PART D

RESOURCE RECOVERY AND DISPOSAL IN BOMBAY

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D-1 INTRODUCTION

This part of the report is concerned with what should be done with the solid waste - its final destination. There is a growing concern around the world that solid waste should not simply be disposed of, but that, as much as possible, materials in the waste should be reused, to reduce the requirement of land for disposal - and the environmental pollution associated with such disposal - , and so that the economic value of the waste, in terms of natural resources, foreign exchange and employment creation, can be fully exploited.

The first section is concerned with present landfill disposal operations; suggestions are made as to how these operations could be improved. Then the informal resource recovery practices are discussed. The final section deals with ways of processing the waste to make useful products.

D-2 LANDFILL

D-2.1 THE CURRENT SITUATION

(i) Basic information

The Municipal Corporation of Greater Bombay operates the following four disposal sites:

- Deonar and Shiwajinagar
- Mulund
- Chincholi at Malad
- Gorai at Borivali

The site at **Deonar and Shiwajinagar** (two adjoining areas which are effectively one site) is used to dispose of more than 80% of the solid waste of the city of Bombay. Important facts about this site are:

- This landfill site has been in operation for more than 20 years;
- The land is low-lying, being adjacent to a tidal creek, and it is being reclaimed for future use;
- The total area of the disposal site is 500 acres;
- Solid wastes from wards A,B,C,D,E,F,G,H (E), L, M & N are disposed of here;
- Refuse is brought between seven and forty kilometres to this site;
- There are 82 Municipal employees working here;
- Slaughter house waste is also disposed of at this site;
- There is no weigh bridge;
- At the time of the study (1992) there were all-weather roads to the dumping sites, and a road to connect Deonar and Shiwajinagar sites was under construction;

(ii) Operational information

- Vehicles arriving at the site are recorded at the gate. The gatehouse is elevated so that the Junior Overseer can check the loads in the vehicles to see whether the open trucks are fully loaded. The vehicles then proceed to the site for unloading. The time of arrival of each vehicle is noted, but not the time of departure.
- Six hundred to seven hundred truckloads of solid waste are received at the site each day;
- 400 to 450 truckloads of debris are received at the site each day;
- 45 to 50 truck loads of industrial waste are received at this site each month;
- Generally the contractors' vehicles operate during the day time and they unload the refuse at the Deonar site.
- Municipal vehicles usually unload at the Shiwajinagar site;

- Private vehicles are unloaded at site manually; it takes 20 to 30 minutes for unloading. The place of unloading of the private vehicles is decided by the Municipal staff. At the peak hours (i.e. between 1100 hrs to 1300 hrs) there are about 80 vehicles standing at a time on the landfill site, occupying a strip of land at least 300 metres long. This makes it very difficult to confine the active part of the site to a small area, which is one of the objectives in sanitary landfill operation.
- Municipal vehicles are mechanically unloaded; much less time is needed for this operation so there are never many municipal vehicles on the site at any one time.
- During the monsoon the refuse is unloaded along the road side in a specially designated dumping ground because the trucks would get bogged down if they tried to drive over the waste to the usual area.
- The unloaded refuse is levelled by bulldozers. There are four bulldozers attached to the Deonar site and one attached to the Shiwajinagar site. One operator and one cleaner are allocated to each bulldozer.
- Two Poclain crawler mounted excavators are working on the site. They are used for excavating refuse - waste that was dumped by the road during the monsoon, and decomposed waste that is to be taken off site. Also they help extinguishing fires by digging out burning material.
- There were fires at various places on the landfill site. It was learnt that the rag pickers set fire to the refuse to enable them to separate tin cans from the other material. They pick up steel items with powerful magnets attached to a wooden handle. These fires cause considerable air pollution which can be seen from some distance (including the flight path of the International Airport) and which has been the subject of letters of complaint from the Environmental Protection Agency.
- For extinguishing the fires, a water tanker of 8000 litres capacity has been provided at the site.
- A break-down truck (fitted with a crane that can lift vehicles) has been provided at the landfill site for attending to breakdowns and for pulling vehicles that are unable to move themselves because their wheels are slipping on the waste.
- There is a workshop near the landfill site for the maintenance of the earth moving machinery.
- A fine of Rs 100 is charged for dumping the refuse at an unspecified place.
- Decomposed solid waste is sold to private parties at a cost of Rs 100/ per truck load. The work of excavation of the digested material is done by the Corporation.
- The slaughterhouse waste and the offal are unloaded at a separate designated location within the site. There was no evidence that this material was covered. Some dogs and birds were scavenging in this area. The paunch manure was taken away for use as soil conditioner after it had decomposed and dried for some time. It was sold for Rs 250 per truck load.
- Part of the landfill site can be illuminated, but there are no lighting arrangements at the site of actual dumping. It is learnt that during the hours of darkness about 100 vehicles are received at the landfill site. It is quite troublesome to operate at and supervise the landfill site at night without proper lighting arrangements.

(iii) Further information and observations

- The official in charge of the operation of the landfill site is an Assistant Head Supervisor. He has not been trained in the operations of a sanitary landfill site and is mainly concerned with record-keeping. As a result, avoidable technical problems cannot be tackled properly.
- It was learned that no studies regarding the leachate had been carried out, nor had any analyses of the decomposed waste been performed. Leachate was observed at the landfill site. It may pose a threat to water resources and fisheries.
- As the refuse vehicles unload, rag pickers search through the piles of freshly dumped waste. There are 200 to 300 rag pickers operating at a time at the landfill site. They are mainly women, and children in the age group of 8 to 15. When the refuse is being

unloaded or levelled, the rag pickers rush towards the vehicles without seeming to pay any attention to the moving machines. This could result in a fatal accident, and the bulldozer drivers may operate their machines more cautiously and slowly as a result of this risk.

- The rag pickers set fire to the refuse with the aim of collecting tin cans and scrap more easily. This is quite hazardous from the point of view of the environment at the site. Also there is the possibility of an accident. Landfill fires sometimes continue for weeks or months on account of the presence of methane in the wastes underneath. Magnets have been confiscated from the rag pickers in an attempt to stop them from setting fire to the waste, but this has not been successful.
- All the rag pickers operate at the site without gloves or protective clothing. This represents a serious health hazard.
- No cover was being laid over the refuse after it had been levelled. It has been observed that there are soft patches and depressions on the landfill site which cause difficulties for the movement of vehicles.
- At the dumping ground about 50 truck loads of industrial wastes are received monthly. However, there is no specified secured site for taking care of these wastes. Such wastes may pose risks to personnel and scavengers on the site, and be a source of water pollution.
- There were large numbers of flies at the site, especially near freshly-dumped refuse. If flies are successfully breeding at the site, then they obviously pose a serious health hazard.
- There is a lot of airborne dust at the site especially where the vehicles unload. When the vehicles move the intensity of dust increases. This is a pollution problem and also a direct health hazard for the persons working on the landfill site.
- There are foul smells at the landfill site, especially where the slaughter house waste and offal are unloaded. This is a form of environmental pollution.
- The sanitary blocks provided at the entrance of the landfill site are not properly maintained. Also there is not a sufficient provision of water for the workers working in the landfill site.

D-2.2 COMMENT AND SUGGESTIONS

COMMENT: From the size of the site, and the number of vehicles unloading there each day, it is clear that the Deonar/Shiwajinagar site is very important. It receives almost all types of solid waste. The landfill site staff maintain quite good records regarding the registration of incoming vehicles, their loads, time of entry etc. However, with slight modifications to the present use of manpower and machinery on the site there is considerable scope for improving the site conditions and the landfill itself.

SUGGESTIONS: Human resources The success or failure of a sanitary landfill operation depends more on the people involved than on any other single factor. The subjects of training, motivation and authority need to be carefully considered.

- In Part A it was suggested that engineers involved in solid waste management should be specialists in the subject, not those transferred from other municipal duties for a short time. It is consistent with this approach to propose that an engineer who has been well trained in sanitary landfill operations should be in charge of the Deonar and Shiwajinagar site, or perhaps all of the Bombay sites. Sanitary landfilling techniques that are used in USA or western Europe may need modification before they are fully appropriate to denser waste, such as that found in Bombay. It follows that the engineer in charge of disposal must have a pioneering attitude, and be interested in undertaking field research in order to develop suitable methods of operation. An engineer with little interest or experience in the subject, and who is hoping for an early transfer away from solid waste

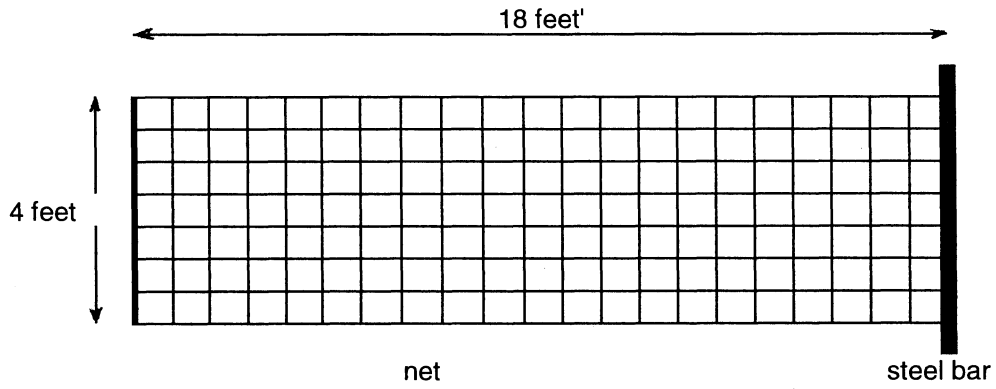
management, would not be satisfactory for this job. It may be appropriate, in the early stages, for this engineer to be assisted by a consultant when developing new methods.

- With regard to motivation of the disposal engineer, thought must be given to building up the status of the job. This might be done by choosing an acceptable title for the post, investing considerable authority in the post, providing opportunities for international travel for training purposes, and providing facilities to encourage the engineer to be closely involved with operations on site rather than staying in his office. (Such facilities might be the provision of an air-conditioned off-road vehicle. Air-conditioned vehicles are normally provided only to much more senior personnel, but are appropriate in this case because of the dusty nature of the disposal sites. Alternatively, a portable, air-conditioned office, that would enable comfortable supervision of operations, could be provided.) It would be helpful if the contract for this position included the requirement that certain goals be achieved within a specified time frame.
- In the short term, the Assistant Head Supervisor in charge of the site should be given training and support to enable him to start to make some of the improvements necessary.

SUGGESTIONS **Vehicle unloading** The long time spent unloading the open vehicles causes a number of problems: the vehicles occupy a large area and the unloading process is very unsanitary and poses health risks to the labourers The following steps could be taken to improve the situation:

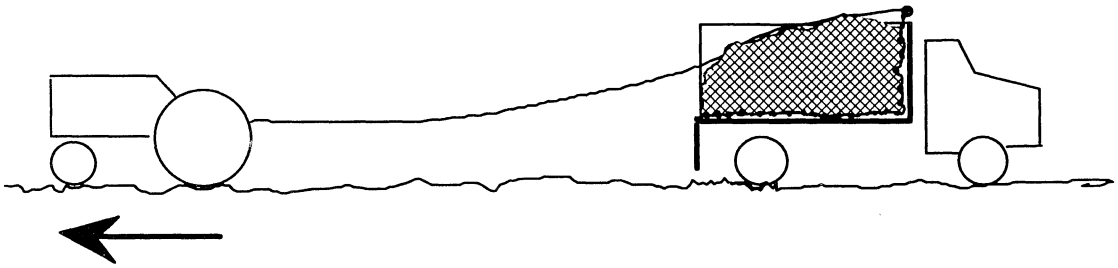
- Data should be collected on the current situation so that costs of proposed systems can be compared with any proposed variation. This will include recording the time that each truck spends on the site (i.e. recording the time of departure as well as the time of arrival).
- An obvious solution would be to use only tipping vehicles or bodies that unload hydraulically. This has been discussed in Part A, where the introduction of a longer contract period was suggested to encourage contractors to employ more suitable vehicles.
- Investigations should be carried out to find methods of unloading open trucks more quickly. Two possible methods are suggested below. The suggestions listed here are not methods that are known to have been used elsewhere, so it is necessary to undertake preliminary trials to determine whether such methods might be feasible:
  a) Before loading the vehicle a rope net such as shown in figures D-2.1 and D-2.2 is placed on the vehicle floor. To unload the vehicle, the ends of the bar could be tied to a rope so that the whole load of refuse can be pulled out of the back of the vehicle. This could be done in only a few minutes.

Figure D-2.1 Net to aid unloading open trucks



Trials would be necessary to determine whether the net should be only on the floor, or whether it should also be laid up the front of the body before the refuse is loaded, what modifications are required to the truck body (such as a taper), and how much force is needed to move the waste.

Figure D-2.2 Pulling net to unload truck



b) An excavator with a back-acting bucket might be used to empty open trucks. There would be the risk of damage to the truck bodies, so they might require strengthening. The cost of providing and running the excavators might be more than the savings accruing from faster unloading.

SUGGESTIONS Rag pickers

- Rag pickers could be given access to the waste immediately after it is unloaded. The bulldozers could come to level that waste after an agreed interval. This arrangement should avoid accidents.
- Efforts should be continued to try to prevent rag pickers from starting fires. This task calls for minimum force but strong determination. In this process, the police, as well as the leaders in the area, can play an important role.
- All plant operating on the site should be fitted with audible reversing warning signals to alert the rag pickers nearby.
- The suggestion has been made that the rag pickers should each be given a pair of hand gloves. Whilst this is necessary in terms of accident prevention it would be difficult for the MCGB to approve such an expenditure for people who are trespassers rather than employees, and it is likely that the scavengers would sell their gloves, and that the offer of free gloves would attract more people to the site. The same argument would apply to the provision of gum boots.
- The staff working at the site should take pains to educate the rag pickers with regard to fires and protecting themselves from health risks and accidents.
- An alternative approach is to formalise the rag pickers by awarding contracts for the salvage of material from the site. Such an arrangement would allow more control of the activities since the contractors themselves would take some responsibility for policing the work; only workers wearing the contractor's uniform would be allowed on the site and near the fresh waste. Offences such as starting fires would be grounds for the cancelling of the contract.

SUGGESTIONS

- It has been observed that the water table at the landfill site is quite high. It is suggested that the leachate could be utilised to control the dust. The leachate could be pumped from an excavated hole into a tanker trailer that would be pulled by the tractor (which is already available). This would also help to solve the problem of leachate to some extent. This recycled leachate could also be used for fire fighting.

- The landfill site receives about 400 to 450 truck loads of debris every day. This debris could be conveniently utilised every day for covering the levelled refuse. This would reduce the numbers of flies and minimise the smell nuisance. The slaughterhouse waste could be unloaded into ditches or pits and be covered with debris. This would keep the place more clean and acceptable. It might also be possible to use some of this debris to

improve the surface of the site, by filling in depressions and potholes and improving the traction of trucks in wet or slippery patches.

- It is suggested that a dog catcher should visit the site every day. The dogs should be caught and sent away in a dog van. This would reduce the problem of the stray dogs to some extent.

- Lighting arrangements - such as portable floodlighting sets with their own generators - should be provided at the actual unloading area. This would make the landfill site more convenient for operation during night time.

- A separate site should be specified only for dumping certain types of industrial waste. This site should be at one corner of the landfill site where the risk of pollution is least. It may be necessary to line the site with puddled clay or plastic sheet. Only some industrial wastes are hazardous and require special treatment - liaison with the industries concerned would be necessary, and the junior overseers at the gatehouse would need special training to recognise hazardous waste loads. If charges for the disposal of this waste were too high, industrial waste might be deposited illegally elsewhere.

D-3 RECYCLING

The term *recycling* is used in a number of ways; here it is used to mean the process by which waste materials are transformed into new products in such a manner that the original products lose their identities. Reuse of returnable glass bottles and retreading of tyres are not included in this definition.

This section is concerned with the recycling of materials from domestic, institutional and commercial solid waste, such as: paper, cardboard, plastics, glass (broken and whole bottles), metals. (iron, aluminium), rags, gunny bags, tyres, bones and broken asbestos shells. Section D-4 describes other resource recovery techniques - vermiculture and composting to produce soil conditioner, and pelletisation to produce fuel.

Much of the information here has been gathered by interviewing rag pickers and hawkers - women, men, boys and girls of different age groups. They were interviewed at the Deonar landfill site as well as in the city (at Dharavi, Kurla, and Sion). Appendix DD-2 shows the prices paid for various materials at different stages.

This section first discusses the ways in which recyclable materials are separated and sold through a network of dealers, and then describes how particular materials are processed.

D-3.1 METHODS OF COLLECTION OF RECYCLABLE MATERIALS

(i) From households

Recyclable items like newspaper, glass bottles, broken glass, cardboard, rags, gunny bags, etc. are segregated by the residents and sold to the hawkers, who go from door to door. The amounts paid are different for different items. The hawker sells these items on to the middleman.

(ii) From storage facilities and streets

Rag pickers pick up recyclable items from the bins, dumps and roads and sell them to middlemen. When they are looking for items from the road side, dust bins or dumping areas, the pickers spread the refuse so that they can sort through it more thoroughly. . As has been discussed in Part B, they often take the waste out of the containers and leave it on the surrounding ground. This creates a visual nuisance, may encourage fly breeding, and adds to the work that must be done by the motor loaders - the productivity of the collection vehicles is reduced because of the time they spend waiting at the collection sites while the scattered waste is being gathered up.

(iii) By municipal employees

The segregation of recyclable items by motor loaders was not observed during this study, but it has been pointed out by some sources that this practice is going on. Occasionally motor loaders in open trucks were seen to throw down some partly-filled sacks when they arrived at a disposal site, but the purpose of this action was not determined. When the loading of trucks was being observed, the rate of working was so fast that there was little opportunity for the separation of recyclable material.

(iv) From disposal sites

Rag pickers pick up recyclable items from dumping grounds where municipal solid waste is dumped by Corporation or private vehicles. The people doing this work are mostly women, but there are also girls and boys, (some of whom are as young as nine years old). Some of the pickers, especially the children, work part-time at the landfill sites.

In most cases one picker collects only one type of material. They do not wear gloves or shoes while picking at landfill sites. They bring drinking water in plastic containers.

At one landfill site it was observed that there was a rush towards each refuse truck when it arrived for unloading. The pickers were inviting injury to themselves by running in front of bulldozers.

Generally the pickers sell their materials collected by them on the same day. Sometimes they keep the items on the road-side or foot path, or near their shelter. They do not in general have any storage facilities.

(v) Direct to middleman

Good quality cardboard and items made of cardboard - i.e. packing cases of refrigerators, television sets, radios, and washing machines, and other boxes and cartons - may be sold by shops and institutions directly to the middlemen.

(v) Organisation of hawkers and pickers

There is no association, union, or organisation of hawkers or pickers; they work independently and individually. Hawkers and pickers do not appear to be interested in forming or joining any organisation because they fear the implementation of rules and regulations which they think would hamper their work.

D-3.2 PROCESSING OF RECYCLED MATERIALS

(i) Plastics

Plastics items are sold by pickers and hawkers to the middlemen, and the middlemen sell them to the owners of small-scale factories dealing with the particular material.

The different types of plastics items (sorted according to whether they are hard or soft, and according to quality and colour) are sold to the specialised small factories dealing only in plastics. These factories use machines to cut the different separated plastics into small pieces about one centimetre in size These pieces are washed in soapy water to remove

dust and dirt particles and then dried in the sun. They are then sold on to the next small industry.
The materials are converted separately into a granular form by heating and cooling. (A flow sheet showing the processes is reproduced in Appendix DD-3) These granular particles are sold to other factories for making plastic items like clothes hangers, washing brushes and soap cases. Minimum wage regulations apply to the workers in these factories.
There are some plastic items which are not suitable for recycling and therefore these are not collected by pickers. These are items like electric switches and adapters which are made from thermoset plastics.
There are some plastic items, such as pipes, which are not cut and melted down, but are kept by the middlemen and sold for reuse.
NOTE: Sufficient virgin material for the manufacture of plastics goods is not available to meet the demand and price range of the market. Therefore, there is a heavy demand for goods made from recycled plastic.

(ii) Paper and cardboard

Newsprint Newspapers and magazines are purchased by hawkers going from door to door, and sold to middlemen. Middleman sell this paper for use in packing fruit, and for making of packets of different sizes for use in small shops.
Mixed paper Paper collected by pickers from community containers and dumping grounds is sold to middlemen who, in turn, sell it to manufacturers of paper and cardboard.
Cardboard The hawkers generally purchase cardboard and items made of cardboard from households and shopkeepers directly. Cardboard is used by industries for making packing cases for consumer goods such as household appliances and shoes. People also purchase packing cases from middlemen directly for their use. Damaged cardboard is sold by the middlemen to paper mills.

(iii) Glass

Broken glass (cullet) Pickers and hawkers sell broken glass to the middlemen. The middleman sells it on to the different glass industries for making different glass items. Broken glass is also purchased directly from the middlemen for putting on the top of boundary walls for security purposes.
Bottles Glass bottles are purchased by the hawkers from households and shops. Sometimes pickers also get bottles from the road-side and refuse containers. The middlemen sell undamaged bottles to the bottling factories for their reuse.
Small bottles are also sold at the main gates of hospitals and dispensaries; patients purchase them for their medicine.
Sometimes people also purchase bottles of different sizes from middlemen for their own domestic use.

(iv) Rags and gunny bags

Rags Rags are usually sold by pickers to middlemen. Manufacturers purchase rags from middlemen for making buffing wheels. Rags are also purchased from middlemen by the paper-making industries.
Gunny bags are purchased by middlemen from the hawkers. Damaged gunny bags are sold to the paper- and cardboard-making industries. Good quality bags are reused. Partially damaged gunny bags are used by the flood control authorities for protecting embankments by putting sand into them. More seriously damaged but serviceable gunny bags are used by the pickers, hawkers and middlemen for storing material that is to be recycled.

(v) Metal

Scrap metal (galvanised iron sheets, scrap from workshops, aluminium items etc) are purchased by the middlemen from pickers and hawkers. These materials are sold directly to the factories which manufacture rods, sheets, angles etc.

D-3.3 COMMENTS AND SUGGESTIONS

COMMENTS

Thousands of people are engaged in the process of recycling (as pickers, hawkers, middlemen, and in the reprocessing factories) and so this sector of activity is an important source of livelihood. There are also less obvious benefits of recycling, such as a lower demand for natural resources and imported materials. Another advantage is the reduction in the quantity of solid waste that is to be disposed of, and the removal of troublesome materials such as plastic and paper (which are blown about by the wind).

Each recycling unit functions independently and most under very unhygienic conditions. These units are not recognised by the local competent authority, and so there is little control over working conditions and pollution. The recycling process is functioning very well from the starting point - the pickers and hawkers - to the manufacturers of the finished products without much support from the local authority. There is a sufficient market for the products made from recycled materials.

The main collection of recyclable material is done by the pickers and hawkers. The pickers create problems at the site of collection for the solid waste collection authority by spreading refuse on roadside and around storage facilities in the city and by starting fires at landfill sites.

SUGGESTIONS

- The attitude of policy makers towards informal sector recycling is important. It is suggested that a seminar on the subject would be useful, with representatives who are in contact with the rag pickers, hawkers and owners of small recycling industries, as well as from the Municipal Corporation, so that city officials can understand the perspectives of the recycling industry. A spirit of co-operation between the two groups would be greatly preferable to a spirit of confrontation and mistrust.

- Some suggestions relating to pickers at community storage sites have been mentioned in section B-3.3 (iv), and others relating to pickers on landfills have been discussed in section D-2.2. In both these situations the pickers are causing serious problems to the refuse management services, and any improvement in the activities of the pickers would be of considerable assistance to the municipal workers, and create environmental improvements.

- It is important that ways be found of preventing the pickers scattering litter around the storage facilities. The provision of extra storage capacity has already been suggested. Another possibility in some situations might be the provision of a sloping tray above the container such that waste could be dumped initially on the tray for sorting, and when the waste has been examined it could be pushed into the bin.

- Other possibilities for improving the situation around the containers include giving the sweepers a role in policing behaviour around the bins, but this could lead to more confrontation, and increase the frustration of the sweepers. Alternatively, it may be possible to enlist the help of pickers by paying them a small fee for cleaning the area around a small number of containers - though the main part of their day, and their main source of income, would still be from recycling activities. It might be possible to allocate picking rights for certain bins to certain people, but protection of these rights might be very difficult and lead to further confrontation. It has also been suggested that the middlemen might be able to control the activities of pickers and prevent littering around bins - each middleman would act as a contractor for a certain area and run the risk of a penalty if bins in his area were left in an untidy state by the pickers that he employs. The

potential success of these ideas depends in part on the working habits of the pickers - what degree of organisation exists among them, how long they continue to work as pickers, and how they divide up the city's bins among themselves.

- In many ways, the best solution is to develop the work of the hawkers, who go from house to house, buying recyclable material from residents. This approach ensures that the recyclable material is not contaminated by other waste, and it avoids the problems caused by pickers at bins and disposal sites, since, if all the recyclable materials are sold to hawkers at the door, there would be no useful material in the waste at the community bin and at the landfill site. A pilot scheme of this type has been set up in Bangalore - residents separate their waste into *wet* and *dry* streams, the *dry* containing all the recyclable material.

D-4 OTHER METHODS OF RESOURCE RECOVERY

About 99.5% of the solid waste collected from Greater Bombay is disposed of at the four landfill sites listed in section D-2 above. The remainder - about 0.5% or about 20 tonnes per day - is disposed of in ways which offer the possibility of gaining some economic benefit from the waste. These methods are:

- **vermiculture** - feeding the waste to worms in order to produce a stable soil conditioner
- **pelletisation** - drying the combustible fraction of the waste and forming it into fuel pellets
- **composting** - by the Excel process

All these methods are operating on a very small scale. It is essential to demonstrate the technical and economic feasibility of such methods on a small scale before they can be developed into large-scale operations. Some information on the vermiculture and pelletisation projects is presented below, but it was not possible to collect data on the Excel process.

For a few years a large mechanical composting plant was in operation, converting solid waste into soil conditioner. This plant is no longer in use, but it is described briefly, and reasons for its closure are discussed.

D-4.1 VERMICULTURE

Vermiculture biotechnology involves the use of earthworms as natural bioreactors for efficient bioprocessing of organic wastes into vermicastings (worm-excreta) - this material is a useful fertiliser for the soil.

Bhawalkar Earthworm Research Institute (BERI) Pune has developed a practical, cost-effective application of vermiculture biotechnology for handling (among various other wastes), the organic fraction of municipal solid waste (see reference 1).

Vermiculture products from such operations have been used by farmers successfully on diverse crops such as sugar cane, grape, guava, banana, coconut, pomegranate, chickoo, bar, vegetables. flowers, and spices in different agroclimatic conditions in India.

(i) Bio-processing under a tree

Five kilograms of vermicastings are applied as a basal dose below a tree and a 100 mm layer of household organic wastes is placed on it as a mulch. (The household wastes form a

protective layer which also serves as food for the worms hatched out.) The mulch reduces the water requirements of the tree, as evaporation from the soil is reduced. As the old layer of mulch are converted into vermicastings, new layers are added on top. Pests are significantly reduced. Trees also show healthy growth without any digging or chemical fertilisers.

(ii) Processing in a container

This process uses a wooden box of size 80 cm by 60 cm by 40 cm with the few drainage holes. Five kilograms vermicastings are applied on a layer of a used newspaper kept at the bottom of the container. Household organic waste is put into the box daily. Some water is also applied occasionally till just a few drops come out from the drain holes. A container of this size will take a year to get filled by a family of four. Lower layers can be removed and used as a rich biofertiliser for potted plants. Several families are practising such recycling in Pune, India and are spreading the news of their success.

The Indian Institute of Technology, Bombay, has been recycling the solid waste produced from ten hostels for one year using this technology.

(iii) The advantages of vermiculture technology

- Reduction of odour and fly nuisance.
- Does not consume electricity or fuel.
- Simple to operate and maintain.
- Destroys pathogens.
- Produces vermicastings which can replace costly energy-intensive, imported farming inputs such as diesel, chemical fertilisers and pesticides.
- Conversion of wastes into resources makes the operation viable and sustainable.
- Helps the economy of the country.
- Eliminates pollution totally.

(iv) Optimum requirements for the process

- Temperature to be maintained at 25-26^{o}C and always less than 30^{o}C.
- High humidity is favourable for the process.
- Neutral pH must be maintained.
- The time required for the completion of process is 8 to 10 weeks.
- Space requirement: for 1 kg. volatile solids/day an area of one square metre is required.

D-4.2 PELLETISATION

The Department of Science and Technology constructed a pilot plant with a capacity of 8O tonnes/day. The fuel pellets have a calorific value in the range of 3500 to 3700 KCal/Kg. The cost of production was estimated to be Rs.780.00/tonne and the realisation from the sale of the product is Rs 1,000/tonne. The present production of the plant is 5 to 8 tonnes per day.

(i) Problems with the final product

- It gives initial smoke.
- It burns quickly - faster than coal
- Its calorific value is less than coal.

D-4.3 COMPOSTING - EXCEL INDUSTRIES PROCESS

Excel Industries is supplied with two truck loads of market garbage for converting it into compost.

D-4.4 MECHANICAL COMPOST PLANT

(i) General information

This plant ran from December 1979 to May 1983. It was installed in Bombay jointly by the Government of Maharashtra (Municipal Corporation of Greater Bombay) and M/s Deccan Sales Corporation - a private body manufacturing granulated fertiliser. The Ministry of Agriculture gave a grant-in-aid to the extent of 33% of the capital cost of the compost plant to the Municipal Corporation. The Ministry of Works and Housing also gave grant-in-aid to the extent of 50% of cost of the various infrastructure items connected with the working of the plant. The Municipal Corporation of Greater Bombay provided 8 hectares of land for the compost plant on a lease basis for a period of 30 years from the date of possession at the rate of Rs 50/m^2. The capital cost was Rs 1.5 crores. It was supplied on a turnkey basis.

The garbage required for the compost plant was provided by the M.C.B.G. free of cost. The water required for the compost plant was provided at the concessional rate. The design capacity of the plant was 45,000 tonnes p.a..

The compost plant started operating in December 1979. In May 1981, the plant was closed because of a strike. The plant was reopened in November 1981. During the monsoons the plant did not function.

The process used was aerobic. The windrows were supposed to be 2 m high; they were covered to prevent the process of fermentation being affected by rain water. According to the design, the compost should have been ready within 7 days.

The price of the compost was as follows:

Year	1979	1981	1982
Price Rs per tonne	55	65	85

(ii) Factors which were responsible for the closure of the plant

- Some of the customers were farmers coming long distances from places such as Nasik, Pachova, Pune and Palghat. Because the farmers were unwilling to pay the high transport costs, they stopped purchasing the compost, and so not all the compost that was produced was sold. For instance, in the seven months - October 1981 to May 1982 - the production was 7699.65 tonnes but the sales were only 3533.44 tonnes (i.e. 46% of production).
- The presence of non-compostable materials like plastics, glass etc. varied in the final compost from 0.5% to 1.0%. Marketing agencies responsible for the sale of the final product indicated that the presence of such materials was hindering sales.
- The compost could not be made ready within seven days as per the design.
- The windrow height could not be maintained at 2m as per the design. It could only be maintained at 1m; this affected the biological processes and a satisfactory temperature could not be maintained and therefore the composting process was delayed.
- Auger shafts were breaking frequently due to high loads. Such disruptions affected the frequency of turning and so reduced the throughput of the plant.
- There were no spare units available to keep the plant running in case of failure of the machinery.
- The machinery, such as the grab bucket, slat conveyors, and rasping machine, could not be utilised fully to their rated capacity because of operational problems in handling the garbage. (For example the rasping machine used for shredding the waste could not shred wet garbage from the markets.)
- The formation of balls of shredded garbage slowed down the microbiological processes.
- The screening machinery allowed compost to pass with the rejects.

- Bombay garbage contained more than 50% moisture (during 1979-82) even in the dry season. The end product for sale should not have a moisture content of more than 30%. Difficulties in achieving a satisfactory moisture content reduced the quality of the end product.
- Because of these problems the full complement of staff was not appointed.

COMMENT: It appears from the history sheet of this mechanical compost plant that it was installed without consideration of the necessary factors like characteristics of refuse (moisture contents, different constituents etc), the demand for the compost, and the technical feasibility of the process (height of windrows to be maintained, the period required for preparation of compost from refuse, etc.). This experience emphasises the importance of small-scale pilot plants in demonstrating the feasibility of such an operation.