Chapter E-2

Alternative disposal methods

E-2.1 INTRODUCTION

Amongst municipal officials and politicians there seems to be a great desire to develop alternatives to land disposal. Sometimes it seems that officials are ready to spend money on *any* proposal for disposal, if it is not landfilling. Why is this? Some possible answers are:-

◊ Public officials are not aware that land disposal can be much better than open, uncontrolled dumping. They think of land disposal as scattered piles of smouldering waste covering a large area, causing serious air pollution, harbouring rats and flies, and spoiling the landscape. They are not aware of the techniques of modern sanitary landfilling, and since money is not made available for the development of such facilities, they may never become aware of the benefits of engineered land disposal - unless they see them in operation in another country.

◊ Most alternatives to land disposal have a financial yield - a material is produced that can provide energy or be sold. The promoters of such options emphasise the potential for generating revenue from the sale of the product, and immediately the officials start thinking of turning solid waste into profit - a very attractive prospect. Land disposal, on the other hand, is seen as pure loss. It usually happens that the income from the sale of products is much less than the operating costs, so that the "profitable" alternative costs more than sanitary landfill in the end.

◊ No-one wants a landfill near their house, let alone in their backyard! Planners feel that a modern plant that processes waste will attract much less public opposition than a sanitary landfill, and so it will be easier to find a convenient site for the plant. In fact, some waste processing units produce unpleasant smells, make considerable noise, and attract flies and rats, and because they are often closer to houses or factories, cause more nuisance to the public.

◊ Land disposal is seen as old-fashioned, whereas processing waste to make a saleable product is modern. Factors such as economy and reliability seem to be less important.

In fact a land disposal facility is always necessary because there are always rejects from every processing unit, and wastes must be disposed of when reprocessing units are inoperative because of failure or maintenance.

Perhaps the main challenge to the development of alternatives to land disposal (or waste processing facilities, as they will be called from now on) is that the waste is heterogeneous, being composed of a wide range of items and materials that are not affected by any one process in the same way. Some wastes float in water, others sink. Some wastes decompose, others are inert. Some adhere to surfaces, others abrade surfaces. Some items found in solid waste can easily be broken up or cut into small pieces by a hammermill or shredder, but others (such as a length of fabric or a roll of carpet) resist these processes. Some materials can only be cut by a sharp knife, but lumps of concrete and large car engine components simply damage the knife blades. Some materials burn to produce heat, others absorb energy because of their high moisture contents, and others still are inert and so are unchanged by high temperatures. Some materials explode at high temperatures, some give off toxic fumes, and others melt. Some materials are beneficial to the soil, others are toxic to plant life. Developing machinery that can handle such diverse materials in a reliable and economical way, and produce a useful output is a task that tests the ingenuity of mechanical and chemical engineers to the full. No machinery should be accepted for a full-scale plant until it has proved reliable with real wastes over an extended period at the pilot scale. (The term "real wastes" refers to wastes that contain the full variety of components that are found in the type of waste that is to be treated - not an idealised synthetic waste made from a few materials that are suited to the process in question.)

India already has a sustainable and well-proven alternative to land disposal for part of its solid wastes - the separation of recyclable materials by rag pickers and reprocessing by many small factories. The drawback of this approach is the exposure of the rag-pickers and sorters to health hazards from their close contact with the wastes. Perhaps the best way of reducing the quantities of wastes that must be landfilled is to improve this informal sector of the economy, by increasing the degree of segregation of wastes in the home and improving the practices of the rag-pickers. Here, the challenge is for the sociologist, not the engineer.

An interesting financial point that is related to waste processing is the price of the solid waste. A number of municipal officials in India indicated that they thought that waste processors should pay the municipality for the waste that they use as a feedstock for their process. They argue that the waste has a value for the plant operator, as does any raw material for any industrial process. An alternative view is found in some European countries. Here it is argued that a ton of waste that is reprocessed is a ton of waste that does not need to be landfilled or incinerated, and so the waste management agency has saved the disposal costs for this ton of waste. If it costs $15 to dispose of one ton of waste, then a waste disposal authority should pay a reprocessing industry the $15 for every ton of waste that is accepted for reprocessing, as *avoided costs* (that is, expenditure on waste disposal that has been saved). Of course the processor should pay the waste disposal authority $15 (or whatever the landfilling charge is) for every ton of rejects that he wishes to dispose of. Disposal costs are currently very low in India because very little is spent to dump the waste in an insanitary way, so the question of avoided costs is of little consequence. As disposal charges increase, the question of who should pay will become less philosophical and more financial.

E-2.2 INCINERATION

Incineration is high-temperature combustion under controlled conditions. Modern large incinerators produce heat or electricity which can be sold to offset some of the operational costs. A modern incinerator was built in New Delhi, and although it is a type that works well in northern Europe, it has not been used after the commissioning trials, because the waste that was brought to it had a calorific value (that is, the amount of heat that is produced when it burns) that was too low for it to burn properly alone, so that a large amount of fuel was required to maintain a satisfactory temperature. The incinerator was designed to save fuel by generating energy, but, because of the type of waste it was required to burn, it was actually consuming large amounts of fuel. The incinerator continues to absorb expenditure as it is being kept in good order by a maintenance crew, but it processes no waste.

Small incinerators may be found at housing colonies, and used for treating medical wastes, condemned food, infected animal carcasses and confidential wastes. In general, such incinerators, unless they are sophisticated and well operated, produce unpleasant odours and harmful pollutants because the combustion temperatures cannot be controlled adequately, and the installations lack the necessary gas cleaning equipment. Problems with such incinerators are mentioned in part F.

The open burning of waste at a dump site cannot be described as incineration. The wastes burn slowly or smoulder at low temperatures, and produce large quantities of harmful and unpleasant smoke. Such a practice should be stopped.

E-2.3 COMPOSTING

> Aerobic composting is a natural process by which micro-organisms convert food and garden wastes, and cellulosic materials like paper, into a stable, non-polluting humus or soil-type material. The final product - compost - is beneficial to all types of soil, and contains small quantities of the nutrients needed by plants. Compost is not generally regarded as a substitute for artificial fertilisers, but helps in the retention and utilisation of artificial fertilisers. The main benefits of compost are to improve the condition of the soil by reducing erosion, improving water retention, improving root aeration and making the soil easier to work. The process is generally though to take between three and ten weeks, and involves control of the air and moisture contents of the material, and arranging and mixing of the mass so that all of the waste is processed, and the naturally-generated temperatures are high enough to kill disease organisms and insects.

The biochemical process of composting has been known for a long time, but throughout the world many large mechanised composting plants have failed. The failure of these composting enterprises suggests that the engineering and business aspects of composting are more problematical than the biochemistry.

The decomposing remains of many large composting machines can be found in many of India's major cities. For example, a plant was commissioned in Mumbai in 1979, but it ran for less than four years. Figure E-2.1 shows one view of the plant at the time of the study. The experiences of other plants were similar. One may guess at the enthusiasm and motivation that inspired the creation of these large factories - perhaps the desire to reduce the dependency on uncontrolled dumps, the desire to see organic wastes put to good use in improving the quality of the Nation's soil (thereby helping to improve the lot of rural Indians and preserve their heritage - the soil). Others may have been concerned to reduce the pollution of water and air from dumped waste. Another benefit would have been seen as the opportunity to reduce the costs of solid waste management by generating income from the sale of the product. All these are laudable aims. Why were they not realised?

Before reviewing the reasons for the failures of these plants, it is important to ask what can be learned from such retrospection. Are there lessons for today? Is it possible that the same mistakes could be made, or are being made, again? Yes, there is a strong possibility that some of these mistakes could be repeated, and so it is can be very beneficial to review the causes of failure of India's large, mechanised composting plants and consider how these causes might be repeated in the programmes of today. The list in the box below comprises *suggested* reasons for failure, because the writer has not had the opportunity to study the case histories of many plants in India. The list is based on the observations of others and experiences in other countries. A more detailed investigation of the reasons for the closures of these plants would, no doubt, produce some instructive conclusions.

Figure E-2.1 A view of the abandoned composting plant at Deonar, Mumbai.
The photo shows the covered area where the compost was formed, and the travelling augers used for mixing and aerating.

Many of the factors that determine the success of mechanical composting plants are also relevant to other waste processing technologies, such as those discussed in other parts of this chapter.

A private company which has a large premises in Mumbai, had become involved in producing compost. The company had already been producing agricultural chemicals for some time and so had good links with the agricultural sector, which would be of benefit in terms of marketing the compost. The company had started with a small pilot scale operation on their factory premises, and after gaining useful experience at this site they set up a plant beside the Malad disposal site. At the site waste was being piled in windrows and turned by a front loader (JCB) every 15 days. Water was brought to the site in a tanker. The operators added an inoculant which included cow dung slurry, and claimed that this quickly stopped the production of odours (even from fish waste) and accelerated the process. When the microbiological processes were complete the rough compost was brought to a

Suggested reasons for the failure of mechanised compost plants

No time to learn *Very few inventions have no need of development. Translating an idea into a reality generally takes time, as the prototype is made and tested, its weaknesses are discovered, and ways are found of overcoming the weaknesses. In chemical engineering, there is first the bench scale demonstration of a process (perhaps producing a few grams of product), then the pilot plant (the output of which can be measured in kilograms), then a small experimental full-scale plant (producing a few tons per year), and then one large full-scale plant, producing quantities on an economic scale. During each stage it is expected that problems will be discovered, and ways will be found of solving these problems, and the process is operated under realistic conditions successfully for a time before the next stage is attempted. When the large, full-scale plant is working well, other plants can be considered.*

Compost plants are complex in that they are required to handle wastes that are inhomogeneous (containing a wide variety of materials and forms) and varying (having different compositions on different days and in different seasons). The design of the machines to handle and refine such an input is not an easy matter, and so long-term trials are needed to identify and solve design and operation problems. If the machinery goes from the drawing board to the full-scale plant in too short a time. it will probably not be trouble-free or reliable.

Market problems *Is composting a method of waste disposal or the production of an agricultural product? Should a composting plant be the responsibility of a municipality or the Ministry of Agriculture? Should the decision as to the size of a composting plant be made on engineering and financial grounds, or on the basis of the market demand?*

A common reason for the failure of a composting operation is the lack of a market for the product. The following factors can affect the demand for the product:-

- *The type of agriculture or horticulture. Growers of high-value crops may be more prepared to invest money and effort into applying compost than farmers having large fields of wheat.*
- *The distance that the compost must be transported. The cost of transporting the compost may be significantly more than the price it is solid for at the factory gate. Compost should applied in large quantities, so large volumes must be transported. Large plants may hope to serve a large farming area, but farmers near the outside of the proposed area may be reluctant to pay for transport.*
- *Farmers may prefer to use alternatives , such as animal manure or even imported composts.*
- *Quality is a frequent problem. If compost is made from mixed waste it is likely to contain fragments of glass and plastic, and significant amounts of toxic heavy metals (which may adversely affect plant growth if the compost is applied in large quantities). For this reason, most new composting operations in Europe are using only segregated waste - that is organic material from gardens or from houses where the organic wastes are not mixed with the other types of solid waste.*
- *Managers of composting plants are more likely to be municipal engineers than experts in agricultural marketing. Marketing skills are needed in a variety of ways, including choosing the name of the product, determining how it should be packaged, what grades of refining are appropriate, and how the product(s) should be advertised and distributed.*

Financial realities *No-one should expect that a large mechanised compost plant will make a profit. Income from the sales of compost and any salvaged material helps to reduce operating costs, but sanitary landfilling is usually cheaper than composting.*

screening plant where the material was passed though rotating screens in order to separate out plastic, glass, metal and other contraries (that is, material that is not desired in the final product). Rag-pickers collected these materials for recycling. The compost was bagged for sale. The whole process was said to take 6 weeks. One hundred tons of solid waste were said to yield about 25 tons of saleable compost. Trial plots having different soil types had been used to assess the effectiveness of the product.

There are differences of opinion amongst compost experts regarding the need to add bacteria as an inoculant, but this particular company was very convinced about the practice, and made enthusiastic claims about the benefits of cow dung slurry.

In 1995, the same company was operating a 150 ton/day plant in Bhopal and a 70 ton/day plant at Ahmedabad, and constructing a 100 ton/day plant at Gwalior. It was claimed that the compost made in Mumbai was transported up to 300 km (perhaps in trucks that had brought produce to Mumbai and would otherwise return empty to agricultural areas).

The selling price in 1995 was Rs 1300 /ton. A fee of Rs 15 was paid to MCGM for every ton of compost produced. Table E-2.1 shows estimates of the capital costs of different components of this type of composting operation, for plants of different sizes. It would be useful to combine these costs with operating costs in order to evaluate the cost of producing one ton of compost, but this information may be regarded as confidential, and it may require further operating experience before such figures can be estimated with a reasonable degree of confidence.

Table E-2.1 Capital costs for semi-mechanical composting plants of different sizes in India

Source: Excel Industries Ltd, Mumbai 1995

Costs in lakhs of Rupees

Plant size - throughput in tons per day	**500**	**300**	**100**	**50**	**20**
Item					
Project feasibility/survey etc.	15	12	5	3	1
Site development and infrastructure	100	60	30	11	2
Plant machinery					
De-fouling, waste treatment facilities	50	20	10	4	2
Fermentation, aeration, material preparation	50	35	22	16	4
Separation, grading	60	48	25	10	2
Sieving, finishing	30	25	14	6	1
Blending, packing	30	22	12	4	1
Other electrical items, quality control	35	28	12	6	2
Total	370	250	130	60	15

This semi-mechanical approach to composting had many positive points:-

- ◊ A private company with a concern to make the project succeed and a readiness to employ the needed professionals
- ◊ An organisation with good links to the agricultural sector and marketing ability
- ◊ Experience based on gradual growth, starting with a pilot -scale operation
- ◊ Relatively simple and well-tried technology

It was not possible to assess the commercial success of the operation - private companies are generally reluctant to divulge technical and financial information - but it did appear that the screening plant was operating at considerably less than its rated throughput on the day of the visit.

E-2.4 VERMICOMPOSTING

Vermicomposting or vermiculture is the processing or organic waste by worms. Under the right conditions of shade and moisture worms feed on the food and vegetable waste, and their excreta, or *casts,* form a very valuable soil conditioner. The moisture content should be in the region of 30 to 40 per cent, and , in addition to shading by trees, a roof or sacking, to keep the temperature below 25C, the worms should be protected from rats and ants. This technique has been used on a small scale in a number of places in India. Proponents claim that the worms neutralise toxic components and pesticides, and that the product has a useful carbon to nitrogen ratio. It was estimated that the process takes three months.

Some small-scale academic research into vermicomposting had been carried out at in Indian Institute of Technology in Mumbai, encouraging the Municipal Corporation to invest in a large scale (Rs 35 lakhs) vermicomposting operation. Nine large enclosures were constructed on a part of the Deonar disposal site which was no longer being used to receive waste. Each enclosure was formed of low walls (about 0.8 m high), and was 40 m long and 10 m wide. The concept was that colonies of the appropriate types of worms would be introduced into each enclosure and selected solid waste - market waste with the plastic and stones taken out of it - would be deposited in each at a rate that would suit the requirements of the worm colonies. It was anticipated that waste could be deposited in each enclosure at the rate of two truckloads a day for ninety days. A research student would control the operation, based in an office and laboratory building adjacent to the enclosures.

The site was visited by the writers on two occasions, and it seemed that the facility was not operating. It was not possible to find any worms, and on the second visit it appeared that no solid waste was being provided. It seems that the investment in construction was wasted.

It is always easy to be wise after the event, and looking back it is clear that it was unwise to take such a big step at one time. The preliminary trials were in enclosures that were perhaps smaller than ten square metres in area, under carefully controlled conditions. To jump to an installation of 3600 m^2 was too big a step. This huge size made it difficult to control the type of waste being offered to the worms, to control the moisture and to provide sufficient shade. It may also be true that a landfill is not a good site for a vermicomposting operation because of the settlement of the underlying wastes causing structural problems, the generation of methane gas, and the probable presence of large numbers of rats.

E-2.5 PELLETISATION

Pelletisation is the production of fuel pellets, often known as refuse-derived fuel, which are in the form of cylinders of dried, compressed solid waste, with a diameter of about 20 mm.

There is a pilot pelletisation plant in Mumbai. A plant in Baroda had been making a fuel using petroleum sludge, but that had closed. The press had reported the construction of a large plant in Madras that would make fuel pellets from municipal solid waste which would then be used to generate electricity, but no information is available about that site. The Mumbai pilot plant will be discussed briefly here. (The information presented here was supplied by the staff, and there was no opportunity for independent verification.)

The plant was conceived as a pilot plant by the Department of Science & Technology and started production in 1993. The plant was designed to receive waste at the rate of 100 truckloads per day and produce 100 tons per day of fuel pellets (i.e. an output of 15 to 30% of the waste received). The first step was to spread the waste on the ground so that it could dry. The partially dried waste was then raised by a conveyor belt where manual separation was done. (One little problem is that coconut shells were not carried up the conveyor because they simply rolled down.) The waste was then fed to a rotating screening drum fitted with cutters and hot air was supplied for final drying. The material was then fed to a hammermill which converted the waste into a cotton-like material which was fed to the compressing machine, together with the required amount of water, and this material was forced through a die with a large number of holes to form the pellets. The pellets were then bagged and sold. The plant was designed to work continuously - 24 hours a day and seven days a week (but at the time of the study in 1995 it was only working one shift.) The water consumption was 300 litres per day and the power requirement 750 kW. The work force was 35 persons per shift. The capital cost of this plant was Rs 2 crores, but no information was obtained about the running cost. The land was provided to the plant at a nominal lease.

The calorific value of the pellets was about 4000 cal/g and the selling price about Rs.1000/ton. To allow comparison the calorific value of coal was 4500 cal/g and its price varied from Rs.1750 to Rs.2000 per ton. The burning characteristics are different from those of coal - in general such pellets tend to burn very quickly.

About 70 per cent of the material that could not be used in the pellets was fed to a small incinerator which supplied the heat for drying. Only inert material was discarded. Coconut shells were separated at the conveyor belt. In the waste there was too much straw. Petroleum sludge was used as a binder as 4 to 5 per cent of the final product.

The pellets were said to be suitable as a substitute for coal in boilers for steam generation. In the monsoon season the pelletisation plant could not operate, and this disruption of supply made the pellets unsuitable for some customers, nevertheless the pellets were being sold to paper and textile mills and the sugar industry. Another problem was the regular replacement of the die which was wearing out after three to four days' use. The plant was also finding it difficult to get personnel for working in the plant. The municipality was not getting any revenue for supplying the waste continuously to the plant. It had been concluded that such plants cannot be run for profit and so such projects cannot be considered to be economically viable.

E-2.6 ANAEROBIC DIGESTION

Anaerobic digestion is a technique that had been used on a large scale for decades for the treatment of wastewater sludges and strong industrial wastewaters. In the absence of air and in carefully controlled conditions (temperature, mixing, acidity) anaerobic bacteria digest the waste, reducing its solids content, making it more stable, and producing gases - mainly carbon dioxide and methane. The methane can be used as a fuel. In large wastewater treatment works, the gas produced by the process is usually enough to fuel generators that provide a major part of the electricity needs of the whole treatment facility.

This is the same process as is used on a small scale in biogas digestors, which have been widely promoted throughout India for the treatment of animal wastes and the production of biogas as a source of energy. The Tata Energy Research Institute of New Delhi has recently been experimenting with the extension of this approach to wastes from a restaurant.

Anaerobic digestion takes place within a modern landfill, provided that there is some moisture in the deposited wastes. Large sanitary landfills produce large quantities of methane, which may be collected

(i) to avoid posing a threat to adjacent housing (there have been cases of houses being damaged or demolished by methane explosions), or
(ii) because methane is much more harmful as a greenhouse gas than carbon dioxide, or
(iii) to provide energy for electricity generation or heat supply.

However, the form of anaerobic digestion that is exciting most interest in India is the processing of mixed municipal wastes in large tanks to produce methane which will be used for electricity generation. The driving force that is vigorously promoting this technology is the large company called Western Pacques India Ltd.

Hitherto most anaerobic digestors have been fed with wastes that are reasonably homogeneous and uniform in composition. The bridge that must now be crossed is the development of a technology for handling inhomogeneous and varying wastes. A pilot plant operated by the parent company at Breda in the Netherlands has been using market and yard wastes, but the plants planned for India expect to accept all types of non-hazardous municipal solid wastes.

The first step was the construction and operation of a pilot plant in Pune, rated at five tons per day, and commissioned in March 95. The next step was seen to be the construction and operation of a number of large plants in India and elsewhere; the plant in Pune is to be capable of a daily intake of 300 tons of municipal solid waste

The company has agreed to take responsibility for all expenses, provided that the Municipal Corporation provides the land and solid waste at no cost.

More detail about the process is shown in figure E-2.2

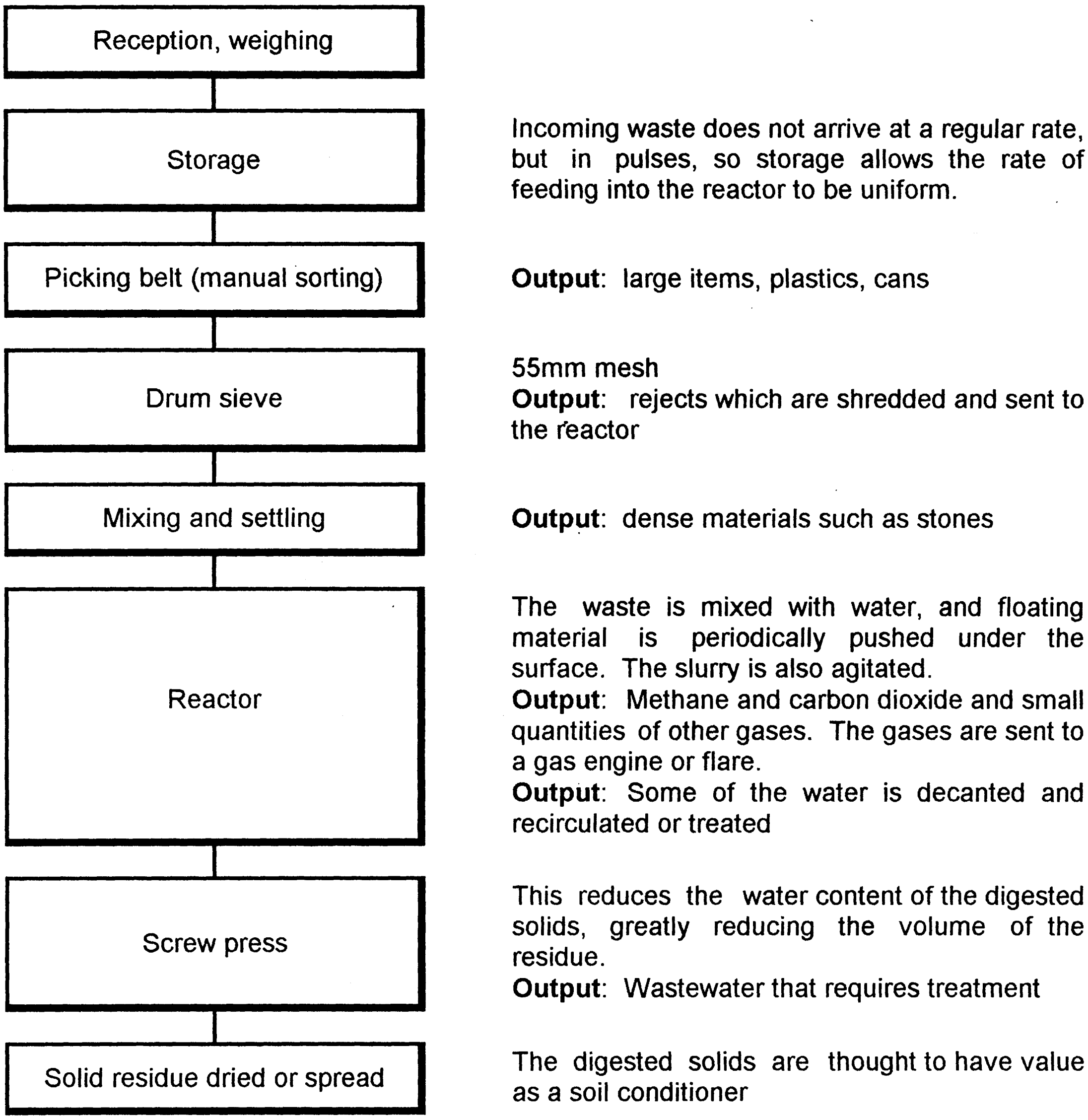

Figure E-2.2 Flow chart for solids through anaerobic digestion plant

The digestion of the wastes takes place in the floating layer reactor. At the inlet end of this long, covered tank there is a hopper-bottomed sedimentation stage where dense material sinks to the bottom and is removed. This would include mineral matter (which does not produce gas) and steel and glass packaging items that have not already been removed and that have little air inside them. The organic waste, having a density close to the density of water, is carried along slowly through the reactor. A novel feature of the reactor is the dunkers which push the floating waste down into the water to ensure that this material has plenty of contact with the bacteria in the water. The produced gas goes first to a storage unit, then to a hydrogen sulphide scrubber (which removes this toxic and unpleasant gas) before being passed to the gas engine which drives the electricity generator. If the power generation unit is not being used because it is being maintained, the gas can be burned off safely in a flare. The hot exhaust gases from the engine could be used for mixing or warming the contents of the reactor, or for drying the solid residue.

There are some issues of concern regarding the residue. In any reactor there is a degree of short-circuiting - that is, some of the material goes through the reactor in a shorter times than other elements of the material. The solids that go through the reactor in a short time will not be fully digested or stabilised, and so will continue to decompose after being withdrawn from the plant. This material may produce unpleasant odours and take nitrogen from the soil, in the same way as immature compost. The solid residue is likely to have a high water content, even after passing through the screw press, and this water will add to the weight of the residue, and the difficulty of transporting it. It has yet to be determined whether there will be a sufficient demand for this material from farmers. Another consideration may be the survival of pathogens and weed seeds since the temperature in the digestor is comparatively low and the short-circuiting material may spend a relatively short time in the process. These are questions which may already have been answered by the company, or may still need to be investigated.

Table E-2.2 shows the expected composition of the solid residue from the process, and compares it with the composition of compost produced in the semi-mechanical process described in section E-2.3. Comparison is difficult without more knowledge about how the determinations were carried out and reported. There are other items of concern, such as the contents of toxic metals.

Table E-2.2 Comparison of compositions of aerobic compost and residue from anaerobic digestion

	Percentage composition	
	Aerobic compost	**Anaerobic residue**
Moisture content		70 - 80
Organic matter		45 - 60
Organic carbon	14 - 18	
Nitrogen	1.5 - 2.0	1.3 - 2.9
Available phosphorus	1.25	
Phosphates		0.3 - 1.0
Potassium	1.05	0.3 - 0.7

Sources: Aerobic compost: Dr S R Maley, Excel Industries Ltd
Anaerobic residue: Western Pacques India Ltd

Notes: Apart from moisture content, results for anaerobic residue are quoted on a dry weight basis, whereas the basis for the results for aerobic compost is not specified.

The installation includes a wastewater treatment plant comprising an aeration tank and clarifier. It is clear that the operation of such a facility will involve a well-trained workforce and management team.

A plant capable of handling 450 tons of municipal solid waste each day requires a land area of about two hectares, and a daily water supply of about 50 m^3. It would be expected to produce up to 2.8 MW of electrical power, of which about 20% will be needed for powering the plant. In addition it would produce 80 to 90 tons of organic residue each day.

All the information that has been quoted here comes from the company that is promoting these projects; there had been no opportunity for independent verification. Some of the operational data cannot be known with confidence until a full-scale plant has been operating for some time. It is hoped that the development of this process will be undertaken in a considered way, to allow the lessons learned from one stage to be incorporated into the next larger stage, so that the errors that caused the failures of the mechanised composting plants are not repeated.