotels			54000	MCGM – Compactor			
				70000				

(Source: SWM dept of MCGM)

Annexure F :

Info on waste generation & current waste management of some of the Municipal Markets in South Mumbai

No	Name	Type of Market	Shops	Waste kgs/day	Current sys	Nature of waste	Space at site
A Ward							
1	Crawford Market	Veg+Non-veg+Fruits+Birds	1154	2500	MCGM+Clean Air Island	Mixed but	No
2	Chhatrapati Shivaji mkt	Fish Market	85	2000	Offal van	mostly	No
3	Colaba Market	Mutton+Fish	231	1000	MCGM	biodegradable	No
4	Fort Market	Veg+Non-veg	180	1000	MCGM	waste	No
B Ward							
1	Dongri Market	Veg+Non-veg	152	1500	MCGM compactor+offal van	Mixed but mostly	No
2	J B Shah Market	Food grain, spices & fruits	120	500	MCGM compactor	biodegradable	No
C Ward							
1	Mirza Galib Market	Veg+Non-veg	250	5000	Compactor+Offal Van	Mixed but	No
2	A P Market	Veg+Non-veg	63	1000	Compactor	mostly	No
3	Bhuleshwar Market	Flowers+Fruits	189	5000	Compactor	biodegradable	No
D Ward							
1	Lokmanya Tilak Market			6000	MCGM		No
2	Bhaji Galli						No
E Ward							
1	Sant Gadge Maharaj Mandai	Veg	530	12000	MCGM Compactor+TDP	Mixed-mostly	
2	Dhamaji Manaji Kela Mkt	Kela shops	32	1000	MCGM	biodegradable	
3	Sant Janabai Mandai	Non-veg	10	500	MCGM	All waste mixed	
4	Kamathipura Mkt	Veg+Non-veg	83	1500	MCGM	but mostly	
5	Babu Genu Mandai	Non-veg	73	1500	MCGM	biodegradable	
6	Mohan Govind Pathare Mandai	Veg+Non-veg	14	500	MCGM		
			3166	**42500**			

Annexure G :

Info on Generation of Nirmalya in C ward where many old temples are situated		
No	**Temple**	**Nirmalya kg / day**
1	Mumbadevi Temple	250
2	Nar Narayan Mandir (Kalabadevi)	40
3	Swami Narayan Mandir (3rd Bhoiwada)	20
4	Parshwanath Swami Mandir (216, Kika Street)	10
5	Laxmi Narayan Mandir (3rd Bhoiwada)	5
6	Oval Jain Saigh Mandir (1/2 Panjrapole)	10
7	Surya Narayan Mandir (3 Panjrapole)	5
8	Motha Mandir (G M Compound)	10
9	Panchmukhi Hanuman Mandir (69 Bhuleshwar)	10
10	Jadamba Mandir (96 Bhuleshwar)	20
11	Maharaj Ladu Belijika Mandir (51/53 A M Rd)	10
12	Vithoba Mandir	20
13	Tirupati Balaji Mandir (Phanaswadi)	80
14	Ram Mandir (J S S Rd)	5
15	Ganpati Mandir (J S S Rd)	5
16	Picket Rd Hanuman Mandir	20
17	Dwarkadhish Mandir (40 Ram Mandir Rd)	10
18	Hanuman Mandir (40 Ram Mandir Rd)	10
19	Kalbadevi Mandir (Tamba Kata)	20
	Total	**560**

Annexure H :

Sources of information

Chief Engineer, SWM – Mr Markandeya

Executive Engineer, SWM – Mr Shrotriya

Head Supervisor – SWM – Mr. Bheldhar

Dy HS, Zone I – Mr Kaskar

Officer on Special Duty – Mrs Seema Redkar

Asst Engineer – SWM – Mr Khan

Commissioner, Market Dept – Mr Wagralkar and deputy Mr Kolambe

Dy Commissioner, Markets – Mr Kalkar

Assistant Commissioners

A ward – Mr. Wale

B ward – Mr. Pingle

C ward – Mr. Marathe

Assistant Head Supervisor

A ward – Mr. Gurav

B ward – Mr. Masurkar and Mr. Bariya

C ward – Mr. Dixit

D ward – Mr. Jadhav

Conservancy staff – Junior Overseers (JOs – section JOs and Motor Loader JOs), Class IV labour & Mukadam of following wards

A ward

B ward

C ward

Supervisor – Arvind Joshi (B R C – C ward)

Mukadam, Bulk Refuge Container at C ward – Mr Ravi Shinde

Mahalaxmi Transfer station

Supervisor – Mr Pawar

Questionnaire for information on waste generation in A, B and C ward

Date:

1. Total waste generation of A ward – Wet and Dry -
2. Ceiling put on private contractor -
3. System adopted – Private and Municipal – give proportion Collection of waste by municipality and private contractor - **** tpd
4. Total number of collection spots – sheds as well as open dumps -
5. Compactors – Which type – Municipal/private - if partly then how many municipal and how many pvt?
6. Compactors provided by pvt contractor - *** No. and Municipal compactor - *** No.
7. Which containers/trolleys are utilized in the ward – Close GI with 1100 ltr capacity or old trolleys with 1 m3 capacity
8. Tempo – How many? Municipal/Private – How many baskets in a tempo
9. TDPs – How many? Their schedule - Spots
10. What is the schedule of TDP lifting vehicles and how many vehicles are provided–
11. Dumpers (with JCB or manual?) – How many and their schedule –
12. Number of shed attendants – Their program – in which shift do they work – Are they available round the clock?
13. Information on door to door collection of waste – hotels/other commercial establishments and residential
14. List of the hotels which are attended by tempo – program?
15. Number of ALMs -
16. Does the ward officer hold monthly ALM meetings -
17. Availability of open spaces in the ward -
18. Municipal properties in the ward – Schools/markets/quarters
19. Number of markets in the ward – Licensed and unauthorized –

Questionnaire for House gallis

Name of investigator

Date

1. House gallis no.
2. Location of the house galli
3. No. of buildings attached to the house galli
4. Is there Darina (long housegalli covering a long lane)
5. Present status of the house galli
   - ❖ Clean or full of waste
   - ❖ If yes then what type of waste
   - ❖ Nuisance of rats and cockroaches
   - ❖ Use of pesticides
6. Is the housegalli closed/open –
7. Is there some commercial activity going on?
   If yes then which –
8. Is some slaughter business taking place – yes/no
9. How narrow is the housegalli
   Length ---------- Width ---------
10. Apprx no.of windows facing towards the house gallis
11. Condition of drainage system
    Whether it is choked –
    Presence of drainage pipes/leakages
10. Windows facing towards the house gallis were closed with nets or they were open –
11. Presence of rag pickers/drug addicts in the house gallis
12. Presence of house galli sweepers – yes/no
    If yes – presence of safety equipments
13. Do the sweepers clean the house gallis every day
    (If no then frequency of cleaning per week)
14. Where the garbage is dumped or is it disposed off immediately