BIOPROCESSING OF RESIDENTIAL ORGANIC SOLID WASTE THROUGH VERMICULTURE BIOTECHNOLOGY

Final Report

By

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To

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BIOPROCESSING OF RESIDENTIAL ORGANIC SOLID WASTE THROUGH VERMICULTURE BIOTECHNOLOGY

INTRODUCTION

Constant migration of people to urban centres, in search of opportunities has led to a continuous increase in the urban population, putting immense pressure on the infrastructural facilities of these areas. In some of the highly populous regions, this pressure has led to unmanagable situations and even health hazards, resulting in great inconvenience and embarrassment to the public, as well as the civic bodies responsible for managing them.

Solid waste management is a vital component of the infrastructural facilities that are normally handled by civic authorities. Currently, it is one of the most serious problems faced by mega cities world over and is likely to worsen with passage of time. It is estimated that by year 2011 the urban population in India is likely to be double that in 1991, but the solid waste generation is likely to be tripled (Down to Earth, 2000). The solid waste problem appears to be far more serious in Mumbai. The city generates about 6000 tons of garbage everyday, of which, 42-60% is the biodegradable component. 12-13% constitutes recyclables (like paper, plastics, glass, metal etc.) and rest of the waste comprises the debris/ inert wastes (Priya Salvi, 1997). This enormous amount of waste finds its way to 4 dumping grounds sites adjoining Mumbai, 2 in Eastern suburbs (Mulund and Deonar) and 2 in the Western suburbs (Malad and Gorai). The present practice of waste management includes transporting this garbage in a mixed form and just dumping it at the already overflowing dumping sites mentioned above. This exercise annually costs nearly Rs.300 crores/- to the MCGM coffers. Of this 75% gets spent on the staff salaries and remaining 25% is spent on transportation. After all this, what the residents get in return, is only shifting the location of the problem to some other site and not a complete solution to this ever increasing menace.

Despite the colossal expenditure, the present practice is becoming increasingly inefficient and unpopular due mainly to several problems created by it in vicinity of dumping sites and the increasing cost of transportation of the wastes to these sites. Besides, the inefficiency of garbage clearance (only upto 60% of the wastes get collected by the MCGM every day!), results in foul smell, ugly sights and potential health hazards for civic population.

The aforementioned facts only go to emphasize a pressing need for a responsible attitude towards garbage generated, which would include:

1. Recycling the recyclables.
2. Land fillings through only debris and inert waste.
3. Conversion of the biodegradables in a most environment friendly and cost effective way to a useful product.

Numerous technological options exit today for processing of the organic waste (Table 1). Out of all the options of organic waste processing that are available to us today, 'Vermiculture Biotechnology' option stands out as the most environment friendly, cost effective way of dealing with the problems of a city like Mumbai.

'Vermiculture Biotechnology' involves use of deep burrowing earthworm *'Polypheretima elongata'* for efficient conversion of nontoxic organic solid waste into extremely useful soil conditioner in a **natural way.** The earthworms maintain aerobic conditions in the soil through their burrowing activities and bring about a complete stabilization of the waste with the help of the beneficial microflora. In absence of such aerobic conditions, the organic matter will decompose anaerobically with formation of foul smelling compounds. The most important advantage of 'Vermiculture Biotechnology' is that, the earthworms always remain hidden underground - being sensitive to light - and waste processing can be safely done even at individual house or housing society level. The product from vermiprocessing -'Vermiculture' - contains not only earthworm cocoons but also several plant nutrients and beneficial microflora which are responsible for making the nutrients available to the plants on a need basis. Due to its several advantages Vermiculture finds its use in:

1. Waste management
2. Sustainable agriculture
3. Waste land development

It is well in line, here, to emphasize the difference in the waste processing by surface variety of the earthworms (like *Eisenia foetida*) and the deep borrowing ones (for example: *Polypheretima elongata*). The former leads to what is widely recognized as 'Vermicomposting' and the later produces 'Vermiculture' (Bhawalkar, 1995). There exists a vast difference in the comparative assessment of their performance (Table 2).

Vermiculture Technology seems to provide a simple, natural, less mechanized, viable and most effectively adoptable-at-the-source-solution to the solid waste disposal problem of mega cities like Mumbai. This has been amply proved by successful application at society and individual levels at many locations in Mumbai. But the efficiency of this technique in waste processing at ward level was never demonstrated before. Successful application of Vermiprocessing at ward level was also necessary to cut down on expenditure on waste transportation to the dumping sites and to achieve effective utilization of the biodegradable component of the waste generated. In view of this, MMR-EIS sanctioned the project entitled 'Bioprossessing of residential organic waste through Vermiculture Biotechnology' in 1998 (letter dt. August 17, 1998) in response to our proposal submitted on July 4, 1997.

OBJECTIVES

The sole objectives of the Project were:

1. Eco-friendly processing of solid organic waste and
2. Demonstration of utility of Vermiculture Biotechnology at Municipal ward level.

METHODOLOGY

Before the actual commencement of the Project work, it is necessary to inform and involve the local public and some prominent persons of the locality. An inaugural ceremony, including tree plantations, can best serve the purpose (Plates 1,2 &3).

Following methodology was adopted during the course of the project:

1. Site preparation.

2. Vermibin preparation.
3. Incubation.
4. Waste loading.
5. Harvesting.
6. Sample analysis and report writing.

1. Site Preparation:

Vermibin sites were prepared as required – the requirement being determined by the waste processing proposed every day and the available space - by excavating the soil from the area marked for processing and preparing pits in the ground itself.

The allotted site at Kannamwar Nagar, Vikhroli, had 3 main problems, namely:

a) Unclean and uneven area: The undulating / uneven area had to be evened out and cleaned of years of accumulated dirt.

b) Water logging problem: While excavating the vermibins, it was observed that a serious water logging problem existed in parts of the region due to
   - Proximity to creek.
   - Choked storm water drains around the site.
   - Absence of sewage drainage for the adjacent household.

   These problems were overcome respectively by filling out the existing slushy land with soil, cleaning the clogged storm water drains and providing a separate *'nalla'* to take away the wastewater from adjacent households.

c) Easy access to site: Before the start of the project various parts of the allotted site were being used as playgrounds, refuge dumping sites and even for answering nature calls. Building a barbed wire compound around the whole site stopped this.

2. Vermibin Preparation:

During this step, layers of various materials were laid in the dug-up 'bins' (Fig. 1). The utility of each of the bin components is as follows:

Limestone:

About 2" layer of limestone (Plate 4A) in the vermibed helps in reducing the acidity in the system during the vermiprocessing operations. The garbage that is normally loaded for processing, already has acidic residues, which need to be nullified. Limestone also provides good drainage conditions at lower levels in the soil and avoids oxygen limitations. Use of limestone is advisable against lime powder, since the latter tends to create alkaline condition irrespective of its need.

Soil:

About 6" of soil is provided to facilitate the earthworm movement and survival.

Vermiculture:

Nearly 5 kg./sq. meter of vermiculture is added in the form of a layer (Plate 4B). This provides for the earthworm cocoons and a favorable microbial population essential for the organic degradation.

Cow dung Manure:

About 1" layer of cow dung offers adequate proteins and growth factors and is an ideal feed for the young earthworms. Cow dung manure along with 2" layer of cellulose material (leaf layer) triggers aerobic bacteria, hatching of earthworm cocoons and their proper development.

3. **Incubation:**

The vermibed was allowed to rest for duration of one month. Regular watering of the bed was done during this period to allow the earthworms to hatch out from their cocoons. The watering was done to the extent that the beds remained moist. Excess watering should be avoided at any stage, as it restricts the oxygen supply to the system and this, in turn, leads to flies, mosquitoes, rats etc.

4. **Loading:**

After 1 month, a proper feed of organic matter was started on a daily basis (Plate 5). The operation comprises regular feeding of organics in the form of a uniform layer and adequate water. The top layer of this may remain dry and unutilized and gets consumed when covered by next feed layer. The process of biodegradation is a vital activity and needs to be closely watched. Any excess in this process can result in an imbalance in the form of a non-neutral pH, bad odor, pest menace etc. These bioindicators serve as important clues on the condition of the bioprocessing and were routinely monitored throughout the waste processing operation. The loading was continued for 1 full year.

The imbalance caused during the processing operation is tackled either by changing the waste loading schedules or by altering amount of waste loading, along with use of mineral additives in the form of rock dust. Rock dust can be used at regular intervals or when there is an acidity buildup in the system, which is normally caused by either overloading or excess watering. Another advantage of rock dust is, it also provides grinding material, which forms an essential component of the earthworm digestion process.

The first site allotted at Tagore Nagar apparently had no problems of water logging. But the one at Kannamwar Nagar did. Hence, to acquire necessary depth for Vermibed preparation, we built a brick wall structure since the ground conditions were not conducive as a result of water logging (Plate 7).

5. Harvesting:

The harvesting of the product - Vermiculture - can be done either after one year (Plate 9 & 10) or anytime thereafter, when market demands. With passage of time the system matures to yield a better quality of Vermiculture. The harvesting process involves stoppage of water to the site for nearly 10 days before the actual operation is done. This forces the earthworms to go deeper down. The bin material is screened with meshes to remove the coarse part which could be in the process of breaking down. The oversized material is then fed back to the system for further processing and the screened portion (Plate 10) is packed in bags, stored and can be transported wherever required as 'Vermiculture'.

6. Sample Analysis:

The samples of the product were analyzed for various inorganic, organic and microbial constituents to understand the composition of the product (Annexures 1,2 & 3).

OBSERVATIONS

Last 18 months turned out to be far more hectic than envisaged. What was intended to be a technical challenge proved to be an exercise of co-ordination between tens of individuals whose working conditions and styles we were least aware of, let alone, had the authority to control. As a result, several bottlenecks were observed. They have been grouped under following 6 types (A to F).

Against this backdrop, the biggest solace came from the Vermiculture technology, which worked excellently throughout the Project duration, and which, incidentally, was our main responsibility. There was never a single time, during the course of the whole year long processing, when problems of smell or pest were sensed at the site, despite an erratic garbage(In terms of time of delivery as well as segregated nature of the waste!) supply schedule and despite a serious water logging problem at the Project site.

A. MCGM support:

The Project was executed with support of MCGM, after MCGM agreed to provide Project space, water connection and required segregated garbage on a daily basis. Based on the agreement by the MCGM to provide 5 tons/day -considering a TMB carries around 5 tons of waste - of segregated waste for the Project, throughout the Project duration, a daily processing of 5 tons was proposed by us. Budgeting, site preparation and all the Project requirements were planned taking '5-tons-of-waste-processing-per-day' into consideration. However, the MCGM had serious problems adhering to this amount throughout the Project duration . This, in turn, adversely affected the progress at the site and scuttled the planned processing at the site. As can be seen from the table provided below, the waste could be made available to the Project only for 201 days during the whole year.

Table - 3

WASTE DELIVERY TO THE PROJECT AND SAVINGS BY MCGM:

Type of Vehicle (Capacity/ trip)	Delivery in 1Year	Expenditure /trip in Rs.	Savings in Rs.
TMB (8 m^3)	65 days	2,200	1,43,000
Collected by Trolleys (750 kg./ day)	18 days		
T.D.P. (5.2 m^3)	39 days	1,200	46,800
Dumper (10 m^3)	36 days	2,200	79,200
Tempo (3 m^3)	41 days	900	36,900
Truck (10 m^3)	02 days	1,990	3,980
Total days	201 days	--	3,09,880

A major hurdle in the MCGM support appeared to be lack of urgency in responding to Project related requests. In spite of a clear understanding of our problems by the senior officials of the MCGM, a great deal of pursuance was needed in getting every single job completed. This worked against the tight time schedules of the Project.

Following were the specific difficulties that we faced:

1. MCGM's irregularity in waste supply schedule, in terms of time, days and also the amount and inconsistency of level of segregation, put enormous stress on the processing operations, whose schedules had to be constantly altered.
2. The waste supplied by MCGM was never ever weighed before giving to us. This and the erratic nature of supply deprived us from any kind of quantitative estimation

regarding ratios of input to output and their variation with change in type of waste used.

3. The mixed nature of the garbage (Plate 6) frequently supplied by the MCGM, put additional burden - of segregating it - on our Project staff. The unwanted segregated portion from such supply had to be deposited in the adjoining municipal bins. Till almost the end of the Project, despite repeated reminders, the garbage bins near the Project site never got regularly cleared. This led to stinking of the garbage bin beside the site and led to violent protests from the residents. For no fault of ours, our Project staff had to face the wrath of neighboring residents on several occasions and this contributed to the Project losing sympathy with the local public. Culmination of this feeling was seen in some miscreants setting the site on fire, leading to an enormous loss to the live system as well (as to the 'bioprocessing cause') and to the Project (Plate 8).
4. In spite of being responsible for triggering the problems at the site, as mentioned above, MCGM had no help to offer, when it came to defusing the tensions at site or in taking the culprits to task, thereby bringing down the morale of our Project staff.
5. Despite our request, there never was a single officer in MCGM assigned to help solve MCGM related problems regarding various necessities of the Project. As a result, we had to run from pillar to post in MCGM, for every single requirement of the Project adding to unnecessary delays. This problem got further aggravated with frequent transfers of MCGM officials.

B. Social Aspects:

It is most important to realize that solid waste management in India is a socio-technological problem and so, it needs to be tackled on both these levels. A simple technological solution alone, however easy it may be, may not be sufficient to take care of the problem. It is a well-known fact that vermiculture is the most efficient, eco-friendly and easiest way of solving our solid waste management problems (Table 1). But there is a social stigma attached to everything related to waste, which has resulted in a general apathy towards associating oneself with this problem. This has, in fact, made even a solution like 'Vermiprocessing', most difficult to implement in any residential area without the active involvement and cooperation of the local residents. The roots of the public indifference, can be easily traced to the uncleared, over-flowing, pest ridden garbage bins / sites with rotting and stinking garbage at almost every city street corner. A closer look at these sites reveal that the high organic content (> 50%) of Indian municipal waste is responsible for the speedy degradation at these sites and hence, immediate attention to the degradable garbage deserves to be a priority area in our SWM departments.

There appears to be a dire need for a total change in the attitude of people towards what is discarded as 'waste'. Attempts at inculcating the idea of looking at waste as 'a misplaced resource' in the minds of people - especially the civic staff dealing with solid waste management - are conspicuously absent and need special attention.

The usual attitude of 'Out of sight, out of mind!' or 'Not in my backyard' doesn't really help in solid waste management in bigger cities due to shortage of dumping space and hence needs to be discouraged. One has to realize that environment is one single system and should be treated as one. If not attended to now, these problems are bound to get to you some time in a much serious condition. So, incentives to bring down the amount of waste through principles of 'Reduce, Reuse and Recycle' must be offered at society and area level, to attract more and more participation in these endeavors.

The advantages of segregating waste at source are needed to be, not only emphasized, but supported by follow up actions, like processing of biodegradable part and reuse of the recyclables, by the civic authorities. Once people see that their efforts are being put to good use, they will automatically get encouraged in the direction.

At the first site in Tagore Nagar, Vikhroli, (Plate1) there appeared to be a total lack of trust in the minds of people, about the civic authorities. They saw the start of the Vermiculture Project in their area, as another ploy to capture a piece of land, that they were using for various purposes. This lack of trust added to vested interests and ignorance about Vermiculture contributed in development of a resistance towards a 'good cause' which finally led us to move out and change to the Kannmwar Nagar site in Vikhroli, thereby putting us to great inconvenience and hardships.

The site at Kannamwar Nagar was also being used earlier as an unauthorized waste dumping ground. But cordoning of the project site by barbed wire compound and clearing up of the site and the surroundings, supported by the local leaders, helped a great deal in discouraging the nearby residents from dumping their waste inside the cordoned area.

The present campaigns against use of plastics, have little effect, as can be seen from the amount of plastics/synthetics that constitute the waste generated. It is observed that cost and convenience are the main reasons behind the use of excessive plastics. The civic authorities should think of schemes that provide these advantages while doing away with the plastic evil.

C. Site Related:

Both sites allotted for our Project, were already in use unofficially for religious, sports and several other activities by the local residents. This has also been responsible for the resistance of the locals to the processing activities. It is necessary for the municipal authorities to have a full control over such pieces of land, before such projects are undertaken at these locations. This could be achieved by cordoning off the area and stopping all unauthorized use of the land at least 3 months before handing it over to such Projects.

Most of the lands in Mumbai, being closer to coast, are likely to have the effect of tide water on them. Although the Tagore Nagar site looked quite safe from this point of view, the Kanmanwar Nagar site was continuously prone to such effects. This aspect has to be considered while taking up new Projects to avoid water logging of the sites and resultant additional expenditure.

D. Technological :

It was seen that the main expenditure in the MCGM budget for solid waste management is eaten up by transportation and by the manpower involved in it. Other disadvantages of the presently adopted practices are:

1. Addition to vehicular pollution and city traffic congestion
2. Use of valuable spaces for garbage dumping
3. Health hazards to the people staying near dumping sites as well as those who are directly involved in the solid waste management work.
4. No useful outcome, as nothing is generated out of the waste.

Vermiprocessing at source, is the best solution to all these problems. Besides, of all the technological options that are available to us (Table-1) Vermiculture seems to be the most easily implementable, inexpensive and eco-friendly option. Further, conversion to bio-manure instead of to energy, appears to be a viable and wiser approach in the long run.

E. Chemical aspects of the Vermiculture generated:

It is not possible to make any benchmarking study by comparing our product analysis with others, as such data doesn't isn't readily available.

From the analysis, however it is clear that the Vermiculture produced in the Project is rich in various micronutrients, available N (in the form of NO3), P (as PO4) and the beneficial microflora such as Nitrogen fixers, PO4 solubalizers and cellulose degraders. Unlike in chemical fertilizers, these micro-organizms play a vital role in providing nutrients to the plants continuously.

F. Cost - benefit aspects of the Project:

Following aspects are needed to be considered in this analysis:

1. Funds saved on transportation of waste from city to dumping sites:

From the figures supplied by MCGM (Annexure 4) regarding how much payment the MCGM has to make on each of the vehicles used for waste transportation and considering the supply vehicles (Table 3) it is seen that an estimated Rs. 3,09,880/- were saved for the MCGM during the Project duration. Even if it is assumed that some of this may have been spent on the local transportation of waste to the Project site, a substantial amount could be saved on transportation.

2. Cost of the vermiculture generated during the bioprocessing exercise:

   It is extremely difficult to assess the total amount of Vermiculture generated during the course of this Project, due to the loss during the fire incident at the Project site.

   However, a tentative estimate of the of the remaining material (Including 1.5 tons handed over to the MCGM and 1 ton used while restarting the work after the fire incident!) shows that an amount of 30 tons of material is still available in ready-to-harvest condition at the site when taken over by the MCGM.

   A minimum cost of Rs. 15 /- kg. for the generated product could mean the cost of the saved material to be around Rs. 4,50,000/-

3. Cost of vehicular pollution and addition to traffic congestion due to the waste transportation
4. Cost of the land used for mere dumping of the mixed garbage
5. Cost of health hazards to the neighboring residents due to dumping sites and damage to the environment.
6. Value of the long term effects of the use of biofertilizers:
   - Self reliance
   - Saving on petroleum
   - Saving on chemical fertilizers and pesticides
   - Support to the green cover in the city.

Even the consideration of first two points leaves no doubts regarding the financial efficacy and viability of the exercise.

CONCLUSIONS & SUGGESTIONS:

Following conclusions and suggestions were arrived at in view of our observations during the course of this project.

1. The total absence of problem with the technology during the Project has clearly proved the efficacy of Vermiculture Biotechnology in waste processing at ward level. It is hence strongly recommended in starting similar projects in various locations in Mumbai.
2. The social aspects involve getting consent and cooperation from the neighboring residents - which could include obtaining political support - and that of the civic staff, before starting of such projects. It is hence necessary to conduct awareness campaigns and orientation programs for the civic staff and the neighboring public, and educating them on the techniques being used in the processing, their effects and their utility in the overall waste processing scenario, well before the start of any such endeavor. Segregation and if possible, bioprocessing of waste at source, needs to be strictly emphasized during such programs.
3. Waste processing / management has, over the years, become synonymous to dealing with dirt. To change this view, the garbage bins / sites - especially those with biodegradables - along the road side, need to be cleared as soon as they fill up and should be kept spick and span by the SWM departments.
4. Facilities for separate collection and accumulation of recyclable and biodegradable parts of the garbage must be made available by the civic authorities.
5. Waste segregation and processing at source, is the best policy to counter the disadvantages in the current solid waste management practices. Models and showcases for homes and housing societies need to be developed and maintained by the municipal authorities. A proper publicity should be given to such examples in the media. Funds that could have anyway been spent on the transportation and dumping of the waste, can be used for this.
6. Web sites explaining the existing municipal strategy of dealing with the solid waste problem should be developed. The sites should also be able to provide answers to the FAQs relating to every aspect of the SWM program, including individual level participation through bioprocessing, recycling and restrained use.

7. To counter the plastic menace, subsidized cloth and paper bags in place of plastic bags should be made available either with private sponsorships or with government help.
8. Sites for waste processing should be fully protected from any kind of unauthorized use by the civic authorities, to avoid the kind of problems we faced. It is suggested that the areas around sewage pumping stations, those on both sides of the water pipeline and under high tension electric wires may be considered for such use.
9. Provision of space and plans, for processing daily generated waste, must be made mandatory before permitting new settlements and buildings
10. To encourage people's participation, incentives in the form of awards / trophies should be instituted by the civic authorities for the attempts in waste processing and minimum waste generation.
11. The MCGM has decided to continue the effort initiated by us from May, 2000. We sincerely hope that our experience, as explained above, will be of immense value to the MCGM as well as, to the organizations to be involved in such exercises, in removing the bottlenecks in successful implementation of similar exercises in future.

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ACKNOWLEDGEMENTS

The Vermculture Project turned out to be an elaborate exercise in co-ordination, besides being a technological challenge to process such an amount of municipal waste in a thickly populated area. Although the technology never let us down, there were quite a few trying moments during the course of this Project that could have unnerved any individual. Since most of these were totally unconnected with the technical aspects, we had to turn to a great number of individuals for support irrespective of their belief, education, political affiliations etc. This has given me an excellent opportunity to see the points of view of a wide cross section of our society and has left me enriched in an experience that one couldn't have ever imagined to have in such a short time span. It is with great satisfaction and gratitude that I wish to dedicate the success of this effort to all these people - big or small - who have contributed in some way or the other towards realization of the objectives of this endeavor.

Fuelled by the goodwill of results of my earlier work, I tried my best to get support for the 'bioprocessing cause' and for the Project from numerous individuals, at every possible opportunity and from every rung of the society and I was glad, I could gather it from almost every level of the society. Naturally, there certainly are several names whose support has made a sea of difference to the outcome of this Project and whose contributions need to be acknowledged.

I must first of all thank the MMR-EIS to have supported this Project and for giving me the opportunity to try out something which I always dreamt of. For this, I must record my gratitude towards the Metropolitan Commissioners Shri. Ramakant Jha and Shri. Ajit Warti for their constant encouragement. Shri. Pendharkar (Chief Planner, MMRDA),Shri. Tondwalkar and Shri. Pantbalekundri (Secretaries of MMR-EIS) deserve all the praise for their constant interest, suggestions and support.

In the MCGM, I have a great appreciation of the encouragement had from Shri. Ratnakar Gaikwad and Shri. A. K.Jain ,AMCs of the MCGM, besides of course, the ever willing and helpful Shri. Chitravanshi, CE, SWM. I must also thank Shri. Shah and Shri. Mirani, the 'S' Ward Officers, for extending their helping hand,

whenever necessary. At the ward level, further, I had a great support from Mr. Padwal, who always came out with a solution and support, whenever I had some difficulty and felt low down. I was very much benefited from his understanding of the BMC style of working.

At the local level, I have to sincerely thank Shri.Datta Dalvi and Shri. Chandan Sharma, 'S' Ward Corporators, who came to help me, out of their way, whenever need arose. I must add, there were quite a few occasions that demanded their support.

On the technical front, Dr. and Smt. Bhawalkar, BERI, Pune, have been a constant source of guidance and encouragement. I am very much indebted to them for helping us during all the stages of the Project and accommodating all the demands of the Project, leading to a lot of financial inconvenience to them.

It may be difficult to mention and even remember each and every one, who helped us out at various junctures. I thank all those whom I met in connection with solving hundreds of problems regarding the Project and who extended whatever possible help they could offer, to continue the efforts.

I cannot forget the co-operation and the understanding shown by all my Project staff (Plate 11) who had to brave the fury of not only the monsoon rains (- without rain gear!), but of the local residents too, for no fault of theirs. I must thank them for their exemplary courage and commitment.

Lastly, I had the unflinching support from my family, especially my son, for whom it was a decisive year of his career. Very many times, the tensions from the Project site tended to affect the home climate and I sincerely believed it was getting beyond my limits of tolerance! During all these difficult times, my family members, including my husband Arun, my daughter Shruti and my son Ashwin, stood firmly beside me and helped me get back to my feet and continue. But for their assistance, the Project wouldn't have reached the stage it has done today.

Mrs A. Inamdar

IIT Bombay, Mumbai
Date: May 10,2000

(Mrs. A. A. Inamdar)

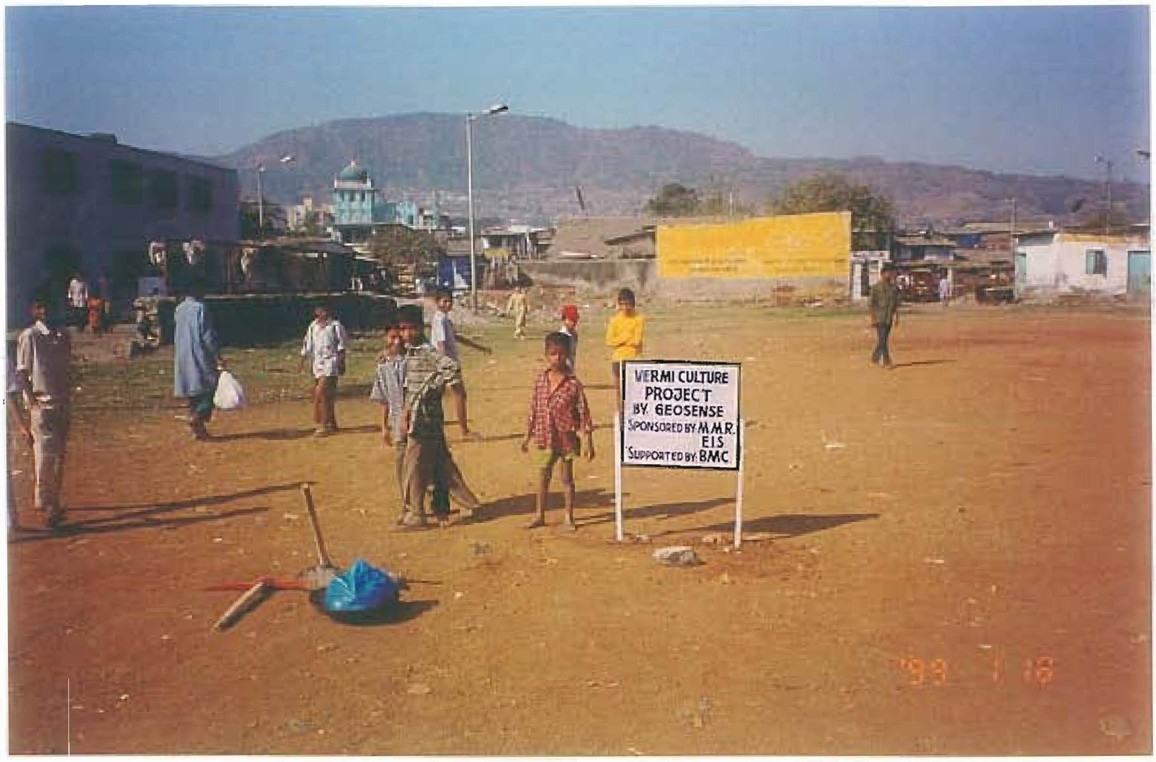

Plate 1 : First site allotted at Tagore Nagar, Vikhroli: The site needed no development and was kept in view for Project budgeting.

Plate 2: Inauguration of the first site at Tagore Nagar by prominent citizens of the area and the 'S' Ward officer, MCGM

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Plate 4(A): Vermibed Preparation

Plate 4(B) : Vermibed Preparation

Plate 5: 'Constructed' bin-with brick walls to acquire necessary depth - in operation.

Plate 6: Typical supply of mixed waste received - One of the root causes of problems at the Project site

Plate 7: Extension of the Project capacity after completion of the site development by MCGM

Plate 8: Fire at site - Just lack of awareness!- or something more?

Plate 9:

Site ready for harvesting!

Plate 10:

The final product
-'Vermiculture'

Plate 11:

Team of committed Project workers who faced it all

VERMIBED PREPARATION

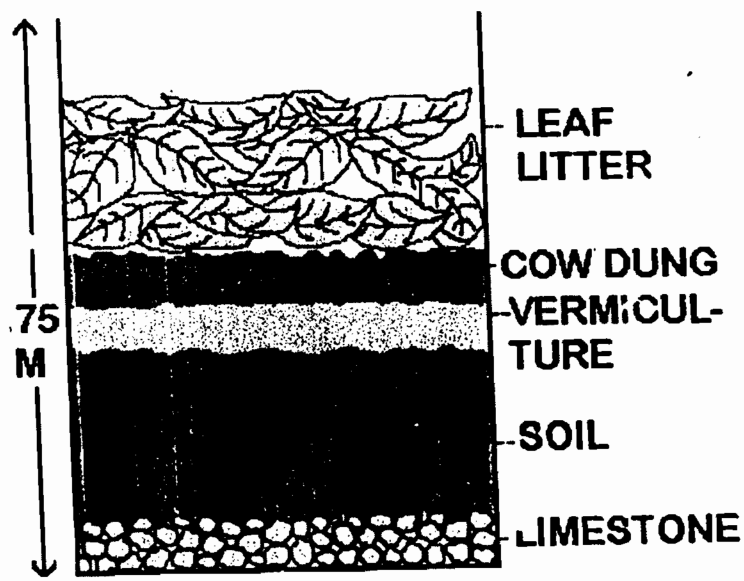

Figure 1: Vermibed design

Estimated features of different solid waste technologies:

Sr No	Item	Composting	Biogas digester	Landfill biogas	Vermiculture	Organic manure	Fuel Pellet & RDF	Incineration	BMF
1	Organism	Random fungi, insects hermophylic bacteria	Anerobic pathway organisms	Anerobic pathway organisms	Earthworm regulated aerobic soil bacteria	Soil bacteria	—	—	—
2	Temp. °C	60-70	25-35	25-35	25-35	25-35	100-120	800	Ambient
3	optimum pH	5.0	7.0	7.0	7.0	7.0	—	—	Ambient
4	optimum C/N	30	100	100	very wide	very wide	wide		wide
5	Raw material	Organic waste	Animal dung	Organic waste	Organic waste	Organic waste	Market waste	urgical aste	Agricultural
6	Additive kg/kg DM waste	Urea 0.05	May be required	May be required	0.1-0.2	0.2-0.3	Small	Small	—
7	Product	Compost (bioash)	Methane, CO_2	Methane, CO_2	Biofertiliser Bioinocculant	Manure	Fuel Pellet	—	Fuel Pellets
8	Product yield (kg/kg DM waste)	0.2-0.3	0.3-0.5	0.3-0.5	1.0	1.0-1.3	0.8-0.9	—	1.0
9	Product uses	Soil amendment	Fuel	Fuel	Culture of earthworm	Soil nutrient $_2$ fixers of nutrient	Boiler fuel	—	Fuel domestic
10	Bioenergy recovery %	10-15	20-25 as gas	15-20 as gas	70-90	70-95	0.3	No recovery	90-95
11	Byproduct/ Residues %/w DM waste	5% Acidic leachates. Needs treatment	30% waste water	30% Acidic residues	No residues	No residues	—	—	—
12	Rate (kgDM/m2d)	0.5	0.2-0.5	0.1-0.2	0.8	1.6	3-4	10-15	10-20
13	Space reqd. 100 kg/d plant	160 m^2	400 m^2	400 m^2	300 m^2	150 m^2	—	20	15 m^2
14	Space reqd. 100 ton/d Market waste	8.0 ha	10.0 0.5 MW	20.0 ha 0.5 Mw	4.0 ha	2.0 ha	1.5 ha	—	—
15	Product cost including interest on fixed assets	Rs. 2800/ton	as Rs.7/kg PowerRs7/kwh	as Rs.7/kg PowerRs.7/KWh	Rs. 5000/ton	Rs. 500-2500/ton	Rs. 5000/ton	—	Rs. 800/ton
16	Investment	high	high	high	low	low	high	high	NIL
17	Power consumption	high	moderate	moderate	very low	very low	high	very high	NIL
18	Scale of Process	centralised	decentralised	centralised	decentralised	decentralised	centralised	decentralised	Decentralised
19	Employment generated	low	low	low	high	high	low	low	high
20	Implementation time (months)	12	24	24	6	3	24	6-8	1-3

Table 1: Types of Waste Processing options : Reprinted from Organic Waste Processing : Workshop on Solid Waste Management and Utilization, Nov. 7-8,1997, IIT Bombay, Mumbai

Table 2: Comparison between surface and deep burrowing types of Vermiprocessing

VERMICOMPOSTING:	VERMICULTURE:
Involves processing of organics using **redworms/ surface worms** (e.g.Mahim Park processing)	Involves processing of organics using **deep burrowing earthworms** (e.g. Vikhroli processing)
Work under **acidic & high moisture** (80-90%) conditions	Work under **neutral pH & in low moisture** (50% moisture)
The processing is essentially anarobic and hence **may smell**	Processing aerobic,so **doesn't give out any odour**.
Redworms **feed on organics & soft proteins like cowdung**	Earthworms don't feed on organics.They are soil processing worms & hence **consume rock particles& organics**. They feed on microorganisms
The **product** in this process is residual excreta of redworms called as vermicompost & hence can be used as **low quality organic manure only.**	The **product** here **is a rich Vermiculture** containing earthworm cocoons, beneficial micro-organics and is quite stable with **several applictions viz. agriculture, large scale waste processing, general greening- lawns and gardening.**
Redworms have a very short life and due to their very specific demand of living conditions, **need to be continuously monitored making the process labour intensive**.	Earthworms have a longer life cycle & can tolerate harsh field conditions. They instead regulate the soil environment. Hence are **not labour intensive**.
Processing huge amounts of organics is difficult. Hence are **inadequate in tackling the garbage processing problems in a city like Mumbai**.	Processing of huge amounts of organics is easier with earthworms. Hence are **most suited to handle the garbage processing problems anywhere.**
Being surface worms tend to come out very often and hence **not preferred in individual households ,ornamental gardening and lawn making**	The earthworms are never seen on the ground surface. This makes them **widely acceptable** in all applications.
Cocoons **cannot be stored for more than 15 days**.	The culture containing cocoons **can be stored. upto 5 years** without much problem.
The **product** can at best be sold for **Rs. 5-10/- per kg**.	The **product** can fetch upto **Rs.25/- per kg**.

MICROBIOLOGICAL CONSULTANTS

Wassiamul Building, D-Block, 1st Floor, M. Shaukatali Road, Grant Road, Mumbai - 400 007.

Dr. S. A. DHALA
Ph. D., D. Sc.
Tel. (Res.) : 640 6642

Dr. A. J. DESAI
M. Sc., Ph. D.
Tel. (Res.) : 620 3176

2000 / 2502

24.04.2000

Indian Institute of Technology
Powai,
Mumbai - 400 076.

Kind Attn : Dr Inamdar

Report on : One sample of soil sent for microbiological tests on 11.04.2000.

Methodology

Standard methods and media were used for the test.

Results

		Count/gm
Total Viable Bacterial Count	:	1.1×10^7
Total Yeasts	:	650
Total Molds	:	4×10^5
Actinomycetes	:	4000
Azotobacter spp.	:	210
Phosphate solubilizers -Bacteria	:	2.4×10^3
Phosphate solubilizers -Fungi	:	3.5×10^4
Cellulose degraders	:	2.79×10^4

For Microbiological Consultants

(Dr A J Desai)

ANNEXURE 1: Vermiculture Analysis by MICROBIOLOGICAL CONSULTANTS

Phones :
Lab. : 511 4243
: 515 1983
Resi.: 414 2085

Fax :
4143719

CERA LAB. PVT. LTD.

Chemical Environmental Research and Analytical Laboratory

Valibhai Haidarali Compound, 2,Musa Estate, D. A. Kale Road,
Bail Bazar, Kurla (West), Mumbai - 400070.

CERTIFICATE OF ANALYSIS Rep No CERA/03973

DETAILS OF SAMPLES

Name & Address of Party	:	MRS APARNA INAMDAR, Vermiculture Consultant I. I. T. Market, Powai, Mumbai - 400076.
Nature of Sample	:	SOIL CONDITIONER
Letter Ref. & Date	:	04/05/2000
Job No. & Date	:	05/05/00204
Packing	:	PLASTIC BAG.
Quantity	:	ABOUT 150 GMS.

Sample submitted by party and not drawn by us

RESULT OF ANALYSIS :-

		PERCENT
NITROGEN AS NITRATE (NO_3)	:	1.59
PHOSPHOROUS AS PHOSPHATE (PO_4)	:	0.36
INORGANIC CARBON (as C)	:	0.26
≡ CARBONATES (as CO_2)	:	0.96
ORGANIC CARBON (as C)	:	1.65

Analysed by

[signature]

Date : 9/5/2000

For **CERA LAB. PVT. LTD.**

[signature]

Authorised Signatory

ANNEXURE 2: Vermiculture Analysis by CERRA LABS PVT.LTD.

Italab Private Ltd. NO. P-1B/ 2259

Industrial Testing & Analytical Laboratories

CARGO SUPERVISORS & WEIGHERS
REGISTERED OFFICE
MEHER HOUSE, 15, CAWASJI PATEL STREET, MUMBAI - 400001.

Sample Submitted by Party Not Drawn By ITALABS

CERTIFICATE OF ANALYSIS

1. PARTICULARS OF SAMPLE SUBMITTED :

a. Name of Party M/s. Aparna A Inamdar, Mumbai-76

b. Nature of Sample Soil

Ref. No. Lt.dt. 10.4.2000

Quantity about 500gms

Date of Receipt 11.4.2000 ~~ii~~ P4 MN 18839

Packing Plastic bag

2. RESULTS OF ANALYSIS :

Moisture at 105°C .. 20.98 Percent

Chemical Analysis on dry basis

pH of 10% suspension .. 6.30

				Percent	Standard Limit
Nitrogen	..	as N	..	0.39	0.02 to 0.5%
Potassium	..	as K	..	0.042	0.2 to 4.0%
Phosphorus	..	as P	..	0.12	0.02 to 0.4%
Sodium	..	as Na	..	0.24	
Sulphate	..	as SO_3	..	0.21	0.02 to 0.5%
Carbondioxide	..	as CO_2	..	1.82	
Silica	..	as SiO_2	..	18.64	
Calcium Oxide	..	as CaO	..	9.24	0.1 to 5.0%
Magnesium Oxide	..	as MgO	..	0.26	0.2 to 2.5%
Organic matter	..		..	4.51	0.4 to 10.0%
Micro Nutrients					
Iron	..	as Fe	..	27.25	0.5 to 5.0%
Manganese	..	as Mn	..	NIL	200 to 1000 PPM
Zinc	..	as Zn	..	0.0048	0.001 to 0.025%
Boron	..	as B	..	NIL	5 to 150 PPM
Copper	..	as Cu	..	112 PPM	5 to 150 PPM
Molybdenum	..	as Mo	..	NIL	0.2 to 5 PPM
Chloride	..	as Cl	..	0.054	0.001 to 0.1%

Tests carried out by :

Countersigned :

Date 2.5.2000

Director

ANNEXURE 3: Vermiculture Analysis by ITALABS PVT. LTD.

बृहन्मुंबई महानगरपालिका
BRIHANMUMBAI MAHANAGARPALIKA

Dr Inamdar Fax 572-3190

In corporation, there are Eight type of Vehicle being used for garbage removal work in Mumbai

1 Contractor Vehicle Rate of Vehicle Rs 590 + 1200 labour + 200 Mukadam

Rs. 590 + 1200 + 200 = 1990 for 10 m^3 garbage removal.

Average 1 m^3 cost Rs 199/-

The above cost may changed as per distance of unloading centre from various area

2 Small Tempo 3 m^3 capacity making three trip

Rate of vehicle Rs 700 + 200 = 900 for 9 m^3

Rs 100=00 per 1 m^3 (Cause changed ward wise)

3 BMC open Dumper (10 m^3 capacity)

Rate of Vehicle Rs 800 + 6 labour + 1 mukadam

= 800 + 1200 + 200 = 2200

Rs 220/- per 1 m^3

4 Jeep capacity 3 m^3

Rs 400 Rate

Rate Labourer
Rs 400 + 400 → 800

Rs 266=00 per 1 m^3

5 T.M.B Vehicle (8 m^3 capacity) BMC Closebody Vehicle.

Rate of Vehicle + Labour + Mukadam.
1800 + 1200 + 200 → 2200

Rs 275=00 per ~~vehicle~~ 1 m^3

6 Compactor Mobile (15 m^3 capacity) Average

Rate of Vehicle Labour Mukadam
1000 + 1200 + 200 → 2400

Rs. 160=00 per 1 m^3

ANNEXURE 4: Information by MCGM on capacity of various waste carriers employed and expenditure incurred.

(Tata dumper placer Vehicle)

7, T.D.P Vehicle for removal of 5.2 m^3 container (Capacity)
Average trip of each vehicle five trips.
ie $5.2 \times 5 = 25\ m^3$ removal of waste by one vehicle.

Rate of Vehicle Mukadam
1000 + 200 → 1200

Rs 48=00 per 1 m

8) T.D.P Vehicle for removal of 2.5 m^3 capacity container
Vehicle carries five trips an average
ie $2.5 \times 5 = 12.5\ m^3$ capacity garbage removal

Rate of Vehicle Mukadam
1000 + 200 → 1200

Rs 98=00 per 1 m^3 waste

Special Arrangement incase of critical period or strike to removal of backlog of garbage

(1) Pvt one J.C.B Vehicle & 3 Dumper Vehicle
Each Dumper has to make three trips
Each Dumper will make 9 trips
ie. 3 Dumper
Capacity of each dumper 6 m^3
$6\ m^3 \times 9$ trips $= 54\ m^3$ garbage will remove

JCB charge per shift Rs 3950=00
Each Dumper Rs 1250 × 3 = Rs 3750=00
} for removal 54 m^3 garbage
7700

Average Rs 142=00 per 1 m^3 waste

(2) Relay System Where heavily generation of garbage
Rate 590 + 400 labour → 990
Rs 99=00 per 1 m^3

Information given as per CHE(SWM)'s order

Dy HSE(I) DS