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Sustainable Waste Processing in Mumbai

Using the Nisargruna Technology

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Abstract

Dumping of Municipal Solid Waste (MSW) into uncontrolled dumpsite sites is the most common form of waste disposal in many cities of India including Mumbai, and other developing countries too, due to limited technical and financial resources. The practice of dumping waste is environmentally and socially unacceptable as it does little to protect the environment and public health. Separation of organic waste from the MSW stream represents an opportunity to reduce the quantity of waste entering landfills by up to 50% by weight.

Nisargruna is one solid waste processing technology, developed by Bhabha Atomic Research Centre (BARC) in Mumbai, India. Using Nisargruna technology (which is based on the bio-methanation concept), disposal of solid organic waste can efficiently be done in environment friendly manner. The technology deals with the putrescible fraction of solid waste which gets converted into two valuable products, Energy and Manure. Besides these two valuable products, it has many other benefits such as producing a clean environment, employment generation, and better health for both employees and people living close to waste dumps. It would also increase the life of dumpsite and avoid further pollution.

A model of the financial viability of the technology and infrastructure suggests it gives attractive returns on the investments. Implementation of Nisargruna Technology should create various opportunities for entrepreneurial ventures. It is a sustainable technology as it is economically affordable, socially acceptable and environmental friendly.

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1 Introduction

1.1 Background

Waste disposal is one of the major problems being faced by all nations across the globe. The daily per capita solid waste generated in India ranges from about 100 grams in small towns to 500 grams in large towns. Major portion of the collected waste is dumped in landfill sites (TERI, 2000). Many of them are unregulated dumps or non-scientific landfills. However, data collected from 44 Indian cities have reveals that about 70% of them do not have adequate capacity for collection and transportation of MSW (Municipal Solid Waste) (TERI, 2000). Organic wastes in a landfill can take several years to rot down, as they do not always have the right bacteria, temperature or moisture conditions to rot quickly. If there are mixed wastes, it can take a long time for the bacteria to migrate through them to reach the organic wastes trapped in layers of inert material. More than 60% of the MSW is biodegradable waste that usually goes to dumpsite. Biodegradable waste causes problems:
(1) it gives off methane and carbon dioxide which can suffocate;
(2) it produces liquid leachate which is badly polluting (high COD),
(3) as it rots down, the landfill settles, so the land is unstable and unavailable for development for over 20 years.
Disposal of biodegradable waste can be achieved through different ways. There are a wide range of composting techniques for waste processing e.g. Vermi composting. Nisargruna technology is one method of processing biodegradable waste. It is an environment friendly technology, which delivers two valuable product viz. methane and manure that makes it economically self-sustainable. Methane fuel gas is a valuable energy product and will support the depleting non conventional energy resources. It produces high quality weed free manure which is a soil conditioner. This report provides overview of Nisargruna technology, its technical, environmental, socio-economic benefits and entrepreneurial opportunities.

1.2 Project Aim

Overall Aim of the project was to determine whether the Nisargruna technology, as used by organizations in Mumbai and elsewhere, is an effective way of processing waste and benefiting the people who operate the plant.

1.3 Project Objectives

- To understand the way waste is disposed of and processed within Mumbai
- To understand role of rag pickers in waste segregation.
- Have a good understanding of the Nisargruna and operation of the Nisargruna plant at Shatabdi Hospital, Govandi.
- Have a list of advantages of the Nisargruna technology that could be used by government organization, other organization or a prospective entrepreneur in other places
- To understand role of Stree mukti sangathan in poverty alleviation
- To understand the possibility of developing business else where in India.

1.4 Project Task

- To visit dumpsite to study the current waste disposal scenario
- Study the present waste handling approach by inhabitant in the city suburb by carrying small survey work
- To carry out observation work to study the operations of Nisargruna Plant located at Govandi, Shatabdi Hospital.
- To visit stree mukti sangathan
- To visit other similar technology plant to evaluate merits and demerits of both technology
- To prepare business strategy to develop Nisargruna Technology in other areas.
- Review of literature and case studies available on waste management at British Council Library, American Resource Centre and All India Institute of local self government in Mumbai.

2 Current status of the way waste is disposed off and processed with in Mumbai

2.1 Introduction

Mumbai, the prosperous commercial capital of India, is a mega polis of almost 18 million people who generate considerable amount of waste (around 7000 tons) every day. A significant challenge confronting engineers and scientists in developing countries is the search of appropriate solutions for the collection, treatment, and disposal or reuse of domestic waste (Chongrak Polprasert, 1996). Landfill disposal is seen in many respects as the bottom rung of the hierarchy of waste disposal options when considering the concept of sustainable waste management (Paul T Williams, 2002). The Municipal Corporation of Greater Mumbai (MCGM) is formally responsible for the management of waste in the city. The prevailing approach has been one of collection and disposal that is, garbage is collected from communities by the municipal authorities and disposed off at the four main dumping sites that are currently servicing the city. Except biomedical waste which is incinerated nearly 95% of the waste generated in the city is disposed off to dumpsite. Nearly 200 tons of waste is claimed to be converted as compost by vermi composting method.

A dumping ground is, generally, a low-lying and marshy area, which is located on the outskirts of a city, where there is, usually, no human population. City has three dumping grounds which are located in northern part of Mumbai. The average life of a dumping ground is 30 years. The remaining life of city's largest dumping ground, i.e., Deonar, is only five to six years and, so far, no other alternative site has been found for waste disposal by Municipal authorities. Organic waste, old batteries, polystyrene, polythene bags, debris is in huge quantities can be found at dumpsite. Since it takes long time to decompose, when dumped, such waste occupies and fills the low-lying areas. In fact, the search for a new dumping ground starts only when the filling area of the dumping ground is exhausted. The waste at the dumping ground is covered with debris and spread evenly in layers. The organic waste undergoes natural degradation and generates a fluid, which is known a leachate and is harmful to the ecosystem if not treated properly. The leachate penetrates the soil and if not prevented, it pollutes the ground water. Also flies, mosquitoes and many other pests breed on the waste and unless properly maintained, the dumps are a public health hazard. When the waste is dumped, it doesn't decompose very quickly and make way for the other waste. The nature of waste being dumped and the time it takes to decompose, pose a serious threat to the environment as well as human health (BCPT, 2006). Vegetables, fruit skins, waste food takes 3-4 weeks where as leather material takes 40-50 years and plastic takes decades to degrade. It is not economical to dump the organic waste on dumpsite as it reduces life by 10 years for the created land.

2.2 Deonar dumpsite visit

Deonar, Mumbai waste dumpsite visit was arranged in month of November 2005 with help of Stree Mukti Sangathan (SMS), Non government organization working for welfare of rag picker women.

Location: Deonar Waste Dumpsite Mumbai.

Observations at Deonar waste dumpsite

- Trucks usually dumping waste at the dumpsite through out the day and waste mainly come from southern and eastern part of city.
- Waste consists of mainly organic waste, dry waste like papers, metal and glass products and construction debris.

- Many rag pickers were seen at the dumpsite. Waste pickers or rag pickers are generally separating recyclable items from the waste dumped by municipal trucks and other vehicles, such as packing cases of refrigerators, television, plastics, tin, metal, electrical wires from the garbage dumped by municipal and private vehicles. After collection, they sort the material and carry it to the vendor. The vendor, an important link in the chain of recycling, provides the cash for collected waste, often cheating and exploiting in a variety of ways.
- Leachate pond can be seen on some of the parts of the dumpsite which remains untreated.
- The people doing this work are mostly women, but there are also girls and boys (some of whom are as young as eight and nine years old – can be seen in the picture). Some of the rag pickers, especially the children, work at the dumpsites. Waste picking or handling has a negative impact on health. The work is very tiring and these people are exposed to various infections, due to constant contact with infected and hazardous waste. Working with waste without protective measures, proves to be a source of a large number of health problems, such as cuts, injuries, back pain, headaches, respiratory and skin infections. Rag pickers normally over look safety issues. Many times fire incidents taking place and many rag pickers get burn. Smoke was observed at many places in dumpsite.
- All though there is not official framework made by Municipal authorities to allow rag pickers inside the dumpsite boundary, rag pickers have to bribe to police, security, to enter into the dumpsite boundary and to be allowed to take their pick of the reusable garbage.
- Cattle from nearest abattoir often come to dumping site looking for vegetable waste. While eating organic waste at dumpsite they gulp plastics and other paper materials too. When looking at the picture of the dumpsite, one could analyze the impact on human health seeing the hazard.
- Many shanties (Slum construction) were constructed around the dumpsite which is believed to be the shelter of rag pickers and storage facility for segregated waste.
- Waste recycling activities seems to be the easy occupation to adopt, which doesn't financial investments and occupational skills. It is clearly then the easiest occupation to adopt for poor people coming to urban areas from rural places. Poor people migrate to cities and find shelter in slums with help of regional connections mostly on the outskirts of the city, near waste dumping sites.
- It can be classified as unregulated dump. As the modern landfill site is an advanced treatment and disposal option designed and managed as an engineering project in which the waste is degraded to a stabilised product and the product leachate is treated to minimise pollution to the environment and the landfill gas is recovered for energy (Paul T Williams , 2002)

2.3 Survey work

Survey work was carried out in Mulund suburb to study the approach of city inhabitant for waste handling. It is essential to identify the key issues involved in waste segregation at the source. Segregation of wet waste is necessary in order to process solid organic waste. Necessary changes in waste handling in the city would

increase efficiency in processing wet waste and contribute in maintaining better environment.

Questionnaire was designed to get the basic idea about awareness and approach of city inhabitants for waste handling and its disposal. Printed questionnaire were distributed among residents, Hotel owners and food caterers to get the feedback. However response was overall poor and only 50% of them have filled the questionnaire sincerely. It is hard to convince them to provide the information about their waste disposal habits. However, information filled in the collected questionnaires could be useful to some extent to evaluate current prevailing disposal routine and level of awareness among the people. Some of the collected information will give us broad idea. On bigger scale projects in the city by municipal authorities would require good segregation for better efficiency of waste processing bio-methanation technology. It would be unproductive if inhabitant awareness issues are ignored.

2.3.1 Response and feed back

1. Do you generate waste? How much per day?

	<2 kg/day	2-4 kg/day	4-6 kg/day	6-8 kg/day	8-10 kg/day	>10 kg/day
Waste generation amount per day	59.09%	22.73%	0.00%	4.55%	4.55%	9.09%

Nearly every one is generating waste but amount of waste varies with residents and commercial setups. However by feed back it is observed that waste generation per family is less than 2 kg per day.

2. Do you know what wet waste is and what is dry waste?

	Yes	No
Awareness about wet waste and dry waste	86.36%	13.64%

Many people are aware of what wet waste is and what dry waste is. But there are some professionals who still don't have idea of wet waste and dry waste difference. Primary reason for that is education given in past in the secondary school didn't include topics related to basic study of environment, surroundings or waste handling.

3. Where do you throw your waste?

	Dispose their waste in Dustbin	Dispose waste in garbage bin	Dispose their waste in road side gutter	Dispose their waste else where
Disposal Habits	54.55%	18.18%	4.55%	22.73%

Most people dispose their waste in household dustbin, which is later collected by the sweeper but it is observed that some people avoid walking till the refuse bins to throw their waste in the open space or road side gutter. However most of the reputed restaurant owners send their waste to the refuse bins. Often it is seen that road side hawkers selling food and vegetables, throw their waste in open gutters. Gutters; many a times remains unclean till the monsoon comes. In monsoon such gutters cause water logging problems.

4. How do you dispose it? Do you go your self to waste dispose point and dispose it? Or do you give it someone to dispose it?

	Sweeper collecting it daily	Servant collecting it daily	Municipal car collecting from the doorstep
Garbage collection	68.18%	18.18%	13.64%

Sweeper working for societies or apartments collects the waste every morning from the doorstep of each apartment. They generally segregate the dry saleable waste near the refuse bin and throw rest of waste in the refuse bin. Servants or house maids also sometimes collect the garbage and dispose it finally to refuse bins. Municipal corporation do provide collection van in some areas where there is problem to provide refuse bins. Some people use that service.

5. Do you use plastic bags to dispose wet waste?

	Yes	No
Use of Plastic bags for disposing wet waste	68.18%	31.82%

Most often, people use non degradable plastic bags to dispose wet waste. People who are aware of the impact of using plastic bags for disposing wet waste generally don't use plastic bags. Waste disposed in plastic bags goes to dump site and

ordinary plastic takes decades to degrade and it take more time to degrade other wet waste that disposed in plastic. Some plastic carry bags are made of recycled low grade plastic through recycling other plastic waste. They are cheaply available. Road side hawkers as well as small shopkeeper use the similar graded carry bags. Use of biodegradable plastic concept is still not very popular because of its cost. Recently government has taken initiative to reduce the use of plastic bags by imposing a ban on production of low grade plastic carry bags.

6. Do you know about segregation of dry waste and wet waste? Would you like to segregate the waste before disposing?

	Yes	No
Knowledge of segregating wet waste and dry waste	86.36%	13.64%

	Yes	No
Willingness to segregate wet waste and dry waste	90.91%	9.09%

Most of resident dwellers know about segregation of waste but some people do not know anything about segregation. When explained to them about segregation, they would like to segregate. However it cannot be implemented as presently there are no provisions for separate handling of waste as Municipal Corporation is not providing separate refuse bins for the segregated waste.

7. Do you know what happens to the garbage once it is collected from nearest waste bins?

	Yes	No
Knowledge of Dumpsite and landfills	54.55%	45.45%

Knowledge about landfills and dumpsite is still not much among inhabitant. However many people are still not aware of dumpsites of Mumbai and present dumpsites scenario.

8. Do you think BMC (Bombay Municipal Corporation) is doing enough in handling of waste properly and cleaning the surroundings?

	Yes	No
Blaming municipal corporation for poor waste disposal	72.73%	27.27%

Some people do not think that BMC is doing enough to maintain the surrounding clean. However there are various reasons involved in maintaining cleanliness. BMC should not be always blamed for poor cleanliness. Resources are used excessively by rapidly increasing urban population by migrants from rural parts of the country. BMC seems to be doing their best to cop up with the situation. Corporation however does not provide separate refusal bins for segregated waste.

9. Are you interested in installing setup or technology which will dispose wet waste in environment friendly way?

	Yes	No
Interested in new environment friendly technology	100.00%	

Every one is interested in new environment friendly technology to process wet waste.

10. Would you like to pay extra for the waste handling?

	Yes	No
Would like to pay extra for waste handling	81.82%	18.18%

Many people are willing to pay the extra handling charges but we can't say that every one will pay extra for waste handling. More than 60% percent of people in the city live in the slums.

11. Do you know that poor disposal of garbage in the city was one of the reason for water logging and flood in Mumbai during last monsoon?

	Yes	No
Knowledge of consequences of poor waste disposal	90.91%	9.09%

People are aware of consequences of poor waste disposal e.g. serious water logging problem in city during last monsoon.

12. What are your comments to improve waste handling and reduce waste generation?

	Yes	No
Willing to comment on improvement in waste handling and reduce waste generation	77.27%	22.73%

Most of people gave fairly good suggestions and feedback was collected during the survey work. Few relevant suggestions are discussed here.

- Waste disposal awareness drive should be introduced in the major metropolitan city by the local Municipal Corporation. With the help of education centre, Media and other sources, maximum people should be taught about the schemes and different programme.
- Most of people suggest that Municipal Corporation should revive their strategies and plan maximum numbers of waste refuse points with effective collection system of segregated dry and wet waste.
- Penalty must be charged to the people not maintaining the cleanliness by not using the refuse bins and throwing garbage elsewhere
- Municipal Corporation should take initiative in introducing and motivating waste processing eco-friendly technology in different parts of city.
- Implementation of BMC rules should strictly follow for bigger township, big residential and commercial complex for installing such systems in their premises.
- Incentives to people disposing their waste by installing the right technology in their place.

2.4 Discussion

It is clearly seen that landfills and dumpsites are not effective solution to get rid of organic waste. In fact, it's an opportunity for Municipal Corporation to take advantage of processing it further rather simply dumping it. It is not environmentally pleasant and economic either to transport the organic waste to dumpsite. Processing organic waste will reduce burden on dumpsite and gives many other advantages. Dumping practice also gives motivation to rag pickers to get involved in the profession despite numerous problems associated with it. Social status of rag pickers can never be changed if vulnerable issues related to dumpsites are overlooked. Education is the best possible way to make every one aware about waste disposal methods and benefits of segregation. Segregating the waste before its disposal could be prime issue for waste to energy projects. Technology can be effective with support of stakeholders' participation. Process of educating people about waste segregation is time consuming hence it would take much time get results. Political determination is required to over come the issue that are ignored in waste handling.

3 Nisargruna

3.1 Introduction

Nisargruna biogas plant for renewable energy is developed by senior scientist Dr. Sharad Kale at Nuclear Agriculture and Biotechnology Division of Bhabha Atomic Research Centre (BARC) in Mumbai.

Biomass in any form is ideal for the biomethanation concept, which is the central idea of the Nisargruna biogas plants. Biomass such as banana plantation, Gylricidia or any other green manure crops, finely powdered straw, biodegradable waste materials can serve as raw materials for Nisargruna plants. Other raw materials would include 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. Municipal authorities, therefore, have to ensure of such segregated waste before putting up of the biogas plant. Waste like Coconut shells, egg shells, big bones, plastic/polythene, glass, metal, sand, slit, debris and building materials, wood, cloth/ clothes, ropes, nylon threads, batteries, rubber products, hazardous and chemical industries waste cannot be treated and is strictly avoided for Nisargruna Plants (Dr S Kale, 2005)

3.2 Technology

Technical details of the plant
Major components of BARC's a Nisargruna plant include a mixture/pulper with 5 HP motor(s) for crushing solid waste, a pre-mix tank, a pre-digester tank, an air compressor, a slow water heater or solar panels, a main digestion tank, a gas delivery system, manure pits, a tank for recycling water, a water pump, slurry pump and a gas utilization system. 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, propionic acid and formic acid (Dr S Kale, 2005).

The three steps of Nisargjyoti (biogas) production
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 4.5-5.5 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 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 obtained biogas is a mixture of methane (70-75%), carbon dioxide (10-15%) and water vapor (5-10%).

3.3 Nisargruna plant observation detail
In order to have brief understanding about operational details and technology, Observation of Nisargruna plant capacity of 5 ton waste processing per day is done.

Picture: Nisargruna plant, Shatabdi Hospital Site at Govandi Mumbai

Table 3.1 Nisargruna Observations

Total space required (storage, operational and set up)	35 m x 25 m = 875 m^2
Actual space required for plant	Approx. 750 m^2
Technology	Aerobic and Anaerobic process Developed by BARC
How often the microbial culture has to be added	Only once at the time of plant commissioning
Number of days/weeks required for establishing the culture in the digester	Only one day (culture can be transferred or brought here from any similar running plant)
Does the establishment of culture vary from season to season (eg. In winter and summer)	Aerobic digester – varies therefore a constant temperature has to be maintained Anaerobic digester – NO
Initially how many days/weeks are required for obtaining the stable purity of Methane	Approximately one week
After how many days/weeks of actual operations, the first waste feeding to the plant begins	First feeding can start from day one but to reach the optimum capacity it will require some more days (for a 5 ton plant it may require 3-4 months)
Working days of plant/yr	365 days (for shatabdi hospital and BARC plant)
Whether any special types of enzymes are used on regular basis	No
Retention time	Actually 12 days (4 pre-digester and 8 secondary digester) but to be on the safer side they say it as 19 days

Table 3.2 Nisargruna Observations

Digester volume for pre-digester and secondary digester	Pre-digester – 40 m^3 Secondary digester – 80 m^3
Capacity of the Plant	5 tons
Power consumed every day	Not known
Water consumed daily	Depends upon the waste input it is 1:1 in case of this technology the quantity of fresh water used is very less it is only the recycled water which is used in the mixer.
Cost of diesel used every day	30 Rs (approx 25 litre/month for running the generator and is being supplied by BMC)
Water condition (hot water is used or cold water)	Hot water is used in pre-digester
Ratio of water used to solid waste	1:1
Quantity of gas produced	Average 150 m^3/ton of input but depend on type of waste.
How many MW or KW of electricity produced per day	108 kwh in 12 hours
Total quantity of manure produced every day/month/year	8 – 10 % of the waste intake (approximately 200 kg)
Owner of the End product	Gas – BMC Manure – Stree mukti sangathan
Total manpower required including security personnel	7
Number of supervisors required	1
Number of skilled labour required	1 (plant Operator)
Number of unskilled labours required	3 + 1 (labours & asst. Plant operator)
Total quantity of waste used every day	Approximately 2 tons
Quantity of waste rejected every day	300 – 400 kg. during the observation but purely depending upon the type of waste and the total waste received every day.
Types of waste used	All types of Biodegradable kitchen wet waste (cooked and pre cooked) and raw vegetable and fruit waste.
Distance of the plant from the waste generator	2 km (radius)

Table 3.3 Nisargruna Observations

Methane CH_4 content in the biogas	Normally varies between 70% to 84% depending on type of waste
Carbon dioxide CO_2 content in the biogas	Not known
Hydrogen sulphide H_2S content in the biogas	Extremely less
pH of loading	6-7
pH of effluent	8
Is there any problem related to scum formation	No
How is scum formation problem get solved	Scum formation problems are sorted in the pre-digester itself by addition of hot water which makes degradation faster and bacteria multiplication is faster also the slurry movement is such that there is no stagnant phase in the system.
How often the generators have to be maintained	Oils levels have to be replaced depending upon the generator running time and similarly there are possibilities of the wear and tear of the panels
Does any part of the treatment facility requires regular replacement	Mixer belts and blades, mixer belts are to be replaced once in three months
A number of bacteria are present in MSW – is it necessary to give MSW a pre-treatment (like treatment of waste at 70º for 1 hour)	Not in this case, as problem get solved in pre-digester itself
Maintenance cost of the plant /yr	2,40000/- at present future projections are 3,60000/-
Loading rate	18.75 kg/m³/hr (calculated as per 1.5 tons of waste input per day)
Feed time	Approx. 2 hrs (for 1.5 – 2 tons at present)
Sludge withdrawal	Continuous
Is sludge recycling done	Yes
Is there any mixing arrangement in the digester	No

Table 3.4 Nisargruna Observations

Heating arrangement	Solar water heater is used in the case of pre-digester (at present bio gas is used with newly designed burner for boiling water, biogas is supplied from gas holder)
Material of the digester	Brick work for both pre-digester and secondary digester but the roof of the secondary digester (gas holder) is of M.S and of floating type
Corrosion prevention is done by	Painting it regularly

3.4 Merits of setup

- Easy to maintain
- System is designed indigenously in India; and does not consist of any expensive imported components, thus ensuring easy availability of spares.
- Most sub-operations does not require high skill. Workers can be trained for plant operation in 3 months.
- Can be more efficient when waste input is good quality of segregated waste

3.5 Demerits of setup

- Most of the operations are manual and no mechanical operations involved in the system, pre-digester system needs manual operation of feeding the slurry further to the pre-digester from the inlet channel. Aesthetically it may not look good.
- Hot water in the pre-digester needs to be poured manually.
- There was bad odour at the plant. It might disturb neighbours and dwellers as well as other visitors too.
- Sludge holding tanks showed bubbles, which indicates that the there might be some anaerobic conditions, which is due to incomplete digestion of the slurry.
- There is no proper shredding or cutting of the waste in the mixer, it only homogenizes with water but doesn't get crushed by the blades. Digestion will be faster with properly crushed waste.

Some of these problems are easy to overcome. The smell from the aerobic digesters could be removed by enclosing these pre-digesters and recycling the air around them. The grinder could be redesigned to break up the feedstock. The aesthetic appearance could be improved, again by enclosing the plant in a building or even shielding it with trees.

3.6 Discussion

Technology is a successful combination of aerobic and anaerobic process. It could be very useful to Municipal Corporations to process their solid organic waste as most of biodegradable food waste can be utilized as raw material for the plant.

Biogas and manure is valuable product. Nevertheless whole technology creates various types of opportunities for different prospects. Lack of knowledge makes local Municipal Corporation unaware of benefits of the systems. Biogas and Electricity generated at the site is not being utilized by the municipal authority, which shows lack of interest. Present infrastructure set up is funded by Municipal Corporation and any up gradation and modification cannot be made without funding agency's support.

4 Evaluating major benefits of Nisargruna

4.1. Technical

Energy in the form of Biogas: The production of an energy resource, biogas from Nisargruna is most tangible benefit. Nisargjyoti (Biogas) use, replacing conventional fuels like kerosene or firewood, allows for the conservation of natural resources. It therefore increases its own value by the value of forests saved or planted. The price of supplied energy produced by Nisargjyoti can compete with distorted prices on the national or regional level of the energy market. A decentralized, economically self-sufficient Nisargjyoti unit - under competitive conditions – can provide energy without market distortions (Dr S kale, 2005).

Environment: Nisargruna will contribute in saving of greenhouse pollutant emission from unregulated dumpsites. Practicing biogas production in rural area can have several advantages, such as relieving demand on electricity, coal, oil, firewood and problems associated with the administrative & distribution network. The organic matter required for biogas production is abundant and readily available. Decreasing the demand for firewood spares the forest and furthers afforestation efforts (Chongrak Polprasert, 1996) and helps in reducing greenhouse pollutants into the atmosphere. According to an Indian estimation, a Nisargruna plant of 2.8 m^3 capacity can save a forested area of 0.12 hectares (Dr S Kale, 2005)

Nutrient reclamation by using Organic manure: The nutrients (N, P, K) present in the waste are usually in complex organic forms, difficult to be taken up by the crops, After digestion at least 50% of the N present is in the form of dissolved ammonia, which can be nitrified to become nitrate, for application to crops so as to be readily available for uptake, thus digestion increases the availability of N in organic wastes to above its usual range of about 30-60%. The phosphate and potash contents are not decreased, and their availability of about 50 and 80%, respectively, is not changed during digestion. Digestion process does not remove or destroy any of the nutrients from domestic and farm wastes, but makes them more available to plants. In addition to being used as a fertiliser, the biogas digested slurry came out from plant act as a soil conditioner and helps to improve the physical properties of the soil. The application of digester slurry to unproductive soils would eventually improve the soil quality, or useless land could be reclaimed (Chongrak Polprasert, 1996)

Landfill life and Quality: Land-fill dumps become unstable by rotting of vegetable wastes in the dump. Rotting of vegetable wastes causes the generation of methane and the reduction in volume of the soil in the dump. It should be possible to build on a foundation made from inert waste (without vegetable wastes) within about 8 years, compared to the 20 years that is required before a dump normally stops being unstable. Separation of organic waste from the prevailing dumping practice of waste will reduce the quantity of waste going to dumpsite. It will thus increase the life of landfill for use and also the quality of land made by filling the land. However, by giving correct treatment to leachate and combustible gases produced by remaining waste will also reduce the pollution and other health hazards.

4.2 Health Protection

In the health sector, benefits from Nisargruna plants arise both at the individual level as well as at the level of society. Nisargruna plants serve as methods of disposal for waste and sewage and in this way directly contribute to a better hygiene situation for individual users. By centrally collecting dung and by connecting latrines, open storage can be avoided. Apart from this, pathogens are extensively eliminated during the digestion process. Theoretically, a reduction in the frequency of disease leads to savings in medicine and consultation costs. Regarding the leakage of health services in rural areas, another approach to savings is suggested. As a consequence of Nisargruna plants, labor productivity would rise due to the elimination of potential disease-causing agents (Dr S Kale, 2005).

4.3 Sociological

Employment: During the construction of Nisargruna plants, there are effects on regional/local income and employment (unless these are built by investors themselves). Permanent jobs are created for plant personnel, and indirect effects result in contracts with local and regional companies for the service and maintenance of a plant, including gas burners in households. The utilization of biogas contributes to an enlarged range of energy fuels offered on the market. In this way the local basis of energy supply can be extended and secured, and it also simplifies the setting of additional commercial activities where the factor energy has so far proved to be a problem. At the regional level, labor intensive, decentralized Nisargjyoti units improve income distribution amongst income brackets and reduce regional disparities, enhancing the attractiveness of rural life. The design of a Nisargruna plant does not involve any imported materials and hence is truly indigenous (Dr S Kale, 2005).

4.4 Poverty Alleviation

Some of the Nisargruna Plant located in Mumbai, is maintained and operated by Stree Mukti Sangathan (SMS, Women's liberation organization); it has provided employment to the poor women (previously who were working as waste picker on dump sites and in streets). They work on Nisargruna Plant where they are trained initially for its operational know how by SMS. Real efforts by volunteer organization like SMS have certainly helped poorest of poor to get better livelihood and social status.

4.5 Financial & Economic Analysis

Municipal authorities: Nisargruna plant will be most helpful to Municipal Authorities. Presently MCGM is said to be spending more than 1.50 rupees for disposal of one kg of waste from community bins to the unregulated dumpsites. If processing of organic waste is done by Installing Nisargruna Plants in a decentralised way then it would economical and save environment to great extent. Municipal Corporations may get different government aid and funds by National (Example: likely to get subsidy from Ministry of Non Conventional Energy) and International agencies for city development. (See Appendix B for detail calculation)

Corporate or Industrial use: Nisargruna Plant is ideal for processing waste in Industries mainly in form of canteen food waste, processed food waste. Nisargruna will be helpful in getting environmental certificates and ISO standards.

Real estate developer: Nisargruna Plant can solve solid waste disposal problems for residential complex or commercial complex. Cost of land for Real estate developer is compensated in the form of incentives from Municipal authorities for getting extra floor space index (FSI) to construct. Real Estate developer can install the system and charge partial amount to its customer for installing the plant. This will help Developer to get project completion certificate from Municipal Authorities. Biogas and manure can be use by residents for heating, cooking and for gardening purpose.

Non Government Organisation: For non government organisation and volunteer organisation, it would be beneficial to sell services based on Nisargruna Technology. It would be beneficial to provide employment to poor people for operating and maintaining plant.

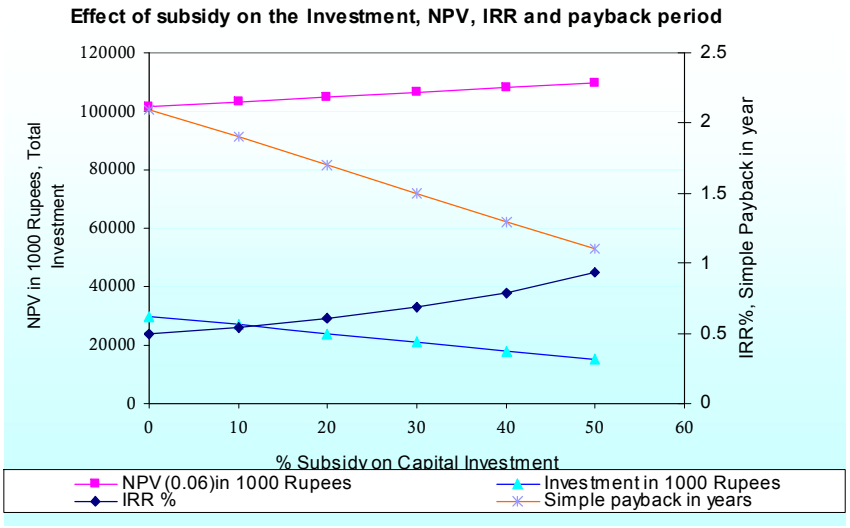
Benefits for private venture: From venture view point, it will not be possible to get high returns on basis of selling energy but profit from waste processing charges is essential too. Bigger scale for 50-100 tons/day waste processing may become viable if it is to be on long term contract basis. When requirement of processing of waste comes from Municipal Corporation or food processing industries, selling methane gas to the local energy companies would certainly make project profitable business in terms of Investment. (Please refer to Appendix B for spreadsheet model).

Table 4.1 Assumptions for Financial Analysis

Main Assumptions:

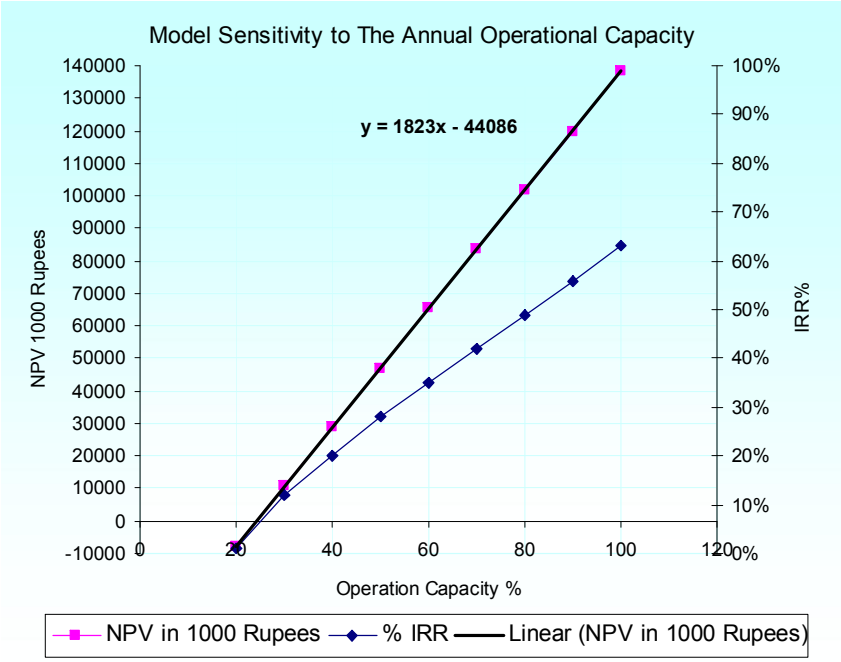
- It is assumed that land will be available for installing Nisargruna plant or will be provided rental free by concerned authority for the project.
- Plant will operate for 300 days per year.
- Plant operating capacity efficiency will be 80%.
- Discount rate is 6% for NPV
- O&M will be 15% per annum of total capital cost through out the project life.
- Retail price of LPG is 21 Rupees (Rs)/kg (subsidized). Biogas selling price is assumed 12 Rs/Kg.(Selling it to Energy company)
- Retail price of electricity is 5 Rs/kwh. Selling price is assumed for 3 Rs/kwh. (Selling it to Energy company)
- Retail price of manure is 5 Rs/kg. Selling price is assumed for 2 Rs/kg (Bulk price)
- Assuming that bank interest rates and tax rates will remain steady through out the project life.
- For Municipal Solid Waste processing projects, waste transportation cost to the plant is assumed 0.50 Rs/kg.
- Plant will be operating for at least 15 years with normal maintenance required.
- Plant decommissioning cost amount will be adjusted by selling infrastructure to the agencies involved in recycling.
- There are no extra benefits e.g. Subsidies and carbon credits given to the project.
- 500,000 rupees will be required setup of generator for converting biogas into electricity on every 5 tons waste processing capacity plant.
- Municipal Corporation of Greater Mumbai is spending around 1.80 Rs/kg for transporting waste from refuse bin to dumpsite. Considering that fact it is assumed that Operator will charge municipal authorities 1.50 Rs/kg for waste processing where operator will be transporting waste from refuse bin to the plant.
- If Municipal Authorities process waste by installing Nisargruna then monthly savings on processing would be 1.50 Rs/Kg
- Price of 5 ton waste processing capacity plant is Rs 2.5 Million without electricity generating equipment setup. Rs 0.5 Million is extra cost for providing electricity generation equipments and infrastructure.

Results: Graph 4.1 Effect of Subsidy on the Investment,NPV,IRR and Payback time



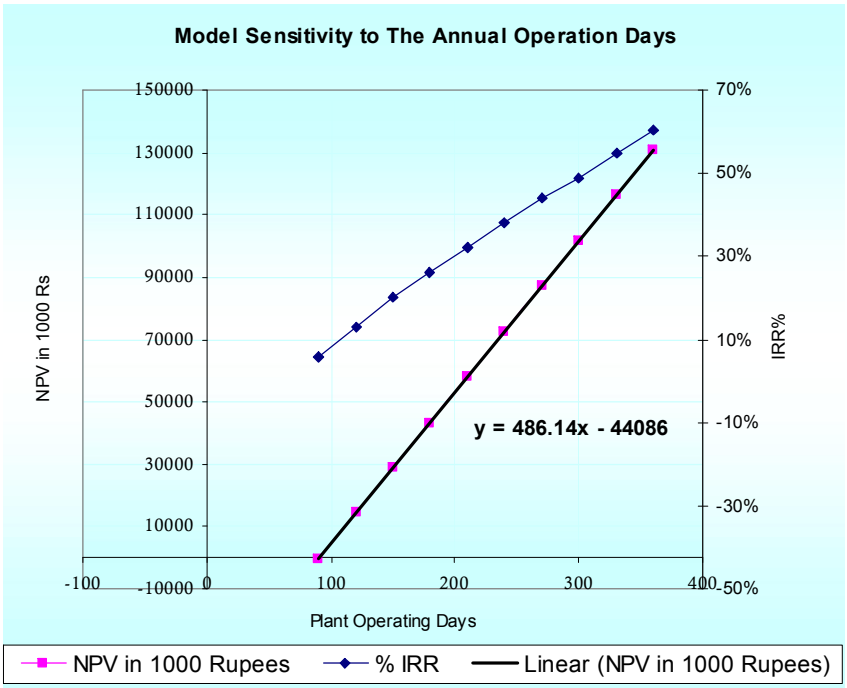
With Increase in subsidy over all profitability increases, with reduction in Investment and payback time. However it is attractive and profitable business with high returns.

Graph 4.2 Model Sensitivity to The Annual Operational Capacity



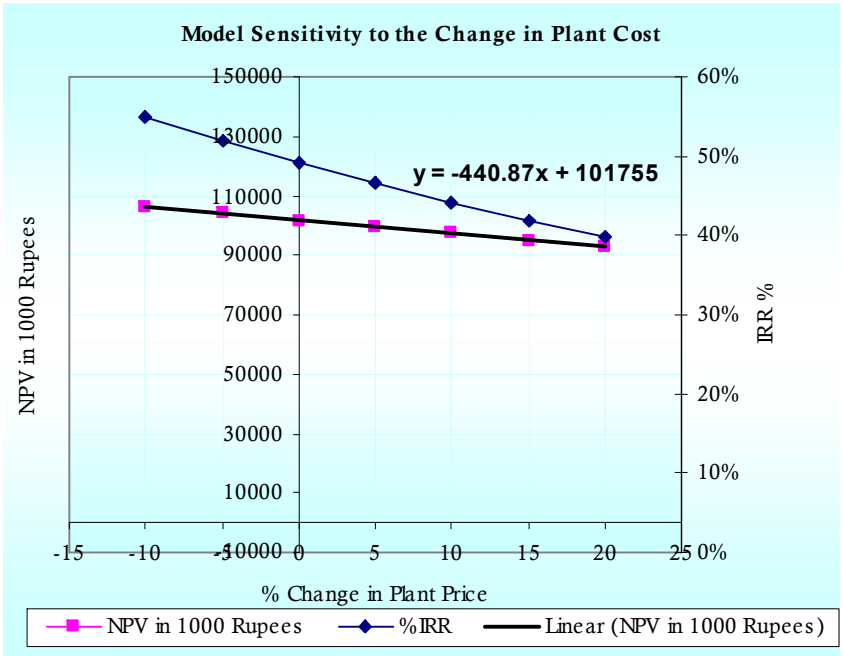
Annual Operational Capacity will have great effect on overall profitability. It will be beneficial to run the plant at its maximum capacity.

Graph 4.3 Model Sensitivity to The Annual Operational Days



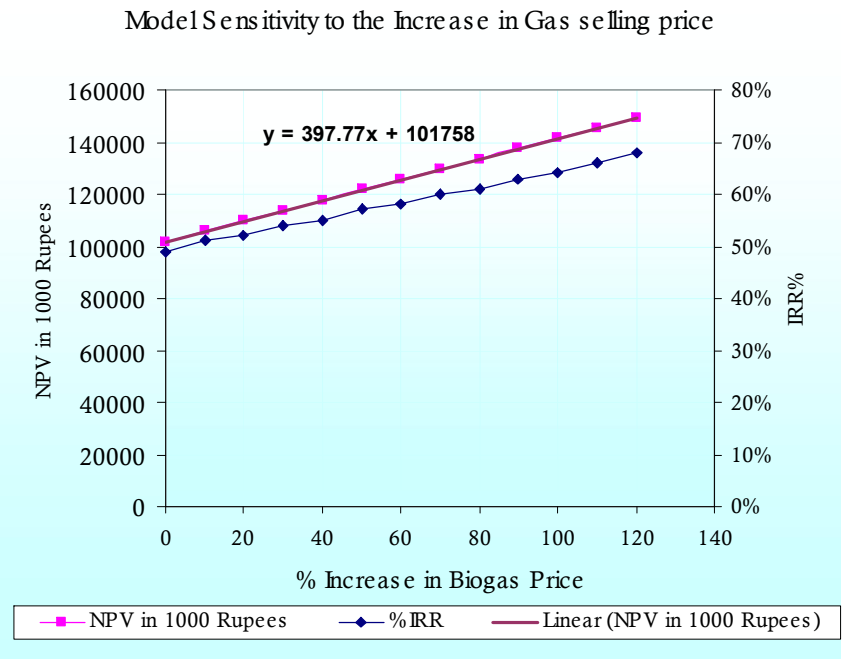
Annual Operational Days will have significant effect on overall profitability. More number of maintenance or repair will reduce the profitability.

Graph 4.4 Model Sensitivity to the Change in plant Cost



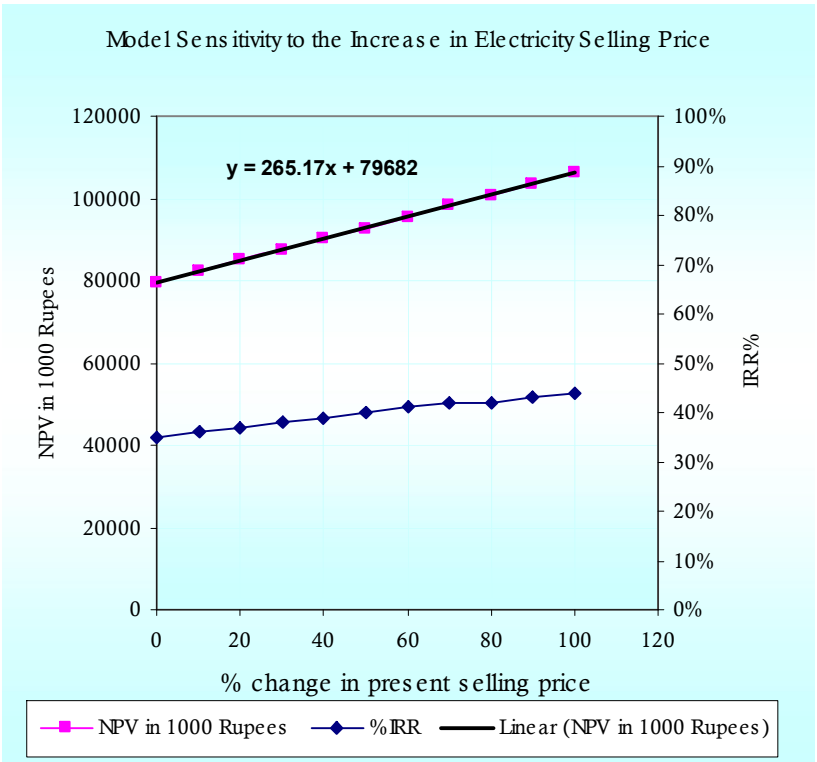
Change in Plant cost will not have much effect as it will be one time cost.

Graph 4.5 Model Sensitivity to the Increase in Gas selling price



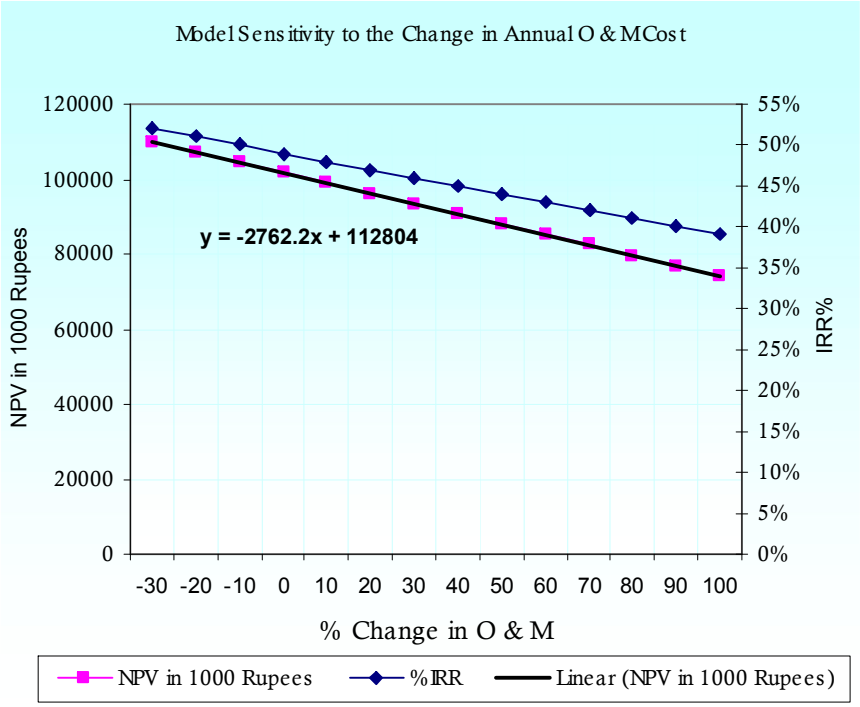
Increase in Gas selling price will make much effect on the over all profitability. LPG price is increasing regularly with increase of oil prices and it will give indirect benefits to the Biogas selling price. It is most likely to happen that price of biogas will increase.

Graph 4.6 Model Sensitivity to the Increase in Electricity selling price



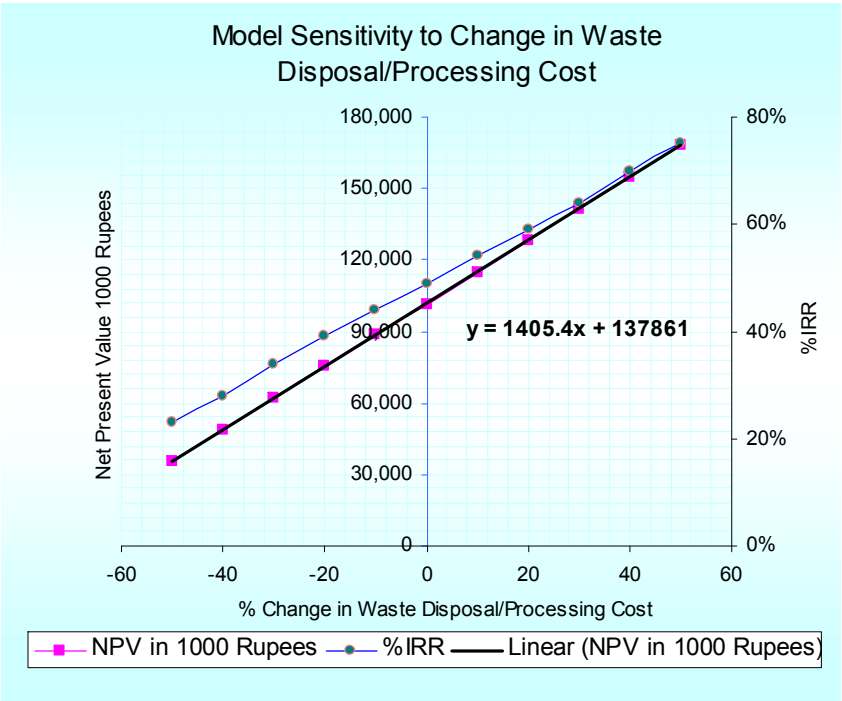
Increase in current electricity selling price will not make much effect on the over all profitability even if it change a lot.

Graph 4.7 Model Sensitivity to the Change in Annual O&M Cost



Major Changes in O & M cost will not much affect to the over all profitability.

Graph 4.8 Model Sensitivity to the Change in Waste Disposal/Processing Cost



In above graph, little change in waste disposal or processing charges has much effect on over all profitability. Since major income comes by processing charges, Waste disposal cost is important factor that could affect profitability.

4.6 Discussion

The project will have integrated impact on Environment and Society. Municipal Authorities and other government organisation can get maximum benefits due to interest free loans and low cost land or perhaps free available land. Non government organisation and entrepreneurs will also have opportunity to sell the services based on technology. This will generate Employment for both skilled and unskilled workers on regional level and state level. Seeing the spreadsheet model it looks highly beneficial. Municipal Corporation seems spending much more for dumping the organic waste in unregulated dumpsites. This type of projects can change life of urban poor and give them social status with systematic approach. But prevailing ignorance in many government agencies will require determination and conscious efforts towards sustainable development.

5 Business strategy and plan to promote Nisargruna

5.1 The Business Plan

Nisargruna Technology is developed by BARC for processing municipal solid waste (MSW). By using Nisargruna Technology, disposal of waste is done in environment friendly manner. Technology is self sustaining when it comes to its economics. It converts MSW into two valuable products such as biogas and manure. Manure is excellent soil conditioner and Biogas, is a valuable energy resource for today and for future. Biogas can be used for cooking and heating purpose and can be sold to energy companies at a good price. Nisargruna technology gives good rate of biogas production which is beneficial for its operators. It is beneficial for entrepreneurial ventures. When Implementation services are considered, it will give attractive returns to entrepreneurs and Investors. This Business plan is for the entrepreneur's company dealing in various services based on Nisargruna Technology.

5.1.1 Overview

- **Business aim**

To provide economically viable solution for processing solid organic waste using Nisargruna technology, Process that deals with the putrescible fraction of solid waste and converts it into two valuable products, - energy and fertilizer

- **Main assumptions**
  - Entrepreneur has expertise of the delivering the Nisargruna Technology Implementation related services and certified by BARC for the same.
  - Entrepreneur has worked individually and successfully implemented Nisargruna projects previously.
  - Entrepreneur has complete knowledge of microbiology of the process and will be closely working with BARC for further modification of the infrastructure and design of the plant.
  - Entrepreneur will be working full time for the company
  - BARC will be forwarding at least 3 Implementation jobs to entrepreneur in a year, Thus entrepreneur will always have advantage to work closely with BARC for technological design improvements
  - Present competitors make nearly 40% of net income on their business.

5.1.2 The company and its Industry

- **Purpose of the company**

Company will be delivering professional services based on technology implementation and will be working closely with BARC for development of new designs and modification of infrastructure.

- **Description of what the business is about**

Business will be based on implementation of Nisargruna technology. Providing infrastructure and related services to implement the technology, also consultancy would be offered for Solid waste management problems. Company will work as

main contractor or sub contractor on the implementation projects depending on the clients and orders.

5.1.3 The products/services

- **Product strategy**

Competitive approach is intended to attract its customers by offering them value addition as compared to current competitors. For example designing systems for faster digestion / more gas production would be competitive approach apart from its low price. Nisargruna technology based plants have great potential in commercial market. Care will be taken to make it most profitable product for buyer. Offering a unique product to the customer and product related services which is comparable to those already in existence but at a lower price, so offering them greater value for money.

Customers will be given choice to choose the services in terms of packages offered by the company, some examples of different packages are discussed here:

- A package of setting up complete plant with 1 year on site warranty.
- A package of complete consultancy service, where customer is free to choose their contractor for building the plant. Consultancy amount will be charged for the various service like providing technical knowledge, site visits and plant commissioning charges.
- A package for annual maintenance contracts for running plants
- A package of leasing complete plant for minimum number of years at client's own site or land. Where clients will be charged upon using biogas from the plant. This will give advantage to both client and entrepreneur in terms of continuous business. However such combinations of package can be delivered in special cases.
- Company will also provide consultancy to clients for generating electricity from Biogas and selling energy to energy companies.

- **Distinctive competences**

Technology is invented by BARC which is country's most trusted and biggest government organization.

- **Technologies and skills required in the business**

Complete know-how of Technology, plant commissioning, de-commissioning and regular operational knowledge is pre-requisite. Enterprising skill is essential in order to promote it.

- **License and rights**

Company will acquire permissions or certificates from BARC to implement the Nisargruna technology, to build plant infrastructure and sell services based on Nisargruna technology.

- **Future potential**

Municipal authorities are likely to introduce new mandatory rules for waste producers to treat solid waste. Under new rules, bigger residential, commercial and industrial establishments will have to process their waste at the source of

generation. This will mainly give demand for processes like Vermicomposting and Biomethanation. Thus it is growing market for company to do business.

It could be highly profitable business if benefits like government subsidies or carbon credits are considered for the bigger projects. Continuous price hike for LPG fuel will increase demand and value for Biogas and make project profitable (chapter 4 for detail)

5.1.4 Markets

- **Customers**

Prospective customers will be Municipal authorities, food caterers including canteen owners, hoteliers, restaurant owners, Property developers, Commercial complex, Industrial food processing house.

- **Competitors (Strength and Weaknesses)**

Other standard technology services like Vermicomposting and Biomethanation by Anaerobic process are offered by other competitors in the market. Vermicomposting is less expensive technology but not profitable business. It requires more space for pits to allow composting.

- **Market segments**

Market is segmented on benefits sought, Usage level, Application, Organization type, Geographic location, Customer loyalty, Price sensitivity. Identified potential buyers are bigger organization like municipal authorities to treat municipal solid waste, Commercial, Industrial, Residential complex, hotels and canteen to treat their food waste. However intention of every customer varies from social angle to commercial angle. Small and medium sized plants from 1 ton to 5 tons waste processing per day are installed by entrepreneur in past. Company would invest in developing 10 tons to 25 tons capacity plant in future.

- **Market size and growth**

Market size varies with geographical regions, but expected to grow further in commercial area, bigger metropolitan city, and township. Small towns will also be attractive to do business but plant size would be small in that case.

- **Customer buying patterns**

Some customers are more inclined to buy low cost products where as some customers are more interested in buying reliable service based products.

- **Critical product/service characteristics**

Product process is unique and technology inventor holds legal rights to pursuit illegal user of the technology name.

- **Competitor response**

Competitors offering waste processing solution based on anaerobic process or Vermi composting, could reduce their price to compete Nisargruna in market.

5.1.5 Marketing

- **Pricing strategy**

Pricing will be dependent on customers.

- Company will be offering attractive price to BARC since BARC will be giving continuous business to the company
- Company will be offering commission to the business associates, agents and intermediates.
- Price for services to the government organization may vary and will depend on competitor's response.
- Pricing strategy will be segmented by service packages
- NGOs many times has to work in limited budget and do not want to invest for superior quality infrastructure. In that case pricing will be done accordingly.
- Corporate houses will be charged premium price for delivering high quality premium products.

- **Distribution strategy**

Intermediaries will be appointed in various locations or in states for trade enquiries, marketing of services in different geographic region. Since Entrepreneur's technology implementation skill will always remains as trade secret. Entrepreneur will be traveling to project site for commencement of project. Company will be accepting sub contracts from other companies for the same implementation job.

- **Promotional strategy**

Initially promotion will be planned for targeted plants and will be limited to the capacity to deal every project smoothly with available infrastructure and workforce. Strategy will be change accordingly with the response, approaches to informing the customers and the intermediaries about the product/service; advertising message, sales promotions (including price promotions)

5.1.6. Design and development

- **Stage of development**

Technology is developed and many plants are running successfully across the country. Research and development work is done regularly by BARC.

- **Difficulties and Risks Assumptions**

Difficulties may come if in future about development of other new products and infrastructure. It may be difficult to carry same designs of infrastructure for many years and therefore new concepts product would be essential.

- **Product/service improvements**

Continuous improvement in infrastructure for better plant capacity efficiency is targeted.

- **Product/Service developments in future**

Company is aiming to develop small scale plants for treating 25-50 kg waste per day for house hold waste, also bigger size plants over 25 tons waste per day for treating waste on bigger scale.

5.1.7 Operation

- **Premises location**

Company's operations will be mainly handled from office premises in Mumbai. Office premises will be taken on lease for period of 2 years.

- **Source of workforce**

Arrangement will be made with voluntary organizations like Stree Mukti Sangathan to providing man power to operate plant.

- **Use of subcontractors**

Different subcontractors will be appointed for building the infrastructure or providing construction services, maintenance services of plant machinery. They will be appointed on regional level to meet the demand of the particular area.

5.1.8 Management

- **Owners**

Company will be formed in partnership. Initial investment will be made by venture capitalist (VC). However equity of VC will be varying from 80 to 90 % depending on the financial capability of entrepreneur to raise the other remaining balance. On that equity VC will be getting 50% of total profit as a share. Entrepreneur will remain with balance 50%.

- **Summary of planned staff members and recruitment plans**

For first year company will have 5 staff members including Entrepreneur. One civil engineer will be employed and one marketing executive will be employed on yearly contract basis to work for the company. Similarly two office staff will be employed to look after sales enquiries and clients feed and registering complaints. More recruitment can be made in second year by reviewing the first year performance of the company and staff members.

- **Consultants and advisors**

External consultants and advisors will be approached for other possible solution when needed.

5.1.9 Financing requirements

- **Funds required**

Equity investment of 2 million rupees is required initially to seed the business. However it will be difficult to predict about cash flow and it will be totally depend on the sales.

- **Exit routes for Investors**

Exit routes for investors could be after 12 months of starting of the company. Investors will have to inform 60 days in advance when withdrawing its stake.

5.1.10 Financial highlights, risks and assumptions

- **Income**

Revenue will be generated from different services offered, e.g. consultancy services, total waste management solutions including setting up waste processing plant, main contracts and sub contracts.

- **Routine expenditure**

Expenditures will be mainly entrepreneur's salaries, employee wages, occupancy, advertising, promotion expenditure, insurance and other supplies.

- **Capital expenditure**

Entrepreneur may develop trial designs of infrastructure for efficient technology implementation but it will be done in second year of business, where some money from first year profit will be kept on future research and development work.

- **Highlights of financial plans**

	No. of Plants	Plant Capacity	Cost per Plant	Total
Sale of Equipment:				
	3	5 Tons	2,500,000	7,500,000
	2	2 Tons	1,250,000	2,500,000
Total Sales				**10,000,000**
Cost of Sales				
Purchase of raw material & other equipment				4,000,000
Cost of fabrication, labor and administrative expenses				2,000,000
Total Manufacturing cost				**6,000,000**
Gross Profit before interest and tax				4,000,000
Less: Interest on capital investment @ 12% p.a.				720,000
Profit before tax				**3,280,000**
Less: Taxes @ 30%				1,200,000
Net Profit after tax				**2,080,000**

Assumptions:
1. No annual maintenance contracts have been undertaken in the first year
2. The cost of land/space for manufacturing equipment has not been factored.
   It is assumed that the plant is fabricated on site.
3. Cost of capital is assumed @12%

Sales of products and services are expected to be 10 Million Rupees annually. Entrepreneur is rather optimistic about selling more than expected with 20% of net income from it. However realistic figure may vary from 20% to 40% depending on the client and type of contracts.

- **Risks:**

Minimum financial risk is involved as entrepreneur will try to cut down extra overheads for initial 2 years till business grows with profit. Business dealings with BARC will be safe enough in terms of Payments. Initial mobilization amount will be charge to the client in terms of advance payment and strategy will be to invest minimum amount to lower the risk factor. However financial risk is always involved if credit is given to the client and recovery is not made for outstanding amount.

5.2 Discussion

Above plan is based on assumptions. The business plan is a necessary but not a sufficient condition for obtaining finance for a business proposal. Many entrepreneurs are suspicious of formal sort of planning because it might limit their options when defining its future. Finally, a business strategy is just a way of doing things. Strategic flexibility is a way of doing things well when faced with uncertainty. It responds actively responding to outcomes and adjusting activity, not just blindly following the set plans. Successful growth of business requires a genuine desire to succeed, amounting almost to a need.

6 Stree Mukti Sangathan's Contribution in Poverty Alleviation

6.1 Introduction

Stree Mukti Sangathan, Women's Liberation Organisation (SMS) established in 1975 has directed its efforts towards the upliftment of women irrespective of caste class, creed, religion, language & nationality. For last 28 years SMS is working among the men & women to achieve equal status in all spheres of life, i.e. political, economic, social cultural & psychological fields. It is a voluntary organization. Waste picking is a caste and gender based activity. By one unofficial estimate there are 50,000 waste pickers in Mumbai with an average daily collection of 10 kg would collect 500 tons of garbage which would be equivalent to the quantum of waste generated by 1.9 million of city dwellers. SMS initiated a meaningful dialogue with 1000 waste pickers (Parisar Bhagini - Neighbourhood sisters). The findings revealed the following facts (SMS, 2005):

- All Waste pickers belong to the scheduled castes (Dalits), and all of them were migrants, belonging to landless labour families.
- Age group of Waste pickers ranged from 7 to 70 years.
- In most cities gender division of waste pickers is: women waste pickers – 85%, Men Wastepickers-10% and Children Waste pickers - 5%
- 90% of all Waste pickers are the primary breadwinners for their families
- 98% of Waste pickers are illiterate with no alternative skills
- Most of waste pickers are from drought-prone areas of Maharashtra and other southern states.
- Waste pickers suffer serious health hazards resulting from unhygienic work conditions. Injuries from carelessly thrown glass and metal pieces, acid bottles, needles and dog and vermin bites are common occupational hazards.
- Due to poverty and malnutrition, most of them are anaemic.
- As they deal with toxic waste the respiratory diseases are common.
- Waste pickers suffer from street dog and rat bites
- Because of the heavy weight they carry on their shoulders most of them suffer from severe backache.
- Waste pickers therefore are the victims of the quacks which are regularly practising in the slums.
- Their day starts at the dawn and extends to more than 10 hours and entails walking 10-12 km. Daily carrying heavy loads of up to 40 kg

6.2 Efforts made by SMS for wellbeing of women working as rag pickers

Seeing the vulnerable condition of rag picker women in the occupation of waste picking, SMS started organizing waste picker women in Mumbai. SMS is working continuously for better living conditions of rag picker women. Some of their relevant activities and programme are discussed here.

6.2.1 An environmental entrepreneurship program for urban poor women

The Parisar Vikas (Development of Surrounding environment) programme started by SMS, aims at addressing the problems of waste picking women, engaged in the tedious tasks of cleaning the waste and the problems of waste management. After organizing the women, SMS found possibility of treating wet waste was more attractive for the benefit of Parisar Bhagini. SMS is sourcing contract based work from large housing areas where wet waste is collected separately in these housing

areas. One experiment in housing colony to convert wet waste into manure proved successful. SMS is getting help from private and public sectors in the form of providing solid waste management contracts from residential colonies (SMS, 2005).

6.2.2 Vocational training programmes

Presently SMS is providing systematic waste management training which includes, house to house collection of dry and wet waste, Sweeping of roads, buildings and staircases, Maintenance of the cleanliness of the roads, maintenance of the cleanliness of the Waste bins, maintenance and economic use of the material provided for the cleaning purpose, finer sorting of the waste, sale of the material and importance of bargaining power, formation of waste co-operative and distribution of amount, Basic gardening techniques. Apart from systematic waste management training, vocational training on work culture maintenance of record, muster, salary register, work rules, basic banking skills, health hazards issues, teaching significance of the organization, communication skills, literacy and basic accounting skills is given in the programme (SMS, 2005).

6.2.3 Initiatives for access to health

SMS is organising health camps for the women and children and provision of counselling facility to the needy families. Developments of special immunization, Anaemia detection, cure and prevention activities are part of health camps. To address the health issues at Macro level, community workers of the project are given special health workers' training with the help of Alert India Organisation. In past, some of waste pickers are covered by particular insurance schemes and food security schemes. A Crèche for the children of Parisar Bhaginis is in operation, in the community centre next to the Deonar waste dump site located in Mumbai (SMS, 2005).

6.2.4 Education

One of the objectives of SMS is the education of the children of the waste pickers, who, due to lack of other options, were continued their mother's job of waste picking. Under education programmes, Pre-primary education is made available to the children of the Parisar Bhaginis by starting Kindergartens in the communities with the help of non government organisation mainly providing primary education. SMS has also started an adolescent sensitization programme for 300 adolescent boys and girls of the waste pickers (SMS, 2005).

6.3 Participation of SMS in waste management

SMS has established two training centres in Mumbai, for training Parisar Bhaginis in bio composting, vermi-culture and gardening. 300 women have been trained in manure and gardening techniques so far. As a result of this 250 women have gained meaningful employment. In November 2004 along with SMS experts, Parisar Bhaginis participated in training the staff, workers and residents of IPCL Township in Nagothane (Dist. Raigad). Today IPCL is the first Petrochemical Township in India achieving near zero waste status. To make this model

sustainable, SMS has developed 5-6 composting models for use with the available space in localities of different Socio-Economic background. SMS also took help of the concept of Advanced Locality Management Groups (Citizens' groups) encouraged by MCGM Authorities. Many of these local groups gave employment opportunity to trained Parisar Bhaginis in their lanes (SMS, 2005).

6.4 Specific role of Stree Mukti Sangathan for Nisargruna

Nisargruna Plant at Govandi is constructed by SMS for Municipal Corporation of Greater Mumbai (MCGM). SMS received maintenance contract for Nisargruna (Bio-methanation) plant developed by BARC with capacity of treating 5 tons of biodegradable waste every day. SMS is maintaining 3 such plant in Mumbai. SMS is also constructing shed for segregated dry waste storage. Waste coming to plant for processing, will be segregated at the plant site. Wet waste will be processed in Nisargruna and remaining dry waste such as plastic, metal glass and other paper items will be segregated further in this shed. It will be stored separately and later it will be sold to the recycling units. Women working on these Nisargruna plant are employed by SMS, they were working as rag picker in past. Partnership with MCGM enables SMS efforts of bringing change into this lot of urban poor lead to another important development. SMS is also planning to start venture where Nisargruna technology based services will be offered. SMS will be training different individuals for operating Nisargruna plants.

6.5 Discussion

Such activities by SMS proves that small groups of waste collectors can be organized to undertake waste recycling activities themselves, increasing in the process not only returns but adding a new perspective to their occupation of waste collection and reuse. It highlights the reality that women from marginalized groups need not be passive victims of poverty and human rights violations; they can successfully participate in the struggle to survive, to gain control over economic, social and political resources, and lead a life of dignity. Different rag picker's programme by SMS aims to better the working conditions of rag pickers and promote their status within the community, while creating a waste management system to improve city's recycling initiatives. Nisargruna technology implementation work by SMS could provide more jobs in future to waste pickers.

7 Bio-methanation technology by Mailhem Engineers

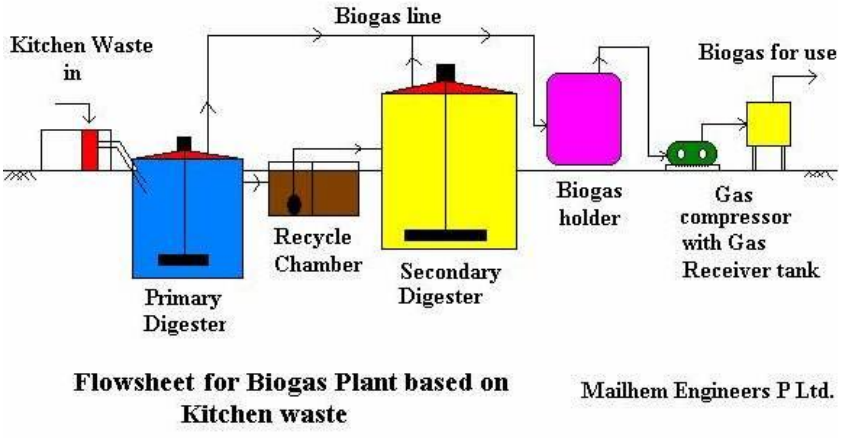
7.1 Introduction

Mailhem group is provider of bio-methanation technology. Basic concept of their technology is based on a process known as Upward Anaerobic Sludge Blanket (UASB). Mailhem uses modified version of UASB process for the waste containing high percentage of suspended solids.

Location: Magarpatta Pune

Mailhem is one of the significant players for providing bio-methanation technology in India. Purpose of visit to Mailhem Engineering Pune plant is to study the working of their technology. However as seen in picture above, visited Magarpatta site was under construction when visited.

7.2 Description of Process



Source: Mailhem Engineers Private Limited

The segregated wet waste (mainly food waste) is brought to the plant site in bins and containers. It is loaded on a sorting table and residual plastic, metal; glass and other non-biodegradable items are further segregated. The waste is loaded into a special crusher along with the water, which is mounted under the sorting table itself. The food waste slurry is directly charged into the modified UASB primary digester.

This digester serves mainly as hydrolysis cum acidification tank for the treatment of suspended solids. It contains internal proprietary modules, baffles and launders made in fiber reinforced plastic (FRP) reinforced with Mild Steel. It is provided with a stirrer drive assembly with blades for scum breaking. It is provided with an

airtight top cover. The overflow of primary digester is collected into pump cum recycle chamber and pumped into secondary digester.

Secondary digester serves as a methane fermentation tank and BOD reduction takes place here. Both states are of proprietary modified UASB construction. The secondary digester too is equipped with proprietary internals, stirrer assembly and top cover. The treated overflow from this digester is connected to the drains. The sludge, which accumulates at the bottom of the digester, is removed once in a year.

The biogas is collected in a neoprene rubber balloon and kept in a suitable enclosure. The biogas compression system comprises of biogas blower with automation, gas receiver tank, pressure switch, pressure gauge. 1" HDPE piping with moisture traps provided up to a distance of 500 m from heating can be done.

The biogas plant is capable of taking: mixed wastes and treating them for optimum results, Segregated Kitchen waste from residential societies, segregated wet garbage from hotels and canteens, Sewage sludge from STP (Mailhem,2005)

7.3 Merits of the setup

- The Plant is compact hence less area is required.
- Biogas produced can be utilized easily.
- Aesthetically looks better
- Produce less sludge comparing to other plants, sludge removed once in a year so less hassle.
- Produces no odor due to anaerobic digestion.

7.4 Demerits of the setup

- Retention time is more. i.e 28 days.
- Mailhem Technology has proprietary upward anaerobic sludge blanket (UASB) modified construction which would restrict its transferability and may not be useful for entrepreneurial ventures for selling services based on its technology.

7.5 Discussion

Magarpatta Plant site was under construction when visited. However setup looks compact and organized. Overall its popularity can be judged by its previous projects done in all over India and hence it is assumed to be performing better. Operation looks less manual especially when comparing with Nisargruna setup at Shatabdi Hospital Govandi. Nevertheless, Nisargruna plant produces higher amount of biogas when comparing with Mailhem's technology. Similarly percentage of methane in biogas is higher with Nisargruna technology. This is due to successful combination of aerobic digestion and anaerobic digestion. Nisargruna technology has more advantages like technology transfer and entrepreneurship for individuals. BARC's all available technologies (including Nisargruna) are developed with objective of serving the society and nation.

8 Discussions

Change in prevailing waste dumping practice is not an easy task for concerned authorities. Municipal authorities have ignored these issues somehow. Picture of Deonar Dumpsite has given the clear idea of the current situation. Change in dumping practice is seems to be difficult but not impossible. Genuine efforts are required with perseverance, Efforts such as willingness to adopt new technologies that are available for waste processing and educating people about waste disposal methods. Nisargruna technology which is one of the solid waste processing technologies proves that dumping solid waste is economically unacceptable. By use Nisargruna Technology for waste processing we get valuable biogas. Everyday more than 5000 tons of waste is disposed in dumpsite of Mumbai everyday and if we consider at least 500 tons of solid waste that is being processed then we could get more than 18000 kg of LPG equivalent biogas and which is significant amount of LPG savings. Besides that, it will have major benefit to environment and economy too. Such sustainable efforts can certainly help in reducing global warming effect to some extent. Nisargruna plant at Govandi has changed life of few waste pickers and helps in poverty alleviation.

9 Conclusions

Serious problems relating to waste disposal methods in major metropolitan cities will remain as it is if immediate action is not taken by concerned authorities. Waste dumping activity by Municipal authorities in Mumbai is certainly a cause of concern for city dwellers.

Dumping approach has many direct and indirect hazards for human, environment and for eco system. Waste segregation at the source will be another major issue which needs proper attention. Without waste segregation at source, solid waste processing projects for any operator will not be economical.

BARC's Nisargruna technology for processing solid waste is indigenous technology. A Nisargruna plant observation at Govandi, Mumbai proves that plant is successfully processing solid waste and technology is beneficial in many ways. Biogas production is faster because of combination of aerobic and anaerobic digestion technology. Present 5 tons capacity plant running at Govandi, is successfully producing electricity. Electricity generation from biogas is also one of the potential benefits of Nisargruna.

This technology development will save environment to greater extent. It will also provide energy in form Biogas, reduction in GHG emission, Health benefits, social benefits and great profit in terms of financial investments.

Financial model results shows that over all its profitable business. With increase in waste processing charges and gas selling price, it will be highly profitable business. In future there will be scope for extra benefits like subsidies and benefits like carbon credits, which will give high rate of return on total investment.

Entrepreneurs will excel in their ventures by selling services and products related to Nisargruna Technology. Stree Mukti Sangathan is operating some Nisargruna Plants, thus enabling employment to the poor waste pickers. In comparison with other waste processing technologies, Nisargruna seems to be sustainable in all aspects including social and business aspects.

10. References

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APPENDIX A: Nisargruna Plant Functional Details

Microbiological Analysis of predigester slurry (Dr. S Kale, 2005)
Total viable count of thermophilic bacteria was found to be- 2.1X108. Fifteen isolates were found to be Gram positive, sporulating rods, which were catalysed positive and belong to the genus Bacillus. Identification of the isolates was done on the basis of their biochemical characteristics. These isolates were identified as Bacillus licheniformis, Bacillus alvei, Bacillus stearothermophilus, Bacillus firmus, Bacillus circulans, Bacillus megaterium, Bacillus laterosporus, Bacillus thuringenesis and Bacillus sphaeriicus, Bacillus coagulans, Bacillus larvae, Bacillus subtilis, Bacillus pumilus and Bacillus lentimorbis.

Degrading abilities of above cultures were determined, particularly to degrade cellulose, chitin, starch casein, urea, pectin.

Table Appendix A-1

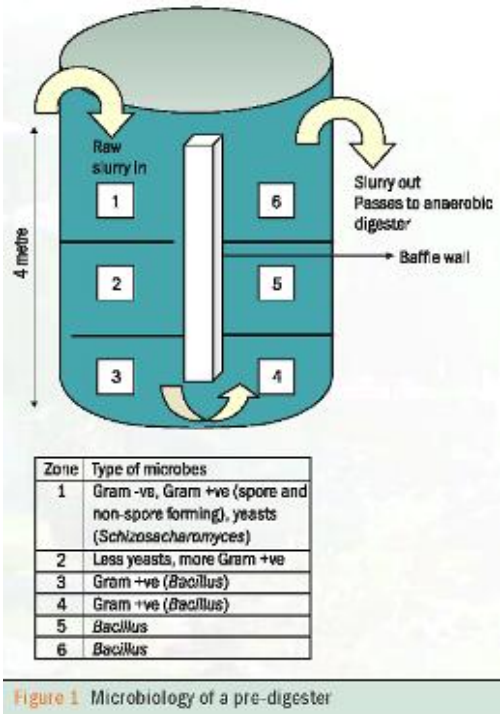
Culture. No.	Starch	Casein	Cellulose	Chitin	Pectin	Urea
1	+	+	+	+	+	-
2	+	+	+	-	+	-
3	+	+	+	+	+	-
4	+	+	+	+	+	-
5	+	+	+	+	+	-
6	+	+	+	-	+	-
7	+	+	+	-	+	-
8	+	+	+	+	+	-
9	-	+	+	+	-	-
10	+	+	+	+	+	-
11	+	+	+	+	+	-
12	-	+	+	+	+	-
13	-	+	+	+	+	-
14	+	+	+	-	+	-
15	+	+	+	-	+	-

Temperature studies- The cultures were grown at 400C, 450C, 500C, 550C & 600C to determine the optimum temperature for the growth (Dr. S Kale, 2005).

Table Appendix A-2

Culture no.	Total no. of cultures.	Optimum temp.
4,6,	03	40^0C
1,2,7,8,9,12,13,16	08	45^0C
3,5,10,11,14,	06	50^0C

Detailed Functioning of the Plant:



Zone	Type of microbes
1	Gram -ve, Gram +ve (spore and non-spore forming), yeasts (*Schizosaccharomyces*)
2	Less yeasts, more Gram +ve
3	Gram +ve (*Bacillus*)
4	Gram +ve (*Bacillus*)
5	*Bacillus*
6	*Bacillus*

Figure 1 Microbiology of a pre-digester

Picture Appendix A-1 Source: www.mnes.nic.in Akshayurja July 2005 issue

In above diagram, the predigester, various zones are formed and different bacteria dominate these zones. Addition of hot water helps in eliminating the mesophilic bacteria and selection of thermophilic bacteria. But these thermophilic bacteria can operate at lower temperatures also. Hence hot water added even once a day should be sufficient for maintaining the pure consortium in the predigester. However if it is possible to maintain the temperature of predigester in the range of 50-55^{o}C throughout the day, the performance of predigester will definitely be better and the holding time may be further reduced. The hot water helps in hygienization of the slurry by killing the enteric bacteria that may be present in the waste. Some Gram of negative enterobacteria and coiform bacteria in the raw slurry are isolated. However in the second zone these bacteria are totally eliminated.
From the pre-digester tank, the slurry enters the main tank where it undergoes anaerobic degradation by a consortium of archaebacteria belonging to Methanococcus group. These bacteria are naturally present in the alimentary canal of ruminant animals (cattle). They produce methane from the cellulosic materials in the slurry. The undigested lignocellulosic and hemi-cellulosic materials are then passed on to the settling tank. After about a month, high quality manure can be dug out from the settling tanks. There is no odour in the manure and the organic content is high, which can improve the quality of humus in soil (Dr S Kale, 2005).

Organic manure
Chemical analysis of organic manure is shown in following table. 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 predigester due to higher temperature and acidic conditions (Dr S Kale, 2005).

Table Appendix A-3

Date of Sampling	Fe	Zn	Mn	Cu	Co	Pb	Cd
05.04.2004	8240	915	443	238	39.5	ND	ND
12.04.2004	8000	870	500	256	29.1	ND	ND
19.04.2004	8120	616	378	178	16.6	ND	ND
26.04.2004	8500	795	484	150	28.7	ND	ND
03.05.2004	7800	700	315	198	40.6	ND	ND
10.05.2004	8110	712	416	210	27.1	ND	ND
17.05.2004	8150	680	400	220	28.9	ND	ND
24.05.2004	8500	865	450	260	40.1	ND	ND
31.05.2004	8260	900	392	252	32.6	ND	ND

Carbon: 35-40%
Nitrogen: 2-3.5%
Phosphorous: 0.5-0.9%
Potassium: 0.5 - 0.8%

Main observations:

Waste: Raw Material

- Waste is supplied by BMC(Bombay Municipal Corporation) through their garbage collection trucks (often called as "tempo" by vehicle model)
- Waste is mainly collected from Ward M- East and Ward M- West of Mumbai
- Waste comes primarily from hotels and restaurants
- Daily 4-5 mid size vehicle load of waste is received at site
- Daily one tempo load of vegetable waste comes from food store
- Another tempo collects waste from Grand hotel, located at Andheri but frequency of delivering the waste to the site is twice or thrice a week
- Tempo bringing waste from Grand hotel has i.e. approximately 2.5 – 3 tons kg of load
- There are some other tempo vehicle, which brings the waste generally consists of 350 Kg – 400 Kg of load
- Timings of waste receiving at the plant are from morning 8am – 11am. Sometimes some vehicle brings the waste in night time but then waste is processed only in the day time.
- Biodegradable waste, which is being treated at Nisargruna Plant at shatabdi hospital are all types of raw vegetable and fruit waste, pre-cooked and cooked kitchen waste and papers.

Plant setup comprises of:

- Receiving Platform: It is slightly raised above the ground level so that waste can be directly transferred from a municipal vehicle to the platform. A separate channel for draining out the excess water has been provided to this platform.

- Segregating Platform: This Platform is slightly raised above the receiving platform (1.7m). Mixer and weighing scale are kept on the same level so that the worker segregating the waste don't have to carry the segregated waste to a some other place for weighing as well as mixing. Generally received waste is segregated same day in day time and filled in the plastic buckets, which are then weighed and transferred to the mixer. However with experience, they have gained some knowledge to judge approximated weight of bucket filled with vegetable waste and buckets with food waste. Thus they don't generally weigh each and every bucket unless it is required for specific data collection.

- Mixer**:** Mixer is used in this system with a 7.5 hp motor for mixing and partially crushing the organic waste. Waste is homogenized by mixing it with water in the mixer. The height and the diameter of the mixer is 120 cm with a round stainless steel blade, having the diameter of 45 cm. The mixer generally acts as a mixing unit, does not fully crush any waste. Waste is segregated and transferred to the mixer in batches. These batches generally depend upon the volume of the waste in the buckets for instance if there is only raw vegetable and fruit waste then only four buckets of waste are added to the mixer where as if there is more of wet kitchen waste then four to five buckets of waste is transferred to the mixer. Generally waste is mixed together with vegetable waste or processed food in the Mixer. Each batch of waste is mixed with approximately 250 litres of water. Normally water added with waste in the mixer is recycled water transferred from the pit. Maintenance of the mixer requires regularly changing of the mixer belts (once in 3 months, but may be required more frequently because at present only 1.5 – 2 tons of waste is being processed). Blades also require regular maintenance.

- Pre-digester tank: The homogenized waste, mixed in the mixer, is let to flow in the pre digester tank by opening the outlet value of the mixer. Everyday the total waste, which is homogenized in the mixer, is first allowed to be collected in the inlet channel of the pre-digester tank and after processing the total waste in the mixer the total homogenized waste is allowed to flow in the pre digester tank through the inlet openings which are 13 in numbers. These 13 inlet openings acts as the waste inlet channels to the pre-digester tank and are provided on one side of the pre-digester tank so that the waste is spread evenly in the form of layers in the first zone of the pre-digester tank. The process in the pre-digester tank is aerobic and needs to be supplied with continuous air system, which is provided by the compressor. Further the waste in the pre-digester needs to be treated with the hot water to maintain the temperature at 50°C - 55°C throughout the day. At this temperature the process becomes faster and hence reducing the holding period of the pre-digester tank. Normally adding hot water is a process of hygienisation of the slurry where it kills all the enteric bacteria, which is present in the waste. The hot water, which is added to the tank, is heated with the help of solar water heater (500 litre capacity. Recently BARC has modified the design by introducing gas burner instead of solar water heater. It may be for the research purpose to see the alternatives for efficient energy utilization. This burner is kept over the new pre-digester tank and hence gas burner is used for boiling water instead of solar water heater. Boiled water is later added to the pre-digester tank. The pre-digester tank is divided into two zones, from the first zone the waste is transferred to the

second zone due to gravitational movement. Continuous aeration is supplied to this zone to maintain the waste in the form of slurry. Total holding period of this pre digester tank is 4 days; from the pre-digester tank the slurry enters the main tank (secondary digester) through provided channel. The total volume of the pre-digester tank is 40 m^3. The depth of the pre-digester tank is 4.2 m.

- Main Tank (Secondary Digester): The slurry from the pre-digester enters the Main or Secondary digester, which is underground and concealed; eventually the slurry undergoes the anaerobic digestion (in the absence of air). The bacteria present in the secondary digester acts on the slurry and produce methane from the cellulosic material in the slurry. The gas produced is collected in a dome shaped tank which is kept rested above the secondary digester tank. Dome is floating type and sealed with water from its outer edge. Once gas production from ends from slurry, i.e the slurry left behind is settled down in the tank and later on when the new batch of slurry is pumped in via gravity the previous slurry is passed on to the settling tanks. Volume of the secondary digester is 80 m^3. Diameter is 6m and internal diameter with 5m and depth is 4 m. The dome, which acts as a gas collector/holder, has a depth of 1.15 m and height 45 m from the top of the dome to the normal level and with the volume of 24 m^3. The biogas obtained from gas holder is at normal pressure at 2mbar but the gas is further compressed by use of weights (steel plates) kept on top of the gas holder (5 plates of approximately 200 kg each). Gas is compressed at approx. 10 mbar pressure. The roof type floating dome is fabricated from mild steel, where as main digester tank and pre-digester tank made of brick work construction (civil).

- Sludge Drying Beds (manure pits): The digested slurry comes out via outlet chamber to the drying beds with gravity without any pumping system. Outlet chamber has depth of 75 cm and dimensions 1m x 1m x 1m. There are total 5 beds (tanks) with the dimensions first one is 3m x 3m with depth 1.3 m, Second pit is 2.9m x 3m with depth 1.3 m, third pit is 2.75m x 3m with depth 1.55m, fourth pit is 2.3m x 2.7m with depth 1.9 m, fifth pit is 1.6m x 2.7m with depth 1.75m. Extra bed is attached for fresh water. Sludge withdrawal is a continuous process and is allowed to settle in one tank and then from there is transferred to the other tanks with the help of slurry pump. Further for recycling, sludge (liquid content) is again used in the mixer with the help of a second slurry pump.

- Generator: Capacity of the installed generator is 10 KVA/hr and it is duel fuel type. Generator is presently working on diesel as well as on biogas. When observed for working of the generator by adding purely diesel it showed the performance for 1 hr and when generator running time was observed by using 1 litre diesel and biogas (under 10 m bar pressure) it showed a performance of 7.5 – 8 hrs. At present Bombay Municipal Corporation is supplying fuel for the generator. At a time 5 litres are added to the generator which will last for approximately 40 hrs. Approximately 25 litre of diesel is required per month (however it is depending upon the consumption of the electricity). Maintenance is required for the generator's panels, also it is prone to wear and tear, and Oil levels have to be replaced.

Table Appendix A-4 Details of the Generator

AC Generator	Engine
Frame – 4DM180/2	Type – TA2 Sr. II
KVA – 10	Engine No – 21.1042/0400314
RPM – 1500	RPM – 1500
Volts – 415	BHP – 12
AMP – 13.9	KW – 8.8
10 HP	

- Recycle Pump and Compressors: 2 compressors with 2 HP and 1 HP are used for continuous aeration in the pre-digester tanks and 2 slurry pumps are used – one is operated for transferring water from one drying bed to the other and the second pump is operated for supplying the recycled water to the mixer.

Table Appendix A-5 Details of 2 Pumps used

1	Recycle Pump– make Kirloskar Engineering	Motor 2 HP
		1.5 KW
		415 V
		RPM – 2830
		Total H – 13.5m
		Efficiency 77%.

	Pump	Head range - 9-18m
		discharge – 4.5 litre/s
		efficiency 45%
		RPM – 2830
2	Make Crompton Greaves	KW/hp 0.75/1
		V – 225
		RPM – 1425
		Current – 7.6 amp
		Head – 18 x 45 m
		Size – 25 x 25 mm
		Discharge 2800/880 Litres/hr.

Gas Meter:

1/Actaris G 10
Qmax – 16 m^3/h
Qmin – 0.10 m^3/h
Tm - -20°- -50°C
1imp – 0.1m^3
Pmax 0.5 bar
V10dm^3

- Manpower : (7 people working on the plant)

Manpower	Salary per month (in Indian Rupees)

1 Plant Overall Supervisor (Nisargruna)	3000/-
1 Plant Operator	2750/-
1 Assistant Plant Operator	2500/-
3 helpers (Parisar Bhagini)	3 x 80 x 30 =7200/-
1 watchman	3500/-
Total	18950/-

- Manure**:** Manure is removed from the sludge beds and it is further let drying out side in the sun. Later when dried fully, it is packed and stored in the bags. Manure production is equivalent to 8 – 10% of the waste input in the plant and hence manure production will be around 160 to 200 kg/day when waste input is around 2 tons. Manure obtained as by- product of plant is weed free, the weeds which are present in the vegetable matter are killed in the pre-digester tank where there are acidic conditions and a high temperature is maintained.

Other Observations: Table Appendix A-6 pH Values Observed

Date	Mixer (input to the pre-digester)	Pre-digester	Digested (output)
30/11/05	6-7	5-6	7-8
	6-7	5-6	7-8
	6-7	5-6	7-8
1/12/05	6-7	5-6	7-8
	6-7	4-5	7-8
	6-7	4-5	7-8
2/12/05	6-7	5-6	7-8
	6-7	4-5	7-8
	6-7	4-5	7-8
3/12/05	4-5	4-5	8
	4-5	4-5	8
	4-5	4-5	8

pH paper was used for the test and value is derived by seeing the colour chart of the paper. pH was observed much high (acidic) on 3/12/05 because the waste input had more quantity of orange as well as lemon waste (approximately 50 kilograms)

Table Appendix A-7 Total waste received in Kilograms

Date	Total received In Kilograms	Actual waste used (Kg)	Rejected (Kg)	Water used In litre
30/11/05	1655	1415	240	2000 lit
1/12/05	1350	950	400	1500 lit
2/12/05	1570	1260	310	1700 lit
3/12/05	3500	3000	500	3500 lit

On an average 1656Kg of waste is being processed every day (during days of observations) and when records of 15 days was referred for the month of November it was observed that the plant is processing an average of 2 tons of waste input each day.

Wet kitchen waste as well as the raw vegetable and fruit waste was measured in the buckets (weight of the bucket 1.2 kg) six different buckets were measured for two days.

Table Appendix A-8 Wet Kitchen waste (in Kg)

Buckets	1	2	3	4	5	6	Average
Day1	42	47	42	36	35	42	40.66 Kg
Day 2	45	43	46	34	40	39	41.16 Kg

Table Appendix A-9 Raw Vegetable and Fruit waste (in Kg)

Buckets	1	2	3	4	5	6	Average
Day 1	27	25	30	29	25	24	26.67 Kg
Day 2	25	28	23	30	27	24	26.10 Kg

Labours normally mix both types of waste when processing it. It was observed that the average weight of the wet kitchen waste was more compared to the dry raw vegetable and fruit waste, because of the Moisture content (water already present in the waste) in the kitchen waste.

- Consumption of gas was noted down under different situations like burning it under one burner, flaring out and also through generator.

In atmosphere (flared out) through gas meter	When the gas was burned using one burner	By passing the gas through the generator
0.06 m^3/min	0.03 m^3/min	0.06 m^3/min
3.60 m^3/hr	1.76 m^3/hr	3.55 m^3/hr
43.2 m^3/12 hrs	21.12 m^3/12 hrs	42.6 m^3/12 hrs

Observations and data collected for the gas which is compressed at 10 mbar pressure. The actual values under normal atmospheric pressures may vary. During the time of observation, when gas was passed through the generator and flared out in the atmosphere through the gas meter, there was an increase in the levels of the gas holder indicating that the production of gas is more than the consumption.

Table Appendix A-10 Information about funding to the Plant (in INR: Indian Rupees)

BMC	700,000
M.N.E.S	500,000
BARC	300,000
Total	1,500,000
Maintenance per month (provided by BMC)	20,000/-

APPENDIX B Financial Analysis Spreadsheet

Table B.1 Cost Benefit Analysis

Cost Benefit Analysis for Project of 5 ton waste processing/day capacity 12 different plants						
Total Decentralized Plants of 5 ton each	12					
Actual Input tons	4	80%				
Each Plant Price (INR)	2,500,000	1				
Loan proportion						
Total Waste Processing Capacity (in ton)	48		Power Generation KWh/day	4800	Waste processing charges INR per Kg	0
Capital Cost (INR)	30,000,000		Biogas Generation (meter^3/day)	4800	Density of Biogas	1.13
Bank Loan (INR)	0		value for 1 kwh (INR)	3	Biogas in Kg/day	4247.7876
			Manure/ day (Kg)	4800		
Land cost	0		Approximate market value for 1 kg manure (INR)	2	O & M (15% of Capital Investment)	15.00%
Govt Capital subsidy	0		LPG equivalent (Kg)	1799.9	Cost of LPG at present(INR/kg)	21
Investment Total	30,000,000		Operation days/year	300	Selling price for Biogas in kg	12
			Waste transporting cost to the nearest plant /kg (INR)	0.5	Savings in Transport cost of waste to dumping site /kg (INR)	1.50
			Carbon Credit	0		
			% Government subsidy on Capital Investment	0%		0

Table B-2 Annual Cash Flow

Annual Cash Flow (INR)		
Average Gas Revenues		6,479,676
Electricity Revenues		
Manure Revenues		2,880,000
Carbon credit		0
Annual Savings on (Waste transporting to dumpsite or) waste disposal/ Waste processing Charges		21,600,000
Cost for Waste Transportation to site		-7,200,000
Interest Repayments		0
O&M Costs		-4,500,000
Insurance etc.		0
Gross Cash Flow		19,259,676
Depreciation 15%		4,500,000
Tax 30%		-4,427,903
Net Cash Flow		14,831,773
NPV (INR)	6%	101,755,749
IRR		49%
Payback Time	Years	2.1
INR = Indian Rupees		

Year	Cash Flow (INR)
1	-30,000,000
2	14,831,773
3	14,831,773
4	14,831,773
5	14,831,773
6	14,831,773
7	14,831,773
8	14,831,773
9	14,831,773
10	14,831,773
11	14,831,773
12	14,831,773
13	14,831,773
14	14,831,773
15	14,831,773

Table Appendix B-3 Cost benefit analysis Assumptions

Assumptions	
No land cost is considered as it is assumed that it will be provided by Municipal Authorities	
No subsidy available for the plant	
Investment will be raised by funding VC or any other source without interest payment	
Selling of Biogas is considered in the model, however electricity can be generated and sold with extra setup	
Plant operation for 300 days annually	
Plant Operation Capacity 80%	
5 ton plant with electricity generator would nearly cost 3 Million Rs & without generator would be 2.5 Million Rs	
Actual amount spent by Municipal Authority to transport waste to dumpsite for one kg is approximately 1.80 Rupees per kg	
Considering transportation cost of Waste to the Plant is assumed to be 0.50 Rupees/kg	
If Plant operated by Municipal Authority then Savings assumed at least 1.50 Rupees per kg	
If Plant operated by Operator then waste processing charges will be 1.50 Rupees per kg	
Discounting rate for NPV : 6%	

Sensitivity Analysis Spreadsheet Tables:

Table Appendix B-4: Effect of Subidy on the Investment, NPV and IRR

Table 4-1 Effect of subsidy on the Investment, NPV, IRR and payback period

% of Subsidy on investment	IRR %	NPV (0.06)in 1000 Rupees	Investment in 1000 Rupees	Simple payback in years
0	49%	101,756	30,000	2.1
10	54%	103,402	27,000	1.9
20	61%	105,049	24,000	1.7
30	69%	106,695	21,000	1.5
40	79%	108,341	18,000	1.3
50	94%	109,988	15,000	1.1

Table Appendix B-5 Sensitivity Analysis Assumptions

Assumption
No Subsidy
Discount Rate 6%
Plant without electricity generation setup
Plant operation days 300 annually
Plant capacity 80%
Energy revenues by selling Gas

Table Appendix B-6 Annual Operation Capacity

Annual Operation capacity		
Operation Capacity %	% IRR	NPV in 1000 Rupees
100	63.00%	138216
90	56.00%	119985
80	49.00%	101756
70	42.00%	83525
60	35.00%	65295
50	28.00%	47065
40	20.00%	28834
30	12.00%	10604
20	1.00%	-7625

Table Appendix B-7 Annual OperationDays

Annual Operation days		
Change in Plant operation days	% IRR	NPV in 1000 Rupees
360	60%	130,924
330	55%	116,339
300	49%	101,755
270	44%	87,171
240	38%	72,587
210	32%	58,003
180	26%	43,419
150	20%	28,834
120	13%	14,250
90	6%	-333

Table Appendix B-8 Change in Plant Price

Change in Plant Price		
% change in plant price	%IRR	NPV in 1000 Rupees
-10	55%	106,164
-5	52%	103,960
0	49%	101,755
5	47%	99,551
10	44%	97,347
15	42%	95,142
20	40%	92,938

Table Appendix B-9 Increase in Gas selling Price

Increase in Gas selling price		
% Increase in Initial considered price	%IRR	NPV in 1000 Rupees
0	49%	101,755
10	51%	105,733
20	52%	109,710
30	54%	113,687
40	55%	117,665
50	57%	121,642
60	58%	125,619
70	60%	129,659
80	61%	133,574
90	63%	137,551
100	64%	141,529
110	66%	145,506
120	68%	149,483

Table Appendix B-10 Increase in Electricity selling price

Increase in Electricity selling price		
% increase in electricity selling price	%IRR	NPV in 1000 Rupees
0	35%	79,682
10	36%	82,333
20	37%	84,985
30	38%	87,637
40	39%	90,288
50	40%	92,940
60	41%	95,592
70	42%	98,243
80	42%	100,895
90	43%	103,547
100	44%	106,199

With Electricity Generator Investment

Table Appendix B-10 Change in Annual O & M

Change in Annual O & M		
O&M (% change)	%IRR	NPV in 1000 Rupees
-30	52%	110,042
-20	51%	107,280
-10	50%	104,517
0	49%	101,755
10	48%	98,993
20	47%	96,231
30	46%	93,469
40	45%	90,706
50	44%	87,944
60	43%	85,182
70	42%	82,420
80	41%	79,658
90	40%	76,896
100	39%	74,133

Table Appendix B-11 Change in Waste Disposal Cost/Processing Charges

Change in Waste Disposal Cost/ Processing charges		
% Change in Waste Disposal Charges/ Processing charges	%IRR	NPV in 1000 Rupees
-50	23%	35,463
-40	28%	48,721
-30	34%	61,980
-20	39%	75,238
-10	44%	88,497
0	49%	101,755
10	54%	115,014
20	59%	128,272
30	64%	141,531
40	70%	154,789
50	75%	168,048

Sensitivity Component	Equation of the NPV trend line
Operation Capacity	y = 1823x - 44086
Operational Days	y = 486.14x - 44086
Cost of Plant	y = -440.87x + 101755
Cost of Selling Gas	y = 397.77x + 101758
Cost of Selling Electricity	y = 265.17x + 79682
Annual O & M Cost	y = -2762.2x + 112804
Waste Disposal Cost	y = 1405.4x + 137861
Assumption	
No Subsidy	
Discount Rate 6%	
Plant without electricity generation setup	
Plant operation days 300 annually	
Plant capacity 80%	
Energy revenues by selling Gas	

APPENDIX C

Mailhem Engineers plant operation & technology Information

Technological and Operational Information:

Table: Appendix C-1

Technology	• Anaerobic Digestion. • Technology is used for Biogas generation from biodegradable organic waste. • Mesopheric System which is energy efficient.
Culture used	• anaerobic microorganisms
Water input ratio	• 1:1
Shredder / Mixer	• Input is biodegradable organic waste with water. • Used for chopping the waste and making it into fine slurry. • It has a capacity of chopping 1 tone waste/hr
Recycle chamber	• Single phase motor is used which is linked with the stirrer/agitator.
Primary Digester	• Made of 3mm milled steel. Inside coated with Fiber glass. • Water pipes are joined from the Inlet cum recycle chamber through which the slurry is fed in this digester. • Agitator is used for stirring up the slurry inside the primary digester.
Secondary Digester	• Body is made up of 3mm milled steel • Sealed tops ensure no foul.

Table: Appendix C-2

Gas balloon (Gas Holder)	• Made up of Neoprene rubber • Balloon is UV protected. • Gas collection varies from season to season • Balloon is protected in a shed which is non smoking or non fire zone for safety reasons. • Gas is stored at NTP conditions • The composition of biogas produced is as follows: Methane (CH_4) 55% - 60% Carbon Dioxide (CO_2) 38% Hydrogen sulphide (H_2S)1-2% .
Blower (Compressor)	• Pressurize the gas from the gas holder to the receiver tank.
Moisture Traps	• Moisture traps are present at the plant and next to the canteen building to trap moisture from the gas and it has to be cleaned once in a week.
Retention time	• 28 days i.e. • Primary digester takes 21 days and Secondary digester takes 7 days.
Manure	• Sludge is removed once a year • Sludge is used in gardens as manure.
Input-Output ratio	• For Input of 500 kg waste • Output of Gas is 40 cubic mt. per day • The gas generation is slightly lower in winter in the range of 30-35 cu.mt. Where as gas generation in summer is around 45 cu. mt.

Installation cost table:

Savings and Cost of plant calculated in terms of Indian Rupees (INR) approximately

Food Waste Treatment Biogas Plants:

Table: Appendix C-3

Waste qty in kg / day	Biogas in cubic meter/day	Manure	Area in Sq m	Savings equivalent to Liquefied Petroleum Gas (LPG) in Kg	yearly savings in INR 1kg LPG=21 INR	Installation cost In Indian Rupees-less civil works
Industrial Canteens / Segregated house hold (kitchen) and Hotel Waste						
1000	80 – 90	0.1 tpd	10 x 10	43	329595	600000-700000
2000	160 – 180	0.2 tpd	15 x 15	78	597870	1,100,000-1,200,000
3000	240 – 270	0.3 tpd	20 x 20	120	919800	1,800,000-2,000,000

- Plant price is approximate and excluding service taxes and duties wherever applicable. Installation and civil cost will differ seeing the soil condition.