

WHO-EM/ES/381-E  
July 1986

**MANAGEMENT OF SOLID WASTES**

A collection of papers presented at  
the WHO Intercountry Workshop on  
Solid Waste Management, Damascus, 1983, and  
reproduced as a background document



WORLD HEALTH ORGANIZATION  
REGIONAL OFFICE FOR THE EASTERN MEDITERRANEAN  
1986

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SOLID WASTE: SOURCES, CHARACTERISTICS  
AND SAMPLING METHODS

by  
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1. SOURCES

Solid waste can be defined as any unwanted material that is not discharged to the atmosphere or via a pipe. It comes from a wide variety of sources and different types are the responsibilities of different agencies.

Domestic solid waste contains mainly food waste, packaging, paper, dust from sweeping, and worn out, broken or torn household effects and items of clothing. Where solid fuel is used ash may be present in large quantities; if hot it may start fires and damage plastic refuse containers. Where sanitation is poor and where disposable nappies are used, human faeces may also be included, and present a serious health hazard. Wastes from home nursing may also be a problem. Some unwanted items may not be accepted by the refuse collector; garden wastes and large items such as broken appliances and furniture are examples of bulky refuse which must often be removed by other means. Offcuts and scraps from cottage industries are often included with domestic waste.

Institutional solid waste - from hotels, schools, barracks, nurses homes and similar establishments - is generally similar in nature to domestic solid waste. However, because food waste is generated in much higher concentrations, farmers often find it worthwhile to

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contract with the kitchens to remove the waste for use as animal feed. Hospital wastes can be divided into two categories: domestic-type waste that can be handled as for other institutions, and surgical waste, used dressings, used syringes and unwanted medicines which should be disposed of with a great deal of caution.

Shop wastes vary greatly in nature. Large supermarkets produce immense quantities of packaging waste, but small shops in poorer or rural regions may discard only a little seriously spoiled food. Garages may cause disposal problems by discarding car tyres and oil, but both items have recycling potential.

Office wastes include large quantities of clean, good quality paper which generally finds a good price on the salvage market. Other wastes of a domestic nature, carbon paper and typewriter ribbons should be kept separate.

Street refuse varies in nature and quantity according to the habits of the people and the effectiveness of the refuse collection system. It usually includes litter and grit, but food waste, human and animal faeces and spilled loads may also be present.

Construction waste often finds a use as a cover material or road base on refuse tips, subject to the particle size and the presence of reinforcing bars and nails. Soil excavated for foundations should be stockpiled for covering refuse.

Abattoir wastes putrefy rapidly and attract flies. They should be quickly and completely removed and buried carefully.

Industrial wastes are produced in very large quantities and are often homogeneous. The industries themselves often arrange the removal of

the waste because of the large volumes and the need for special equipment. However industrial wastes are often mixed with domestic wastes at the tip. Supervision of waste contractors is necessary to ensure that no wastes are dumped illegally where they might cause serious environmental damage. Inert wastes can be used as cover material instead of soil.

Sludges of various moisture contents may be deposited on refuse tips. These sludges usually come from industries and wastewater treatment plants, though occasionally environmental considerations might require water treatment plants to landfill their sludges. To save on transport costs the sludges may first be dewatered to reduce their volume. Such sludges may be in the form of a cake, which may rapidly revert to a semi-liquid after standing in rain. Other sludges may arrive at the tip in a liquid state. Undigested sewage sludges have a very strong odour and serious health implications.

Radio-active wastes should be deposited in special sites.

Industrial wastes are often uniform and of a high purity, and so are suitable for recycling. Secondary materials merchants should contract directly with the industry concerned so that offcuts or by-products are removed from the factory directly before they are mixed with contaminating material. Such recycling creates jobs and saves on disposal costs.

Mining wastes are rarely mixed with other types of wastes. The tonnages involved are often enormous. Unplanned spoil heaps may impair the landscape, threaten landslides and pollute water courses.

Agricultural wastes can be divided into animal wastes and crop residues. The natural and beneficial return of organic wastes to the soil is increasingly prevented by modern intensive farming

techniques. Careless handling of these wastes may cause water pollution.

## 2. CHARACTERISTICS

It is easy to think of parameters that can be used to characterize the solid waste of a particular town and to find values of these parameters that have been measured elsewhere, but it is much more difficult to determine values that will provide reliable guidelines for a given situation.

Refuse generation rates are usually quoted in terms of the weight discarded per person per day. Whilst the weight is important in the design of equipment for manual operation (such as handcarts and bins), the volume occupied by the waste is very often the appropriate criterion for the design of equipment and facilities. Mechanical equipment (for example, the tipper truck) is usually designed to handle materials that are much denser than refuse, and so it is the volume of the waste, and not its weight, which determines the carrying capacity. Similarly refuse volumes are needed to calculate the life of a landfill site. So in addition to the weight, the volume or density of the solid waste must be known.

Other properties of interest are the moisture content, the compressibility and the size. The moisture level enables estimation of the actual weights of material, and is important in the composting process. Knowledge of the compressibility aids in the choice of collection and disposal systems. The fraction of the refuse passing a given mesh size indicates the possible value of size reduction as a disposal process.

Laboratory analysis may be required to determine the carbon to nitrogen ratio and heavy metal content of the refuse in feasibility studies for composting and the calorific value of the waste must be carefully determined if incineration is being considered.

Solid waste generation rates and composition vary greatly with both time and space. Table 1 illustrates some of these differences and Table 2 presents some extreme values.

Quantities of refuse discarded each day vary through the week according to shopping days, weekends and other factors. And the quantities often also diminish during the storage, collection and

Difference	Situation	Solid waste generation rates per person per day		
		Weight g/cap·d	Density kg/m <sup>3</sup>	Volume L/cap·d
Different countries	Iran, Islamic Republic of USA	290	231	1.3
		900	128	0.7
Different towns (India)	Calcutta	512	540	0.9
	Poona	300	300	1.0
Different socio-economic levels (Iran)	Low income	260	257	1.0
	High income	400	169	2.4
Different times	UK Pre-1939	-	290	-
	Post-1945	-	229	-

Table 1. Examples of Place and Time Variations in Solid Waste Characteristics (1)

Refuse parameter	Range of values
Per capita weight    kg/d	0.2    -    3.0
Density                    kg/m <sup>3</sup>	100    -    500
Putrescible fraction    %	5       -    90
Paper fraction            %	0.25   -    55
Plastics fraction        %	0.1     -    7

Table 2. Ranges of Values of Refuse Parameters (2)

disposal processes because of: burning of refuse in the home, dumping on vacant land or in flowing water, door-to-door collections of glass or paper for salvage, separation of items of value, burning or unauthorized dumping by the refuse collector, and scavenging at transfer stations or at the final tip. Refuse analysis values therefore depend on the point of sampling. Densities also tend to increase because of handling and overburden.

Refuse varies with the season, according to availability of fresh fruit and vegetables, holidays and tourism, and requirements for home heating. Finally, refuse quantities and compositions change over the years with changes in prosperity, diet, packaging, fuels, literacy, use of disposable paper products, and type of building material.

Refuse characteristics differ from country to country, from town to town, and even from street to street. International variations are caused by a variety of factors, including wealth, climate, diet, literacy and work habits. The differences are often very great.

Residents of large towns also seem to throw away more than people in small towns. Income level and lifestyle are associated with differences within a town. The general rule is that as one goes from a small, poor, traditional, illiterate community to a large, rich, modern, literate one, the refuse weight becomes more, the density less (and therefore the volume more), the food preparation waste becomes less, the paper and packaging fraction increases and the average particle size increases. But these trends do not always hold; an exception is cited in the section on socio-economic implications in a later paper.

It follows from these observations that results of solid waste analyses should be interpreted with care. An annual average figure does not reveal seasonal peaks, and a sample taken from one place may be significantly different from the city-wide average. (The author recalls hearing of a 'survey' performed by a few students sent out on one day only into the prosperous area of a city; such results have virtually no value at all).

Refuse parameters vary greatly with time and space. Furthermore the variety within a sample of waste is great. Solid waste is a collection of objects having very different properties. Densities, sizes, degradabilities and strengths vary enormously. This pronounced inhomogeneity leads to many conflicts that require compromises. One example is the refuse bin designed to be emptied by lifting: if filled with packaging waste the contents would weigh about 7 kg, but if filled with construction waste the load could be 100 kg. Another example is size reduction: steel cans might be bent by the equipment, glass would shatter, some material might adhere and nylon tights might wrap themselves around the shaft. It is difficult to design equipment to

handle all types efficiently. Incineration affords a third example: the temperatures and residence times for satisfactory combustion of different materials differ greatly, so that the right conditions for plastic and paper may leave a water melon rind only lightly singed. The design of refuse handling equipment involves compromise.

### 3. SAMPLING METHODS

A vital question to answer before embarking upon a programme of analysis and measurement of solid waste is:

"For what purpose will the results be used?"

The answer to this question will determine the point in the lifetime of the waste that will be examined - when an item is first regarded as waste, when it is received by the authorized collector, or when it reaches the end of its journey. The answer will also decide the depth required of the study and the number of man-hours to be spent on it. For some purposes a short discussion with some supervisors, coupled with some careful observation, might provide sufficient information. A tally of refuse collection vehicle loads entering a disposal site on a given day might serve another purpose. But in other cases it might be advisable for a complete and detailed analysis to be performed. Some information can only be obtained through careful observation of a pilot scheme. It is therefore best to first consider the use to which the data will be put, and the accuracy required, before initiating a sampling programme as described in the text book.

Data may be required for many purposes; examples are the sizing of containers, determination of manpower requirements, vehicle

requirements and scheduling, estimation of tip life and feasibility studies for composting, resource recovery or incineration. The knowledge of the refuse composition on the "macro" scale allows the preparation of a truly representative "micro" sample for laboratory analysis. A further use of refuse data is the forecasting of likely trends of refuse characteristics for longer-term planning.

A detailed study of solid waste generation requires the division of the area concerned into different groupings, usually on the bases of socio-economic status, style of housing and type of source - domestic, institutional, office, etc. Sectors of the town or city must be chosen so that they are homogeneous, that is all the refuse collected in the area must come from the same type of source. Some means of quantifying the socio-economic levels of the domestic sources is necessary to enable an estimation of the fraction of the town or city represented by each group. The timing of the analyses must be such that all major seasonal effects are included.

The next choice is the size of the refuse sample that is required. Recommendations on this point vary. Stirrup (3) reported the use of one ton for Britain and Flintoff (4) has advised 200 kg. American research (5,6) has indicated that 90 kg gives satisfactory results provided that obviously untypical objects (such as dead horses) are not included. In discussing what is the minimum satisfactory weight, three points should be borne in mind:

- (i) The number of sources (households) is more important than the total weight because the generation rates will approach the true average as more sources are sampled. Ninety kilograms on a weekly collection basis in the USA could come from as few as four households whereas the same weight collected on a daily basis from a developing country might represent fifty households.

- (ii) The method of collection of the sample is important. If a school and a few shops have contributed to a "domestic" sample a larger number of domestic sources will be needed to reduce the impact of these outsiders on the final figures. A sample that is taken from carefully selected sources will be more precise than a "grab" sample taken from a collection vehicle after its normal round.
- (iii) If at least three samples are taken from a particular grouping, statistical methods can be used to indicate the reliability of the results.

It follows from these three points and from the author's observation that under certain circumstances a sample of 50 kg is quite sufficient to give a reliable guide to all categories of refuse, except perhaps those present in very small quantities.

The method used to obtain the sample depends on the method of collection. If the refuse is normally collected from bins at the roadside then sampling involves simply emptying the bins of the selected sources into an appropriate vehicle. If the resident normally hands his bin to the collector, he may be somewhat suspicious when giving it to a man with a clipboard or notebook. Many people feel that the refuse they discard contains information about their way of life which they would prefer to keep private. Even if the purpose of the sampling exercise is explained to them they may feel reluctant to discard their refuse according to their habit. So when the householder is aware that his domestic waste is being examined, the results of the analysis will be less reliable. For this reason measurement of refuse generation rates in areas served only by communal receptacles is difficult. The usual approach is

to collect refuse from the sample area by a special door-to-door collection with plastic bags. Residents may either prefer to continue to use the communal facility to avoid divulging any secrets, or they may make extra use of the special service by spring-cleaning when someone else is willing to remove all the rubbish thereby cleaned out. This grass-roots approach may therefore be no more accurate than keeping a record of the solid waste removed from the communal receptacles in an area, and noting the population of the area.

Though the task of analysing solid waste is neither pleasant nor likely to attract public sympathy, it is important that a supervisor who has a clear understanding of the aims of the survey, a feeling for the accuracy required and some concept of statistics, should be present at every stage. He will be required to make many decisions during both collection and segregation stages.

Various data must be collected along with the refuse. It is essential to know with confidence when the previous collection took place so that the number of days' generation is known. The number of people contributing must be ascertained. The date, time, weather and any other observations can also be valuable. When collection is more frequent than weekly it is important to know if the weekend's refuse is included.

The methods used in the analysis have an effect on the results obtained. The size and shape of the container used for determining the density can influence the result; if it has corners these may not be filled, and if one dimension is small, large items of refuse may bridge between the walls to produce large voids. A minimum dimension of 0.5 m is probably satisfactory. The refuse should not

be compacted into the container. The conditions in which the refuse is sorted can also affect the rate of drying of some of the component materials. Drying modifies both the weights and the percentage composition, because different materials absorb water to different extents. The working definitions of the categories also affect comparisons between segregation studies done by different people; dry cell batteries and old shoes are examples of items that could be placed in different categories. Bottles containing liquids can also be handled in two ways. Results for plastic content are usually overestimated because of food remains that adhere to film and containers. The size of the sieve mesh used to define the fines will influence results for that category. The conclusions from these points are that refuse analysis is not a very precise science and that comparisons between different studies should not be overzealous. Where studies are performed at regular intervals to reveal temporal trends the methods and category definitions must be consistent.

The organization and conduct of the segregation analysis depend on the size of the sample and its location. If the sample weight is around 100 kg and samples are to be analysed at various locations, a kit consisting of plastic sheets, plastic sacks, a sieve and a spring balance will suffice. Density measurements need more cumbersome equipment - a 200 L barrel and a weighing device are satisfactory. These density determinations can be made quickly and need not be combined with the segregation analysis.

For larger samples that can be delivered to a convenient depot, the method described by Flintoff (4) is suitable. A frame covered by 50 mm mesh is used as a sorting table and items are separated

into bins. A wooden box 0.5 x 1.0 x 1.0 m is used for density measurements. Material falling through the 50 mm mesh is further classified using a 10 mm sieve. A larger group of labourers is needed to sort the refuse, which should be weighed in its categories within two hours to minimize drying effects.

If the exercise has a socio-economic dimension reliable data must be obtained for each area sampled. In some cases municipal records will furnish enough information, but in others a survey will be required. The author was responsible for this type of survey in Iran, where residents were asked about income, ownership of property, and consumer durables, education, employment, housing and family size. More details are given in reference 7. In framing the questions for such a survey it is valuable to build in crosschecks to allow for misinterpretations and unanswered questions. A questionnaire also provides an opportunity for collecting information on habits linked with refuse generation.

mation on habits linked with refuse generation.

When comparing analysis figures for different socio-economic groups, or for different towns, it is useful to apply a statistical test to determine whether the difference between groups is significant when compared with the differences between the several values measured for each group separately. To do this at least three readings must be taken within each group, and student's "t" test should be used. Even when this approach is inappropriate the results should not be reduced to a single average figure because maxima are often critical.

Industrial wastes require a rather different approach because generation rates are much higher and the wastes are more homogeneous. The WHO Rapid Assessment guide (8) is a useful starting point.

Projections of quantities and characteristics are important when new equipment is being chosen or designed. The best projections are derived from measurements made in the same way at the same time of year over a number of years. If such values are not available trends observed in other locations of a similar nature can be useful, and variations between socio-economic groups can also suggest developments, if it is assumed that the overall standard of living is rising. Industrial production targets may also be of some help. But the lurking threat to any projection is the sudden change of packaging of a popular item made in the name of progress or economy or because of a change of supplier. Examples are the change from the returnable glass bottle to the metal can, the paper carton or the PVC semi-rigid bottle.

Refuse generation rates are an important element in the design of an efficient collection system. Refuse densities also must be known. In some cases the breakdown of the solid waste into its components is necessary. But there are many situations where the obstacle to good solid waste management is not the lack of technical information about the wastes, but rather a lack in the organizational, supervisory or maintenance spheres. In these cases the blame must not be attributed to the lack of comprehensive data.

Careful observation on a day-to-day basis is far better than a large and complex table of figures.

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STORAGE AND COLLECTION  
OF SOLID WASTE

by

Dr Adrian Coad\*

## 1. METHODS AND PROBLEMS

(a) Introduction. The design and operation of a solid waste collection service is much more challenging than most of the work that engineers are doing today. The task involves a large workforce and requires the cooperation of all of the public. The choice of systems available is very wide and the apparatus that is used must be carefully selected from a large range and must perform at a very high level of reliability and withstand abuse. Solid waste management is an expensive undertaking which is always in the public eye. The need for clear thinking and good management should not be underrated.

The most important consideration is reliability. The residents must play their part, and so to help them develop the necessary habits the service must always be provided as promised. The residents will not do their part if they feel that the collection agency is not doing its part. The service must be dependable in spite of vehicle maintenance problems - vehicle failures must be expected and allowed for in the plan. The service must be dependable in spite of absenteeism - management must aim to minimize absenteeism and have an emergency pool of replacements. The service must be dependable in spite of the weather - equipment must be provided such that the

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labourers can continue to work in the rain, and tip managers must have contingency arrangements. Dependability should be valued more highly than theoretical efficiencies or prestige. Dependability requires careful analysis of the local situation so that the methods used are appropriate. Dependability comes from flexibility so that in a crisis there are alternatives.

The subject of refuse storage and collection is too large to be covered comprehensively in one paper; for further information Flintoff's book<sup>1</sup> is highly recommended. The reader is also referred to the author's paper on street refuse since some of the points made there are relevant to the subjects of this paper.

(b) Point of collection. In areas of unplanned housing where access to each property is very restricted, communal storage is appropriate; residents are responsible for bringing their refuse to the communal container. This method is also used in other situations because of its cheapness.

High-rise buildings may employ chutes down which refuse is sent to a communal bin. Provision must be made for cleaning and unblocking the chutes, and residents must be encouraged to wrap their refuse to prevent fouling. The arrangements for emptying the central hoppers must be flexible so that the failure of one particular vehicle does not interfere with the removal of the waste.

Collection directly from the householder's bin to the refuse vehicle can take place in several ways. The cheapest is street-corner collection, in which residents are advised of the approach of the collection vehicle by means of a bell, hooter or loudspeaker. The residents must then bring their bins out to the vehicle. However,

since in many cases there may be no one at home during collection periods such a method may be unsatisfactory.

The next cheapest door-to-door method is kerbside collection, for which residents must leave their bins by the roadside on the appointed day. For this method to succeed dependability is essential; the waste must be collected on the right day. The presence of the bins by the roadside renders the contents liable to scattering by human or animal scavengers and the bins liable to theft or damage.

Yard collection requires nothing of the resident except that he does not lock the door giving access to the place where the bin is kept, so that a refuse worker can take the bin, which will be returned later. Often one man walking ahead of the collection vehicle brings the bins out, another man with the vehicle empties them, and a third man takes them back. The second entry of the premises can be avoided if bins are exchanged - the labourer taking in an empty bin before taking the full one out - or if the bin is emptied into the collector's own bin in the yard. Disposable sacks also save the second journey. Yard collection is not appropriate where the entry of the refuse worker would be regarded as an unacceptable invasion of privacy.

Door-knocking collection is perhaps the most time-consuming because the collector must wait for a resident to answer his knock and bring the refuse to him. There is, however, no intrusion of privacy.

Pipeline collection is used on an experimental basis at a few sites around the world. The water-carriage system includes a grinder so that food preparation wastes can be carried away in normal waste pipes, either to a separator in the same building or to the sewage treatment works. In the vacuum system a large vacuum pump and valves which open in sequence, draw even quite large items of refuse

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along ducts. The capital and operating costs of these systems severely limit their application.

(c) Frequency of collection. The frequency is primarily determined by the need to control fly breeding; the refuse must be disposed of before the adult fly emerges. Therefore in cooler climates once a week is quite satisfactory, but in tropical locations twice a week is preferable. Communal facilities must be emptied more frequently than householders' bins because the refuse may have been several days in a private bin before it was brought to the communal one.

Collection may be required at closer intervals if the volume accumulated is great, as in markets where more than one collection each day be necessary. The odour or aesthetic unacceptability of the wastes may also call for more frequent collection.

(d) Storage containers

(i) Communal storage. A satisfactory communal storage system has yet to be designed for developing countries. Table 1 lists briefly the requirements for such containers, the various types, and their shortcomings. The spacing between the storage facilities is very important for, although money can theoretically be saved in land acquisition, construction and operation by having fewer, bigger containers, in fact the total cost will increase if people are unwilling to walk further to deposit their rubbish, and simply dump it on the road. A maximum walk of 100 m may be acceptable in most cases. The loading time is also important. Often large trucks are loaded by shovel or basket - a practice wasteful in both labour and equipment.

REQUIREMENTS FOR COMMUNAL REFUSE CONTAINER (Order is not significant)	TYPES OF COMMUNAL REFUSE CONTAINERS AND THEIR DRAWBACKS	
a) sufficient volume b) accessible to children c) can be emptied quickly and without skin contact d) acceptable cost e) satisfactory in rain (but propped or sliding lids are left open) f) durability g) reliability (should not depend on the availability of one particular type of vehicle) h) refuse not available to human or animal scavengers which would scatter it i) not liable to damage or theft	Type	Requirements from column 1 <u>not</u> satisfied
	Masonry enclosures Permanent hoppers with lids Skips and removable hoppers 1 - 3m <sup>3</sup> bins emptied into trucks Oil drums or 70 litre bins Trailers Elevated enclosures (Figure 1)	c, e, h b? c, e b? d? e, g d, e, g a? e, f, h, i b? d? e, i d? h?

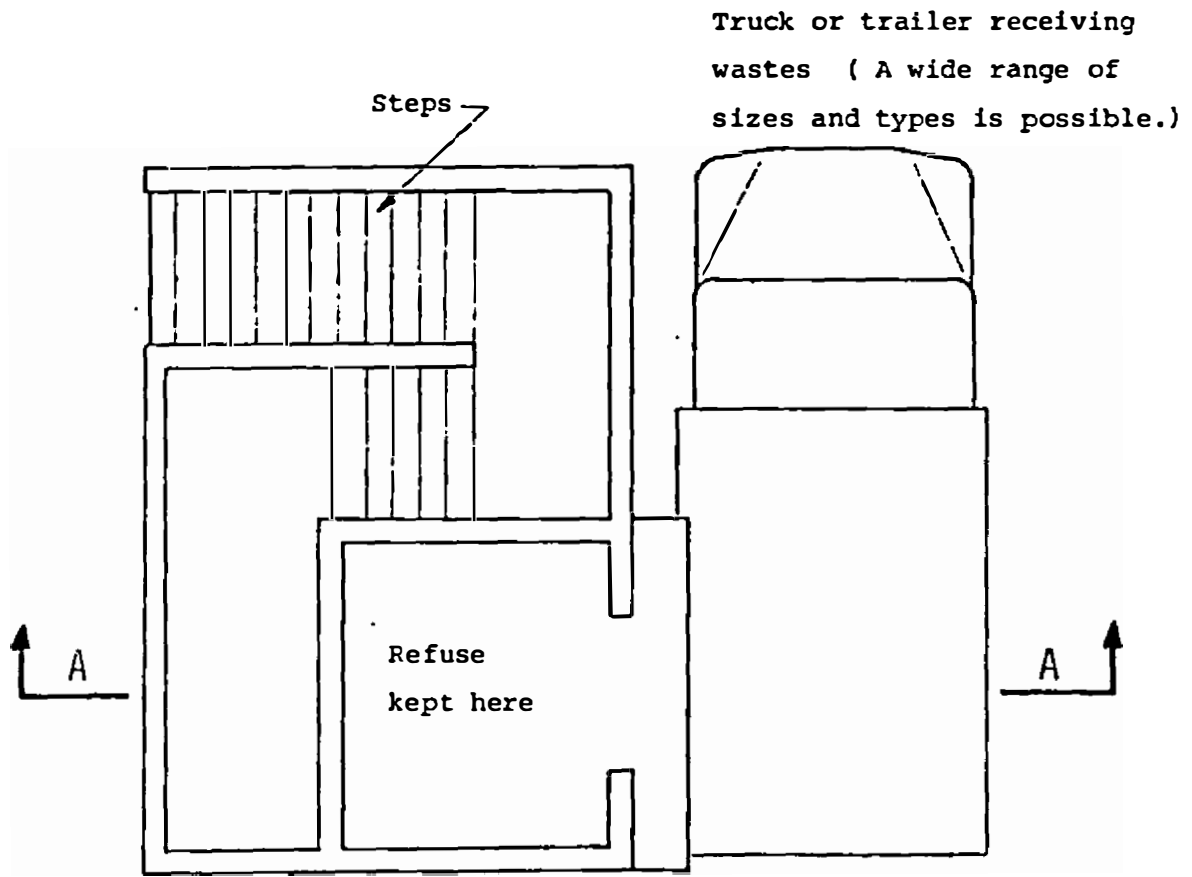
Table 1. SUMMARY OF PERFORMANCE OF VARIOUS TYPES OF COMMUNAL STORAGE FACILITIES

(Loading can occupy 75% of a vehicle's time if done inefficiently. If that time were cut to 50% the vehicle fleet could be halved).

A trailer can provide an efficient means of storage where sufficient refuse accumulates in two days to fill it. The elevated enclosure (figure 1) has not been widely used, but it has several advantages, notably the ease with which it can be emptied into almost any type of open truck, so that, in an emergency, a tipper truck hired from a general haulier could be used to maintain the service.

A facility that belongs to everybody is nobody's concern. If no-one is appointed to supervise and maintain a communal facility it may be used carelessly. If people see that refuse has been dumped on the ground near a communal bin they will probably dump theirs on the ground too. Therefore every effort must be made to keep the surroundings clean and to encourage residents to deposit refuse responsibly. Children usually deliver the waste to the storage unit, so cooperation with schools, and incentives should be considered.

- (ii) Storage in the home. If the refuse can be stored in a bin with a lid, outside, the collection frequency can be lower. Unsatisfactory household containers such as buckets and boxes expose the wastes to animals and flies, and the neighbours to unpleasant odours. Very often householders are supplied with, or required to purchase, standard bins with lids. These bins may, however, be stolen or used to



PLAN ( WITHOUT ROOF )  
ELEVATED REFUSE ENCLOSURE

FIGURE 1A

store other materials or water. Their cost is often too high for significant proportions of the population. The size of the bins must be sufficient to hold wastes generated in periods that include public holidays.

In Zimbabwe reusable sacks made from recycled plastic are issued instead of steel bins. The sacks are emptied into the collection vehicle and returned to the householder. The life expectancy of the sacks is six months. The mouth of the sack can be tied to prevent fly and odour problems.

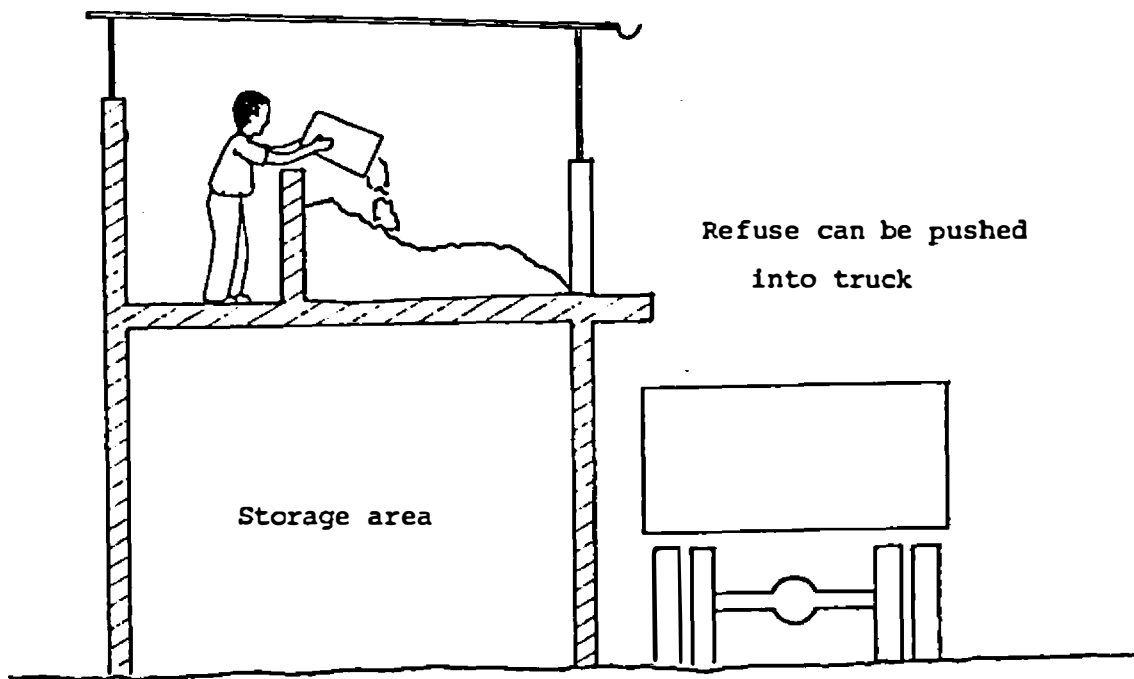


FIGURE 1B

SECTION A - A

Disposable sacks take two forms. Kraft paper sacks are hung from a frame and are strong enough to support usual weights of refuse. Plastic sacks are used as bin liners because they are more easily torn, but they are strong enough to contain the refuse when it is loaded into the truck. In Britain there are differences of opinion about whether they actually save money. One advantage is that only one trip into each house is necessary so that the cost of the bags is offset by the saving in manpower. Another is that bins remain clean and spillage and dust are reduced. The drawbacks are the probable slowing of settlement of landfills and the hiding of items of value where recycling is practised. Where wage costs are lower than in the U.K. they would not be economical. Hot ashes in the refuse cause fires and rule out the use of plastic or paper for containers.

Where wastes are generated in large volumes, containers of one to three cubic metres capacity are common. In most cases these are loaded into compactor trucks by hydraulic mechanisms. The number of bins may warrant only one truck, but at least one extra truck is necessary as standby, making a very high total cost. Furthermore it is quite possible for both to be out of action at the same time. Therefore a more flexible and simpler system - such as tractors and trailers or portable containers - is recommended.

(e) Collection vehicles

(i) General

It is essential that the engineer choose the vehicles, since he will be able to determine the best choice and will not

be misled by smart salemen or ready-made financing. In choosing the most suitable type of vehicle the engineer should consider what type of vehicle is already in widespread use on other business in the locality because spare parts and mechanics will be easier to find for this type. The width and condition of the roads should also be considered; some vehicles may be too wide or too heavy or not robust enough for bad surfaces. Traffic congestion and speed may also influence the choice because in some conditions faster vehicles will have little advantage. Standardization within the fleet is vital to keep stocks of spares to a reasonable level (and to allow cannibalization in extreme cases) and so that the mechanics are well acquainted with all the vehicles. Refuse collection vehicles must not be shared with other departments because refuse trucks need larger bodies than general purpose tippers and because the need for refuse collection vehicles is constant so that they cannot be spared to go elsewhere.

Maintenance is the key issue in refuse collection. Table 2 shows some serviceability figures for Nigeria and Zambia to illustrate the seriousness of the problem.

Preventive maintenance procedures (whereby vehicles are called in at regular intervals for checking, replacement and adjustments) should be practised faithfully because this approach improves reliability, saves money and aids planning. Record-keeping is an important aspect of preventive maintenance; the records also indicate how specifications for new vehicles should be modified to cope with local conditions, and which drivers cause more wear to their vehicles. A chart of the number of

Table 2. Availability of Refuse Vehicles for Service

Location	Total number of vehicles owned	Number available for use on day of visit	% serviceable
Ibadan, Nigeria (2)	56	16	29
Warri " "	5	1	20
Onitsha " "	26	2	8
Uyo " "	4	0	0
Kaduna " "	25	4	16
Kano " "	40	10	25
Lusaka, Zambia (3)	55	16*	29

\*Some of these vehicles are being operated with defective hydraulics.

vehicle-days worked each week would provide encouraging feedback to the mechanics, and the encouragement would be even greater if the weekly vehicle availability were linked with a bonus.

Vehicle operations should be studied to pinpoint unnecessary holdups or excessive unproductive travelling in the daily schedule. Examples of these are queues for fuelling, queues for unloading refuse, or long journeys to the collection area. Often relatively simple remedies can boost productivity. Tachographs have been used to monitor vehicle speeds and waiting (or leisure) time, but such instruments may not withstand rough conditions for long.

It is often necessary to transfer refuse from a small, short-range vehicle (such as a handcart) to a larger, faster vehicle. Such facilities should be designed to minimize refuse handling, health and environmental hazards and obstruction to traffic. The refuse should not be dumped on the ground, but transferred in bins or by means of a split-level layout. (The designer should remember that loaded handcarts cannot easily be pushed up steep slopes). The cost of a transfer station will have at most a very small foreign exchange component, and the investment will give a good return for many years. This facility can also serve as a parking area for local collection vehicles.

(ii) Types of vehicle

Handcarts are useful where roads are flat and surfaces good. A well-designed handcart is stable yet manoeuvrable, it is comfortable to push and its wheels have good bearings and rubber tyres. If well maintained it can project a favourable image of the solid waste agency. The range is limited to about two kilometres and the payload to about 200 kg. At least 200 dwellings can be served in one day under suitable conditions.

Tricycles with a hopper, or a tray for carrying bins, are appropriate in low density areas because of their higher speed.

Animal-drawn carts have a range of at least 3 km and a large carrying capacity. They should be considered wherever such carts are used for other purposes. Panniers on animals can be used in steeply-sloping areas.

Small two-stroke motor tricycles, fitted with tipping bodies, are sometimes used, but they have several disadvantages,

including their cost, the need for a driving licence, the need for a workshop to repair a large number of vehicles which are constantly stopping and starting, the noise and fumes which are particularly unpleasant in narrow alleys, and their instability on rough ground. Their advantage is speed to and from the collecting area.

Electric vehicles are quiet and well-suited to stopping and starting, but their first cost is high and repair know-how and spares are likely to be rare. With some types the driver rides, with others he walks.

The tractor and trailer combination has many advantages. Compared with trucks, tractors are cheap. They are simple, robust and widely used, so maintenance is less of a problem. Tipping trailers can be fabricated locally, and one tractor can be responsible for several trailers. The low speed of the tractor is a disadvantage in certain traffic conditions and where haul distances are long.

The conventional tipper truck is not designed for low density materials like solid waste and so its capacity is small unless the sides are built up - in which case loading from ground level is impossible. Tarpaulins or nets can be used to cover the refuse to prevent it being blown away in transit, but good discipline is needed to ensure that they are properly used. Unloading is simple and the trucks are generally strong enough for rough tip conditions.

Side-loader trucks are specially designed for refuse collection. They have a low loading height (1.6 m or less) and a large body to carry their full payload. They have sliding

shutters to prevent waste blowing away in transit (but such shutters have been known to jam). The body tips to unload.

Skips can be left at transfer stations and communal storage sites.

The most common size is too small to carry an efficient load of domestic refuse because it is designed for construction waste, but larger types are available. "Roll on - roll off" skips of 20 m<sup>3</sup> capacity are also used. Most types need a tarpaulin cover.

Tip loaders aim to fill an enclosed body by tipping it at intervals - the front loader tips backwards only, against closed doors to load, and with doors open to unload. The "fore and aft" tipper tips forwards to load and backwards to unload. Loading heights tend to be high.

Many people think of compactor trucks as the only modern means of collection but in fact they are only appropriate under certain conditions. This type of vehicle is designed for wastes of low density and high compressibility, and where wage levels are high compared to equipment costs. Most models are heavy and wide, and all are much more expensive than simpler types, both to purchase and to run. But the main problem is maintenance; most types have sophisticated hydraulically-operated loading mechanisms which need a good supply of spare parts and well-trained mechanics. In many situations a compactor truck is an unnecessary extravagance which changes, almost overnight, into an embarrassment.

(iii) Further suggestions

(a) All applications for planning permission for new buildings should be subject to recommendations from the solid waste management agency concerning access and provisions for removal of refuse.

(b) Refuse vehicles should be serviced and repaired in a workshop specifically devoted to them, or should be guaranteed priority in the municipality's central workshop.

(c) Central government should assist in the development of refuse vehicle maintenance centres by providing a training and troubleshooting team to advise on maintenance.

(d) Engineering students at universities should be invited to assist in planning, designing or monitoring of storage and collection systems as their project work; the solid waste management service would benefit from their fresh approach and the students would develop an interest in this subject.

(e) Participants in the workshop should contribute to an annual newsletter, sharing their experiences with different types and makes of equipment and with new approaches to management issues.

2. COMPARATIVE COSTS AND ECONOMIC ASPECTS

Solid waste management absorbs 20% to 40% of many municipal budgets<sup>4</sup> and usually about 80% of this share is spent on storage, collection and transport, so it is most important that the money is

wisely spent and that the methods used are the most economical. However, the economic analyses and the equipment choices must not be made without regard to realistic estimates of reliability and down-time. If a machine is supposed to work continuously for the purposes of costing, and it is actually serviceable for only 30% of the time, the costing is very inaccurate.

Cost comparisons must be made for a wide variety of decisions. For example, the choice of type of communal container would depend on cost, amongst other factors. Similarly, cost information would be considered in the choice of collection system - whether it should be communal or house-to-house, and if the latter, which method should be used, and whether disposable bags would produce a saving, etc. Other choices that require costing include the method of loading from communal enclosures or transfer areas, whether refuse should be taken directly to the tip or transferred to another vehicle, what type of vehicle should be purchased, and what size of crew is most efficient.

Cost comparisons are not universal. For each situation the local data must be collected and analysed to provide a conclusion specific to that situation. It should also be remembered that the results of a cost comparison, no matter how complex, will never be more accurate than the data fed into it; unrealistic costs and rates will produce unreliable conclusions. The appendix shows examples of cost comparisons which the reader might use as examples. Some of the factors that cause differences in input data for different times and locations are discussed below:

(a) Costs of equipment and materials are affected by supply and demand (for example 200 litre oil drums are becoming much more

expensive in some places); they are affected by marketing strategies (for example a manufacturer may wish to gain entry into a new market and therefore lower his price); costs of imported goods are influenced by transport costs, excise duties and exchange rates.

(b) Interest rates vary significantly, and different interest rates can lead to markedly different conclusions when capital-intensive methods to be amortized over long periods are compared with labour-intensive methods. Calculations should be performed for a range of interest rates to examine the sensitivity of the conclusions to the interest rate used.

(c) Unskilled labour costs differ very greatly from place to place, having a profound effect on cost comparisons for refuse collection especially, since it can be a highly labour-intensive activity. Manpower costs should always include superannuation, leave and sickness allowances, and overheads. The costs of maintenance and administration also depend on location.

(d) Comparisons of different working methods require information on rates of working - such as the number of dwellings that a handcart can collect from in one day, the time taken to load a specific type of vehicle, or the average speed of a tractor and trailer on their way to the disposal site. These, and other rates, are influenced by factors such as: type and density of housing, access to dwellings, topography, climate, refuse characteristics and generation rates, working hours per day, road surface conditions, traffic density and distance to the disposal site. Many of these rates can be determined by work study, which must be carefully executed, with everyone involved understanding the purpose. The most difficult information to gather concerns the response of the public and the serviceability of equipment.

The influence of public response can be illustrated by a comparison of communal storage and house-to-house collection: the former would be cheaper if it did not result in widespread indiscriminate dumping, but if it did the extra cost of street sweeping might tilt the balance the other way.

General statements on equipment costs can be made (for example tractors are cheaper than side-loading trucks, and side-loaders are cheaper than compactors), but the costs of the total system must be evaluated for each specific case.

A few comments on finance are appropriate here. Financial planning is essential to solid waste management so that regular replacement of vehicles and expansion of the fleet are allowed for. If the agency is not able to plan, but goes from crisis to crisis, reliability and morale will be low, and standardization of the fleet will be a remote dream as loan arrangements made by equipment manufacturers are hastily seized upon. Failure to pay wages promptly rapidly lowers morale and increases absenteeism.

It is not generally satisfactory to collect revenue for refuse management separately from other taxes because of the extra clerical work involved and because of a lack of sanction against defaulters. (If a householder refuses to pay for the collection service and therefore the service is withdrawn, he can easily dump his refuse outside a neighbour's house so that he himself suffers very little inconvenience, whereas if his water were cut off he would pay).

The size of the foreign exchange component of a cost can have a pronounced effect on the choice of method or equipment.

An issue which has caused considerable debate in some quarters is whether collection should always be done by a public body or whether

it should be offered on tender to private contractors. Private contractors are probably more motivated towards efficiency and a fixed-sum contract simplifies financial planning. In situations where it is almost impossible for a public body to dismiss employees for incompetence or inactivity, the freedom not to renew a contract leaves the officer-in-charge with some influence over performance. But if a contractual arrangement is made it must stipulate performance standards so that, for example, the failure to empty all the appointed bins on a particular day would attract a financial penalty. A contractor is more interested in personal profit than environmental and health factors, and if the duration of the contract is short he may be unwilling to purchase appropriate equipment, fearing that the contract will not be renewed. (Some contracts include leasing of vehicles from the municipality or an agreement to purchase vehicles from the contractor if the contract is not renewed). Competitive tendering may force the price down so low that the contractor is unable to perform satisfactorily. In some cases contractors may be interested in only the prosperous areas where the salvageable content is higher and the access easier. If the work is contracted out, the public body should maintain close supervision and should retain disposal as its own responsibility because of the long-term implications.

To conclude, three points should be reiterated. The first is that cost comparisons are not universal, but must be calculated for each situation. Secondly, because of the importance of reliability and difficulties in obtaining foreign exchange, the cheapest alternative will not always be preferable. Thirdly, data on reliability and actual performance should be used wherever possible when alternatives are being costed.

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Source	Section or page	Description	Location	Date	Interest rate	Conclusion
Flintoff <sup>1</sup>	Ch.10	Productivities for different collection vehicles	-	-	-	-
Flintoff <sup>1</sup>	Ch.11 Fig.12,13	Optimum crew size at two wage levels	-	-	-	Optimum crew size depends on ratio wage costs: vehicle cost
Flintoff <sup>1</sup>	s.11.2	Vehicle operating costs	India	1975	10%	Comparisons not made
Flintoff <sup>1</sup>	s.11.3	Comparative costs of systems	India	1975	10%	Costs per tonne e.g. portable communal bins Rs20; house-to-house with truck Rs106
Cointreau <sup>4</sup>	p.55	Manual loading vs front-end loader	India	1980	Not used	Ignoring interest, mechanised is cheaper
Cointreau <sup>4</sup>	p.59	Direct haul or transfer	Nigeria	1980	Not used	In that case transfer is cheaper
Cointreau <sup>4</sup>	pp.66-7	5 collection vehicle alternatives	Sri Lanka	1982	16%	Tractor and trailers cheapest
Cointreau <sup>4</sup>	Annex D,E.	Guide for preparing costings	-	-	-	-

## STREET REFUSE

by

Dr Adrian Coad\*

## 1. INTRODUCTION

The problems and challenges of the task of keeping the streets clean are mostly in the realm of man management; only in a few cases are the difficulties of a technological nature. The successful manager considers how to give responsibility to all who work under him, he considers how to encourage high standards by giving incentives, he aims to keep the morale of his workforce high and give them a pride in their work, he ensures that supervision is effective and that lines of communication are kept open, and he is concerned for the health and welfare of his employees. A good manager will also provide the most appropriate tools for the job and endeavour to plan all operations in an effective way. All these points may seem obvious and too general for an article of this nature, but where the city streets are not clean the reason will usually be shortcomings in the areas listed above.

An organizational problem that occurs too frequently is the failure to centralize responsibility for refuse collection, street sweeping and clearance of open drains. These functions are linked physically and managerially and so should be under the same administration. In one city where these responsibilities are not linked, the person who clears the drains does not take away the material he has cleaned out, but must request someone else to cart it away. The

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resulting delay means that the material is knocked or washed back into the drain before it is removed. In another case one man clears the drains and leaves piles of debris at the roadside, which the road-sweeper later sweeps back into the drain. It is difficult to know which detriment is worse - the effect on the environment or the effect on the morale of the cleansing workers - when such lack of co-ordination occurs. The author observed a very satisfactory arrangement in Iran, where one man was responsible for all the functions: refuse collection, sweeping, drain clearance and irrigation of roadside trees. This system gave responsibility and the possibility of pride in one's work.

There are other relationships between refuse collection and street sweeping. If the refuse collection service is inadequate, more refuse will be left to litter the streets. It is more efficient to load wastes from a container than to first sweep them up from a wide area and then load them, and therefore it is important to have an effective refuse collection system. Overzealous attempts to trim the collection workforce will result in the need to add a larger number of men to the street sweeping side, unless the refuse is left to pile up in the streets. A very rough guide to the effectiveness of the collection system may be obtained from the ratio of the number of men involved in collection to the number involved in sweeping. If the ratio is less than unity there is probably scope for making considerable savings by improving the collection system.

In certain situations there are other possible links between the two functions. Where street sweeping and refuse collection are performed by different people, some of the sweepers should be trained in collection procedures so that in the event of illness the sweeper

can deputize on the collection crew to maintain the regularity of service. Where communal refuse storage is used and a supervising labourer is required at the storage sites, the same man should be responsible for sweeping in the area. Refuse transfer depots can also be used as street sweeping depots. So street sweeping and refuse collection should be in the same organization.

#### Types and sources of street refuse

Natural wastes include dust, tree debris (blossoms, seeds, leaves and branches) and animal excreta.

Litter can be defined as wastes caused by carelessness of people on the street as they spit, or drop paper and food waste.

Domestic and shop wastes may be swept onto or left on the streets and may be the result of inadequate storage and collection. They may alternatively be caused by a refuse collector in a hurry. In many situations it is not possible for a sweeper to follow a collection crew around because collection is a faster process.

Markets and roadside stalls produce large quantities of waste in a short time and in a confined space. The refuse is often rapidly putrescible and must be removed quickly. Special attention must be given to such areas.

Human excreta is particularly offensive, both aesthetically and from a health standpoint, and may pose a particular problem where many dwellings do not have satisfactory toilets. The necessity of removing such material will downgrade the job of sweeper severely in most people's eyes.

Traffic wastes include oil, rubber, mud and broken glass from motor vehicles, and animal droppings. Spilled loads may also

seriously contribute. Animals killed by accidents pose a particular problem. Mud on the road causes vehicles to skid in wet weather.

Bulky wastes include old tyres, discarded furniture and unrepairable domestic appliances. A special team with an open truck or cart is needed to remove such wastes.

Abandoned cars, often with all removable parts removed, are a nuisance in some locations. It is occasionally possible to trace the owner, but usually all identification marks are removed. In some countries such wrecks pose a serious problem, and their handling requires special equipment; perhaps a team able to handle car hulks could be shared between a number of towns, and visit each in rotation.

Locations. Public open spaces attract litter. Vacant land often becomes a dumping ground and so poses a problem. The owner may be obliged to build a high wall around it to screen it from view or be responsible for keeping it clean. A periodic clean-up campaign involving schoolchildren is a third alternative.

Road carriageways are often free of low-density refuse because of air turbulence caused by passing cars, but animal refuse and mud are not easily removed because of the danger from traffic accidents. The pedestrian areas require sweeping. If the drainage system consists of buried sewers and shallow gutters the walkway refuse can be swept into piles in the gutters. If open drains are used every effort should be made to keep refuse out of them; their depth makes cleaning difficult and if they contain water they will make the refuse both heavier and more unpleasant.

## 2. METHODS OF COLLECTION

In choosing the equipment both the user's preference and efficiency should be taken into account. For this reason all equipment should be subject to a trial in normal conditions and evaluated by all concerned. If mechanical equipment is being considered, great attention should be given to the availability of spare parts and the skill and available time of the mechanics, because reliability is vital. The mechanized approach may appear much more efficient on paper, but the efficiency of a broken machine is zero.

Sweepers need brooms, shovels and boards. The bunch broom, made by tying a bundle of fibres together, is suitable for loose surfaces and light refuse, and some people can sweep with it comfortably for long periods. But generally the stock broom is more appropriate; a narrow, very stiff one might be used for channels, with a wider (500 mm), softer one for pedestrian areas. As they are worn down they must be repaired or replaced. Records of replacement rates for different types would indicate which type of bristle gives the best value. Two shovels may be necessary - a flat one for picking up piles of refuse and a curved one for deep drains. A pair of boards is useful for picking up leaves.

Removal of street refuse involves two operations: sweeping or collecting, and transport. If the area cleaned is to be maximized the time spent on transport should be minimized, and this can be done by reducing the distance that the wastes must travel before being unloaded or by reducing the number of trips. Usually the refuse is carried in a handcart to a transfer depot from where it is carried in bulk by another vehicle. Transport time is therefore minimized by siting transfer stations close together and by using handcarts which can

carry as much waste as possible, so that fewer trips each day are required. A well-designed handcart on smooth, level roads can be used to carry up to about 200 kg; if the refuse density is known the required volume can be calculated. The handcart must have brackets for carrying all the tools that the sweeper requires.

A refuse management authority that is concerned with its public image can be attracted to sophisticated machinery by the glossy pictures of powerful mechanical monsters that are distributed by manufacturers. Such equipment makes a good impression - until it breaks down and lies useless, waiting for spare parts. A cheaper and longer-lasting means of making a good impression is to keep simpler equipment well painted and in good working condition. If each labourer has equipment assigned to him as his responsibility and incentives are given for maintaining it well (for example spot-checks leading to cash benefits for the best-kept cart), the public image of the agency will rise. The introduction of a bright uniform and other measures promote good morale and job satisfaction amongst the workforce.

The transfer stations, which enable unloading of the sweepers' carts and the loading of the wastes into another vehicle, also can serve as a parking area and store for carts and as an administrative office. The provision of toilet and washing facilities and a covered area would be appreciated if a meal-break is taken after a load is brought in. The actual loading of refuse should not be done with shovels or baskets from a pile beside the truck, but rather by means of bins which can be emptied into the vehicle or by bulk loading from a high level platform in a split-level arrangement. If bins are used

they should be sized so that they can be lifted without causing injury and the handcarts should be able to carry enough of them to give an efficient load. They should be locked in place on the handcarts to discourage theft. The bin system requires that there is always a container - a skip or a trailer - at the depot to receive the wastes, or else that there is a sufficient supply of empty bins for which full ones can be exchanged.

In most city centres there is very little space for transfer stations, so there is a tendency to try to do without a permanent site with the result that refuse is piled up at the side of the street for laborious and wasteful shovelling into trucks, or the street sweepers waste time making rendezvous with the trucks. Alternatively the pressure on land may cause the transfer stations to be spread out with large distances between them, so that sweepers must walk a long way to their beats. If the unproductive walking distance is over one kilometre consideration should be given to the use of tricycles. (If tricycles are to be ridden with a full load their capacity must be less than a handcart's).

The efficiency of the operation depends not only on the choice of tools and motivation but also on the planning of the sweepers' routes or beats to minimize unproductive travelling. Generally men should work individually, but teams should be used where a large volume of waste must be cleared in a short time, as in markets. Animal carts or electric or motorized vehicles may be needed for team operation.

The supervisor (or foreman or ganger) is of great importance. He should spend his time in the streets, not in an office. He must have a bicycle or other means of transport to enable him to visit every part

of the area he is responsible for. It may often be necessary to relocate a man when he is promoted from sweeper to supervisor because it will be difficult for him to establish his authority amongst his former equals. An observant foreman is often in the best position to see how improvements can be made so his suggestions should be welcomed by his superior, who should consider them carefully and discuss his conclusions with the man who made the suggestions. A bonus for a good suggestion can save money.

The 'finish and go' system may not be as successful in this area as in refuse collection (when the number of bins to be emptied is defined), but it still has some advantages. The supervisors must be very alert so that a slipshodsweeper does not "go" before he has properly "finished" the day's allotted work.

Mechanical sweepers seem attractive because they appear impressive, they promise efficiency and they suggest an escape from the problems of supervision of a large workforce. There are two basic types - smaller pavement sweepers for large, paved pedestrian areas, and larger road sweepers - but they operate on similar principles. Road sweepers are generally designed to sweep into gutters and not for deep drains. The sweeping equipment may be mounted on a standard truck chassis or the whole unit may be purpose-built. The main features are:

- (i) a system of two to four revolving brushes which sweep the road surface and against the kerbstones;
- (ii) a water spray system to control dust around the brushes;
- (iii) a vacuum pump to draw solids into a hopper;
- (iv) a "wander hose" which can be used for cleaning leaves etc. out of recesses;

- (v) a hydraulic tipping mechanism to unload the hopper.

Whilst these facilities seem to be very advantageous, there are several reasons why any proposal to purchase this type of vehicle in many developing countries should be rejected:

- (i) These machines require highly skilled maintenance and a ready supply of spare parts. They are very complex and specialized; most of the spare parts needed would not be held elsewhere for other purposes. Some types have two different motors, their control gear is complex and the brushes need regular replacement. It follows that they may operate for only a short period before a fault renders them unserviceable. The author heard of one case where they lasted only one month. The efficiency of a broken machine is zero.
- (ii) These machines are designed for uniform and firm road-surfaces. Where the surface material is weak it may be dislodged so that the road sweeper becomes a road remover.
- (iii) Purchase of these vehicles requires considerable foreign exchange.
- (iv) While operative, these machines take the jobs of men and women and wherever unemployment is a problem, this will be socially unacceptable.
- (v) These machines are not suitable where cars are parked; a prohibition on parking on certain days is difficult to enforce.

There is an attitude amongst some senior officials who authorize purchases that the acquisition of a piece of equipment or the building of a facility solves the problem in question. What they fail to realize is that it is not the acquisition but the day-to-day operation at full efficiency, that achieves the goal.

If mechanical sweepers are to be used anywhere, they should be kept for busy urban roads where parking is not permitted, largely from road safety considerations. However in this situation a team of men would be safe if an animal-drawn cart with a large, reflective warning sign were used and kept between them and the oncoming traffic.

Litter bins should be located in busy areas, especially where wastes are likely to be generated. They should have a neat appearance and be easily visible. A good litter bin is easy to empty, is not destroyed by fires which might accidentally start inside, does not allow the wind to scatter the contents and does not fill up with rain-water. The maximum size is set by the requirements for emptying and the need to avoid causing an obstruction. Litter bins are normally emptied by street sweepers.

### 3. ENFORCEMENT

There are three important steps that should be taken before legal sanctions are used to prevent littering and indiscriminate dumping of refuse.

The first step is to ask why the wastes are dumped. It may be that there is no satisfactory alternative in many cases. If the collection of domestic solid waste is irregular or at too low a frequency, residents may dump their refuse on the street because their containers

are full or the smell and condition of the wastes are too bad to keep on the premises. Defaecation on the streets may be a result of the lack of latrines and a programme of latrine building may be the first step to cleaning up the streets. Bulky wastes may be the problem if the refuse collector is unable to take them; if so a collection service must be instituted that will take away garden refuse, old furniture and other large items. If a charge must be levied it must be modest, because the alternative of removing such items from a canal or waste ground would not be paid for, and would be a more expensive operation. It is also important that the existence of such a service be well publicized. Litter may be thrown onto the streets because there are no litter bins or because the bins are full; remedial action should be taken. So the first step to enforcement is to ensure that the citizen who wishes to cooperate can do so.

The second step is to consider the power of example. On the negative side, solid waste management agencies are often amongst the worst offenders with regard to street refuse. Collectors may be careless in their hurry to load refuse and so spill some on the street. Some "transfer stations" are simply piles of solid waste dumped on or beside a road, and some of the waste may even be left at the end of the day. Refuse vehicles carelessly loaded spill their load on their way to the tip, and on the way back spread mud on the road because no wheel cleaning bars have been installed on the site road. Actions speak louder than words. The agency must first set a good example. On a more positive note, people are less likely to discard waste in a clean street, where they are the first to do so, than in a littered street. We often accept the standards of those around us. As people see a higher standard set in the surroundings, there will be a tendency to follow.

When facilities are provided such that there is an alternative to littering, and when the refuse agency has put its own house in order, it is the time to educate the public. A coordinated campaign involving schools and television should be launched. Health hazards, the benefits of a clean environment, each person's responsibility, and refuse collection procedures should be simply explained. A competition amongst schoolchildren for the best posters, and the enlistment of help from sociology students, would both increase the impact. It could also be stressed that, contrary to the opinion of many, open drains are the worst place for refuse, and that citizens' cooperation could reduce costs to the local taxpayer.

Enforcement by legislation can only be effective when the public knows of the laws and generally respects them. Unrealistic requirements and excessive penalties devalue the law. When the three above-mentioned steps have been taken, laws relating to the following aspects should be introduced or reactivated: dumping of wastes in public places (with stiffer penalties for using open drains), interfering with refuse bins (scavenging), misuse of litter bins (e.g. for domestic or trade waste), shedding of vehicle loads, and spitting. Legislation requiring market stall-holders to have a bin and maintain the vicinity of their stall in a clean condition might also be of benefit. Small, on-the-spot fines are more appropriate than cumbersome court procedures.

Legislation rarely lives up to its promise. Cooperation is better than coercion, and wherever possible, by liaison with community leaders and by campaigns in the media, the support of the public should be courted.

#### 4. ECONOMIC ASPECTS

The main challenge for the economist is to suggest the level of resources that should be devoted to solid waste collection from houses etc. directly so that the total expenditure on both refuse collection and street sweeping is at its minimum. In most cases the concentration of more effort on collection would take the total cost downwards. However, because (to the author's knowledge) there are no mathematical models to allow computation of the ideal, the only means left is the pilot study, in which the effects of different levels of service are studied.

In most industrializing countries there is no need for economic analysis to compare capital intensive and labour-intensive methods because of the difficulties in maintaining the sophisticated equipment concerned. Where compacting refuse vehicles have been in operation for 5 years or more, and no more than 15% of them have been off the road at any time, the availability of spares and the level of maintenance may be sufficient for mechanical sweepers to be considered. In estimating the operational costs, full account must be taken of maintenance costs and downtime. Financial packages, in which the supplier arranges a loan, seem attractive but are often regretted when the shiny new machine becomes solid waste itself.

There is no simple formula or rule of thumb for estimating manpower requirements and planning beats and schedules. Observation of current practice or pilot schemes indicates required frequencies, which may vary from once a week in quiet areas to three times a day in market or tourist sectors. The rate at which streets are swept depends on the tools used, the amount and type of refuse and the width and surface of

the walkways. Careful observation and the flexibility to make adjustments are both important if a satisfactory and economical service is to be offered.

SOLID WASTE MANAGEMENT: SOCIO-ECONOMIC,  
ENVIRONMENTAL AND HEALTH IMPLICATIONS

by  
Dr Adrian Coad\*

1. SOCIO-ECONOMIC IMPLICATIONS

In general solid waste management is of greater concern to the poor than to the rich; the poorer neighbourhood is more likely to have unpleasant piles of refuse dotted around it, together with the attendant health hazards, and the livelihood of this neighbourhood is more likely to be related to solid waste.

Unplanned, squatter communities are often not served by a regular refuse collection service. Overstretched collection authorities are glad of any excuse to avoid expanding their responsibilities. But if the unplanned areas are ever to develop they must have a regular refuse removal service, in combination with other improvements. Removal of solid waste is an obvious need, and can be an obvious improvement by which to encourage other environmental improvements. A failure to deal with piles of refuse can detract from progress in less obvious ways. Waste management can be used as a starting point for organization and self-help in a community, so that other improvements, such as drainage and pit latrines, can be implemented and maintained. Furthermore, if these arguments do not impress, it may be observed that insanitary conditions in one part of a city may not respect

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planners' boundaries, and flies from the squatter areas may visit the town hall, or the business sector.

Residents of traditional areas may also have only a sub-standard service if access to their houses is too narrow or hilly for refuse collection vehicles, so that communal storage points are provided. Unreliable removal or poor public participation can make this system unsatisfactory. Storage of refuse within the premises may be unsatisfactory in congested housing.

Residents of expensive, low-density housing are likely to have the best service. Paved roads provide easy access to their boundaries. Collection is regular and careful because of anticipated bonuses, and the many salvageable items discarded. (Items such as old clothes, shoes and utensils can be reused, and materials like glass can be sold). Storage between the regular collections presents no problem because a bin with a well-fitting lid can be afforded, and there is plenty of yard space to keep the container out of sight.

The effects of these inequalities can be minimized by firm policy and by education. The responsible agency can determine that every part of the town or city shall have a collection service at least at a set minimum frequency, and not accept a lower standard. The privilege of collecting from richer areas could be used as an incentive for good service by regarding it as promotion. Alternatively, responsibilities could be rotated annually so that each labourer has an opportunity to work in the more popular areas. Close supervision is important.

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The nature and daily quantity of solid waste generated has been shown to vary with socio-economic level. The author studied the differences in the waste produced in different parts of Shiraz, Iran, in 1973, and obtained the results shown in Table 1 and Figure 1.

Domestic solid waste in industrialized countries has a lower proportion of putrescible organic waste and a higher proportion of paper and packaging than refuse in developing countries. One would expect that the trends shown within a city would be similar, with the inhabitants of the more prosperous areas producing refuse more like that of the USA or northern Europe. This assumption was supported by the paper, plastic and glass categories, but not by the food waste - more was discarded by the wealthier areas. Therefore equipment that is appropriate for industrialized countries cannot be assumed to be appropriate for the more luxurious sectors of cities in developing countries. There was also much more small-sized material coming from the more traditional areas, probably resulting from sweeping unpaved surfaces near walls largely made of mud.

Such studies can assist in the preparation of forecasts of refuse quantities and nature; a growing literacy rate will produce a growing consumption of printed paper, and as more money is available for spending on food, quantities of discarded packaging will rise. However, the extent of reuse and recycling in the future is not easy to determine.

Table 1  
 Refuse generation of different socio-economic groupings -  
 per capita weights g/d

Categories of refuse	Socio-economic Groupings			
	AB	C	D	E
Food waste	92	197		273
	92		217	273
Inert and mineral matter	114		14	20
Paper	21		31	68
		28		68
Glass	0.6		5	
	0.6			6
Plastic	2.8			9
Total refuse	257			399
			288	399
Fines-passing 20 mm mesh	97		40	
	97			59

#### Notes

1. Groups A and B were in a high-density traditional housing area near the bazaar. Group E was in a low-density, recently-constructed residential area. Groups C and D were in the middle-income range.
2. Results shown on one line were all significantly different from each other at a confidence level of over 97%. (Taking the category of glass as an example: the first line shows that the results for areas A and B were significantly different from those of area D and the second line shows that the results for A and B were significantly different from those of area E. However, there was no statistically significant difference between results for area D and results for area E.)
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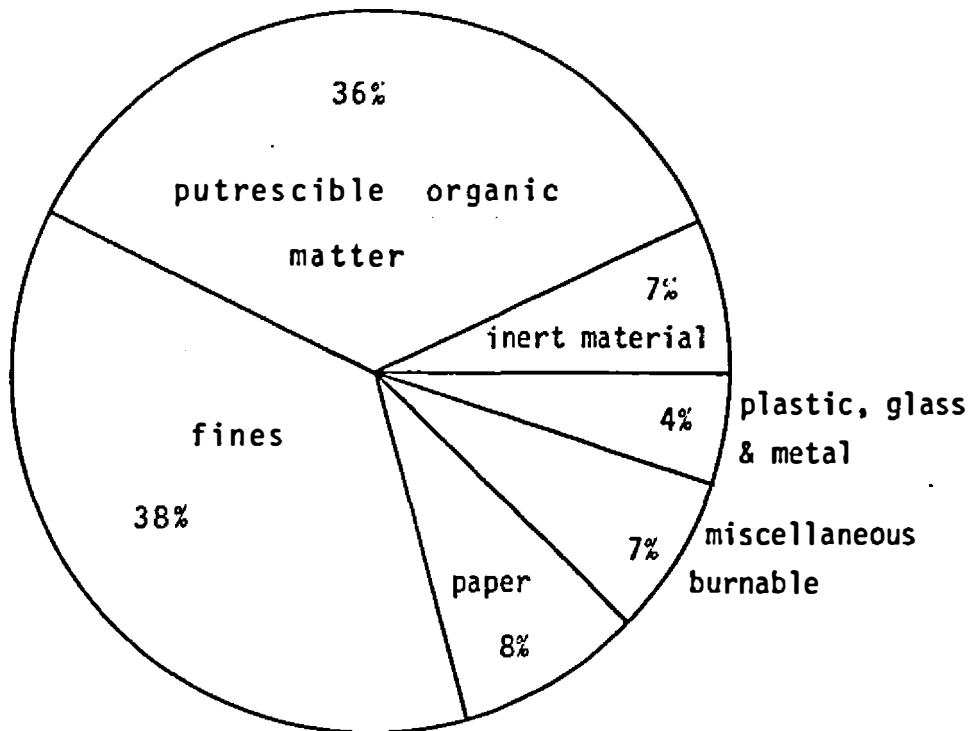
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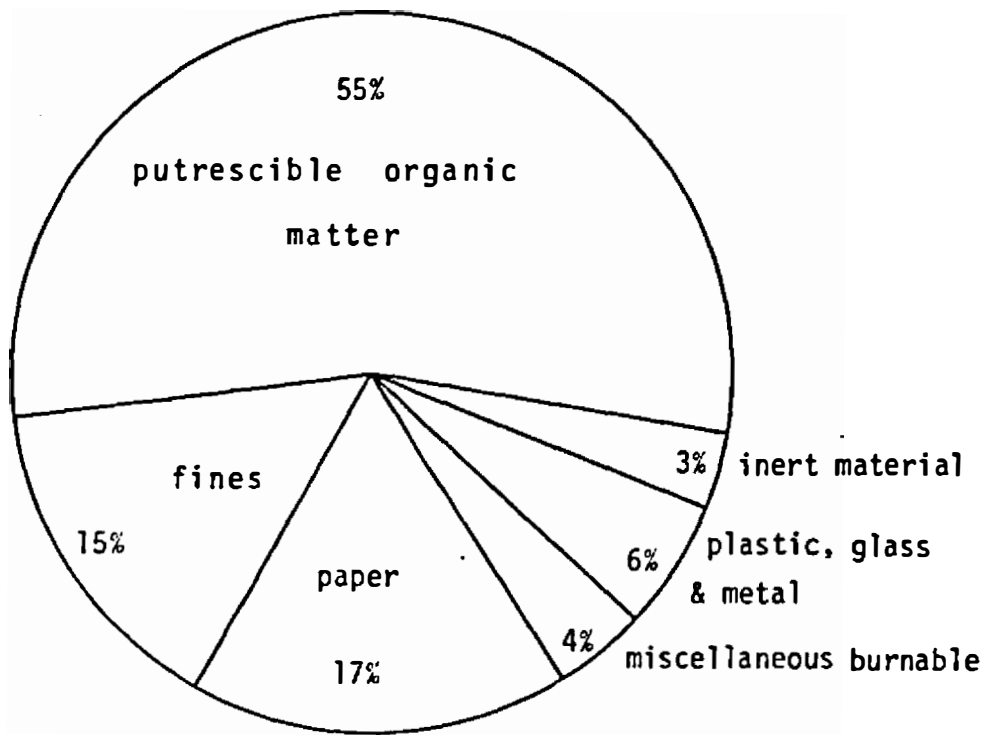
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Figure 1  
Domestic solid waste compositions from  
different socio-economic groups  
(Shiraz, Iran, 1973)



(a) Refuse from a low income traditional area.

Figure 1 (cont'd)



(b) Refuse from a high income modern area.

Whilst it is true that a man's socio-economic level affects the nature and the quantity of the refuse he generates, it is also true that the nature of refuse and the way in which it is handled affects the socio-economic level of many. In many cities around the world a considerable number of people spend their days as scavengers, looking through piles of solid waste for material or items which they can sell, and so the nature of the refuse determines their livelihood. Their salvage work also provides jobs for those who handle and process the waste "downstream". The other people affected are the labourers who collect and dispose of the solid waste. Solid waste collection and street sweeping can be very labour-intensive activities employing perhaps one percent of the workforce. High wage levels in industrialized countries have forced the introduction of sophisticated machinery, but where wages are much lower in comparison to the cost of equipment, and where there are restrictions on foreign exchange, it is preferable to adopt procedures that will involve more men and fewer machines.

Scavengers are rarely welcome. They may scatter refuse that was neatly stored, they may obstruct operations on disposal sites and they may spread contamination from a tip site (as, for example, when fertilizer bags are washed out in a stream). But they do fulfil a useful role. Modern techniques of automatic separation are not as precise as the manual sorter, and material recovered can provide jobs in reprocessing (e.g. making shoes from tyres or metal goods from tin cans) or be recycled with a lower energy input than the virgin material, or save the use of virgin non-renewable resources, or save foreign exchange.

Volumes of waste are reduced by the extraction of some components, and, more importantly, the waste becomes more uniform in composition so that the settlement of landfill is more uniform or the compost produced has fewer "contraries" such as glass.

This "informal sector" recycling needs both control and encouragement. In Harare, Zimbabwe (2), the disposal site was moved away from the city to discourage scavenging, but a contractor was engaged to collect material of value (such as paper, plastic, metal and bottles). The contractor pays a fee to the council and his employees wear easily recognizable uniforms. Police are present to enforce regulations. By these controls operations are not impeded. Government assistance is often required to encourage resource recovery because market prices for secondary materials are very unstable, and most scavengers have no starting capital. Loans, provision of facilities and guaranteed prices would provide both social and economic benefits.

Refuse collection and street sweeping are often regarded as degrading and unpopular occupations. In many cases this concept may be reinforced because of poor management and a lack of representation in the higher levels of municipal organization, so that equipment is allowed to remain in a shoddy state, and working conditions are much worse than they need to be. Yet there are examples in Asia, Africa and Europe where positive approaches to building morale by enthusiastic management have done much to improve the image of the refuse collector.

Another socio-economic implication is the property blight (or reduction in market value of houses) which affects real estate in the vicinity of a refuse tip. Little can be done about the

increase of heavy traffic to and from the tip, but the disposal area itself can have much less impact if it is well organized and visually and acoustically screened. The reclaimed land, when operations cease, can be a valuable amenity.

## 2. ENVIRONMENTAL IMPLICATIONS

In many cases the degree of nuisance that a person regards as acceptable is a matter of taste, and is conditioned by experience and habit. People who have long been accustomed to a certain level of pollution may not be as readily motivated to do what is necessary to reduce it as an outsider (coming from a cleaner environment) might expect. Where the pollution leads to damage to health the definition of unacceptable pollution is easier to draw. Direct health hazards will be discussed in Section 3.

### (a) Land

Urban areas are marred visually by refuse lying in piles, or scattered. In some cases streets have been almost choked by solid waste. Piles of refuse resulting from citizens' carelessness or inadequate collection produce unpleasant odours, block drains and attract scavengers of all kinds who scatter the refuse yet more. Blocked drains cause flooding.

Refuse tips, if uncontrolled, can rapidly develop into large tracts of useless land, producing only ugliness, smell and health hazards. If the land is to be reclaimed the deposition of waste must be organized to promote even settlement. Generally, erst-while tips are unsuitable for building on because of the large

settlements, the evolution of methane during decomposition of the refuse such that explosions may result, and the acid conditions below ground which attack piles.

An intelligent use of compost is of great benefit to soil, but harm can result from careless use. Some composts contain small quantities of heavy metals (originating, for example, from printers' inks) which can poison the soil over long periods. Non-degradable material like glass may detract from the value of the compost, and if high temperatures are not attained during the composting process, pathogens may survive to infect crops or farm workers.

Despite these possible problems, controlled tipping (or sanitary landfill) or composting are very satisfactory methods of disposal if well managed, because both can improve the land.

(b) Water

Water is polluted by contact with refuse, mainly in large tips. Soluble salts such as nitrates and sulphates, complex organic substances, bacteria and toxic chemicals from industrial wastes may be leached out of landfilled refuse. The movement of this polluted water is often very slow, and it can take years to appear. However, simple civil engineering measures can reduce this pollution risk to an acceptable level by careful site selection and by reduction of leachate volumes. Leachate from a refuse tip is not as easy to treat biologically as domestic sewage; it is sometimes recirculated through the refuse or used to control dust.

Solid waste tipped into standing water can quickly turn the water anaerobic and produce foul-smelling gases, if the level of

the refuse is not above the water surface. The unpleasantness of floating debris should discourage dumping in rivers and streams.

(c) Air

When refuse is burned in the open the resulting heavy smoke reduces visibility, threatens lungs and is unpleasant. Fires in refuse tips can burn quietly for months and pose a threat to surrounding properties. Such fires may be started deliberately in an attempt to reduce the volume of the waste, or accidentally by scavengers, spontaneously by chemical reaction or a focusing of the sun's rays, or maliciously.

The gases and dust produced by large incinerators can be controlled by sophisticated equipment, but maintenance of this equipment requires great skill.

The characteristic smell of refuse has closed some urban facilities. Aerobic composting is theoretically an odour-free process, but attempts to save on transportation by building mechanical compost plants in urban areas have not been successful because of complaints by residents of the smell.

Refuse tips often have large bird populations. The birds feed on the refuse and scatter it, and can be a hazard to aircraft if the landfill is near an airport. They are difficult to scare away because they are accustomed to the noise and activity of the site. Their natural enemies (owls) and broadcast distress calls have been successful in controlling them, but it is possible for the "cure" to be worse than the "disease".

Dust can be a problem in both collection and disposal operations; transfer stations and open vehicles can cause a nuisance

as can temporary roads on tip sites. The latter problem can be controlled by spraying water or leachate on the roads in dry weather by means of bowsers.

(d) Noise

Refuse collection vehicles can be very noisy - a handcart with steel tyres or a small two-stroke tricycle vehicle can be as bad as a compactor truck. Particular attention should be paid to the noise of equipment that is used in the early morning or at night. Tip operations can also cause a nuisance.

### 3. HEALTH IMPLICATIONS

The desire to minimize the threat to public health posed by refuse should be the main motivation in solid waste management. Refuse is hazardous because of harmful constituents, because it is a popular breeding place for disease vectors and because of the activities involved in collecting it and disposing of it. It follows that certain of the potential dangers can affect only those handling refuse, whilst others threaten the public at large.

(a) Hazards to the general public

Flies are the most dangerous enemy. They breed in solid waste. They pick up bacteria on the hairs of their legs and bodies, and by feeding, and deposit them on food and utensils. In this way they carry the micro-organisms of dysentery, diarrhoea, gastro-enteritis, typhoid and trachoma. The main source of most of the pathogens is faecal material, so the need for control of flies is much greater where excreta disposal is unsatisfactory.

Indiscriminate defaecation and faeces in solid waste (including dirty nappies or diapers) put the community at risk. Flies are not the only means of faecal-oral transmission. Hands and water are other ways. But Watt and Lindsay (3) have shown that intensive fly control measures will bring about a substantial reduction in the incidence of infection in areas in which disposal of human faeces is still inadequately safeguarded. If the fly population is to be controlled, those in charge of solid waste collection and disposal must be aware of the fly's habits and life cycle.

The common housefly lays its eggs in faeces or moist refuse. The eggs look like tiny grains of rice - 1 mm long, pearly white and in bunches of about 120. The eggs hatch into white larvae (or maggots) within about one day, and these larvae feed on the surrounding material, just below the surface. The mature larva then finds a drier place in which it pupates, travelling up to several metres and burrowing as much as 600 mm in loose soil. When the adult fly emerges it makes its way to the surface. Adult flies have been shown to travel over 30 km (4) but they probably stay closer to their native ground if the food and breeding sites are plentiful. The time span of the life cycle depends on the ambient temperature, taking about eight days at 35°C, 14 days at 25°C and 30-50 days at 16°C (4).

Good solid waste management controls flies by preventing their access to breeding sites and killing the maggots or pupae by high temperatures, or preventing the emergence of the adult. Access for egg laying can be denied by keeping the refuse in a container with a well-fitting lid or in a closed plastic or paper

bag. Once eggs are laid the life cycle can be interrupted by removing the refuse and raising its temperature. To ensure that all of the maggots or pupae are removed, refuse should be stored on an impervious surface which the maggots cannot penetrate, and all of the refuse should be moved; none of it should be left to harbour the larvae. The temperature of the waste can be raised by compacting and covering it so that sufficient heat from the process of anaerobic decomposition is retained, by composting or by incineration. A temperature of 46°C is sufficient to kill the insect. Otherwise when the adult emerges from the pupa a considerable depth of compacted material is necessary to prevent its escape. So fly control is concerned with the method of storage of the waste material, the frequency of its removal and the method of its disposal.

Insecticides have been used to control flies, but they do not provide a long-term solution. Some organochlorine pesticides are no longer effective against flies (though they may still kill the flies' natural enemies). Pyrethrins are effective, as are organophosphorus insecticides, but the widespread use of the latter may have unwanted effects on the environment. Blowflies breed in decaying animal matter and so can spread disease via meat and fish. They can burrow as much as 250 mm through compacted fill to escape heat, so the main means of control is to deny them access to breeding grounds. Hospital wastes should be buried deep or incinerated.

A concerted attempt to educate the public regarding the role of the fly in spreading disease should complement a review of collection practices by the solid waste agency. Both approaches are necessary if fly control is to be significantly improved.

Rats and cockroaches also breed in refuse. Cockroaches contaminate food with bacteria and roundworm ova carried on the hairs of their legs and bodies. They need exposed refuse, so their breeding can be controlled by good landfill practice - compacting and covering. Rats, too, like voids in the tip.

Rats need to be controlled for three reasons. They are involved in the transmission of several diseases - plague, typhus, salmonella and leptospirosis. They bite humans, particularly infants. Six hundred cases of rat bites have been recorded in New York in one year, and one hospital in Bombay recorded 20 000 cases in one year (5). Such bites lead to disfigurement and secondary infection. Rats also consume large quantities of food; it has been estimated that 33 million tons of bread grains and rice in storage are lost to rodents each year (5).

Rats multiply very rapidly. A few on a refuse tip will do little harm, but if their numbers grow unchecked, they begin to invade the surrounding areas, including houses. A well-run landfill is less suited to them than an open tip, and the presence of rats is easier to detect where there is uniform soil cover. They are most likely to be seen at night when surprised by car headlights. The main means of control is poisoned bait. A slow-acting anticoagulant rodenticide is usually mixed with cereal and laid in heaps of 200 to 400 g down rat-holes and under cover along the paths that the rats have made. (Pipes along the paths provide suitable cover to prevent other animals from eating the poison). The supplies of bait must be replenished regularly for two to three weeks, and then a few permanent traps should be left to prevent reinfestation. Further information is given in Reference 6.

Mosquitoes breed in pools of water, in tin cans, discarded tyres and drainage channels blocked by solid waste. Malaria and filariasis are transmitted by these insects.

Metal and glass objects littering public places are a hazard to children and bare-footed passers-by. Abandoned cars can be dangerous because a small quantity of petrol remaining in the tank can explode.

(b) Special hazards to refuse workers. Skin contact with solid waste can lead to a variety of problems. Glass, jagged metal and razor blades cause cuts which may become infected or lead to tetanus. When faeces are mixed with refuse, skin contact is likely to lead to worm infections - a study in India found that 94% of the refuse workers were infected with certain types of parasites, compared with 4% in the control group (7). Contact with industrial wastes could lead to skin ailments.

Refuse collectors are also prone to sprains and back disorders because of the heavy lifting their job requires. Traffic accidents are another hazard because of the frequent need to cross the road. American research shows that refuse workers lose about ten times as many days through accidents as the average man (8).

Respiratory disease is a possible consequence of inhaling dust from refuse and street sweeping, especially where spitting is common.

Accidents on disposal sites may be caused by heavy, noisy plant and vehicles. Some large tipper trucks are very unstable on soft ground when the body is fully elevated. Caution is required when handling rat poison. Aerosol cans are dangerous when hot or punctured.

Most of these hazards are readily preventable. Handling procedures should be developed, and equipment supplied, such that no skin

contact with the refuse occurs. Workers should have a means of travel other than sitting on the day's accumulation in the truck. Regular medical examinations can detect parasite infection so that treatment will return the worker to his full vigour. Tetanus injections should be given as a matter of routine. Washing facilities should be available for use before meal breaks. Each worker should be carefully trained in personal hygiene, how to lift heavy loads (including how to check the weight before lifting), and road safety. Careful record-keeping of all accidents will suggest where accident-prevention effort should be concentrated. The provision of reflective waistcoats is also recommended.

(c) Hazards of recycling. Scavengers working on piles of refuse are open to many of the problems mentioned in the previous section. Children playing in the vicinity are even more at risk and likely to contract any of a wide range of infections. Hospital wastes, including syringes and dressings, are a potential danger if not properly disposed of. It is conceivable that scavengers might keep medicines or food for their own use.

The reuse of bottles which have not been properly washed and sterilized presents a risk to the general public; this possibility indicates the value of some supervision of "informal sector" recycling.

In countries where pork is eaten there is the possibility of the spread of trichinosis when pigs are fed with infected kitchen scraps. The transmission can be prevented by heating the garbage directly or with steam.

The possibility of transmission of disease via improperly composted refuse which is used as soil conditioner has already been

mentioned; the wearing of shoes in the fields and the cooking of the vegetables grown in the compost are wise precautions.

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COST-BENEFIT STUDY OF SOLID WASTE MANAGEMENT  
IN ALEXANDRIA  
(A CASE STUDY)

by

Professor Hassan Mitwally, Ph.D.\*

*Abstract* Solid waste management in Alexandria is divided into household collection and street collection. Domestic Solid Waste is collected door-to-door by the private sector from about 44% of the city. Several proposed systems were studied to choose the optimum collection system. The best proved to be that of kerb collection using non-compactor trucks. Street solid waste is collected manually at present, by the public sector using different types of trucks. This is then transported directly to the northern shores of Lake Mariut where it is openly dumped. Evaluation of the current method of direct haul as compared with that of a proposed indirect haul indicated that the latter could be applied to save time, effort, and money. Actual and optimum norms related to solid waste management are included in the text. A flow diagram showing solid waste management in the city and 13 tables showing the actual as well as the proposed systems of collection and transportation are presented. A questionnaire on domestic solid waste, sanitation and attitudes of citizens towards the solid waste problem is also presented.

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## DOMESTIC SOLID WASTE MANAGEMENT

The total length of streets in Alexandria is 1160km, with a street surface area of about 17.5 million m<sup>2</sup>. The estimated 1981 population was 2.7 million.

Domestic Solid Waste (DSW) is collected by private contractors who serve only 44% of the city apartments (1981 estimate). Door-to-door collections are made by workers using baskets and donkey carts. Waste is sorted, and valuable items e.g. paper, glass, bones, etc. are sold to industry and the rest, mostly garbage, is disposed of as animal food stuff or soil conditioner, or is dumped on landfill sites.

The number of contractors is not enough to serve the city, and conditions are becoming worse as shown in Table 1 which presents a comparison between 1978 and 1981.

Contractors charge each tenant a monthly fee ranging from 15 to 200 piastres (average 0.33 LE/month). Citizens lacking such service throw their waste into the streets, or carry it to the communal containers.

Table 1  
Comparison between number of private sector contractors responsible for DSW collection in Alexandria, during 1978 and 1981

	1978 <sup>1</sup>	1981
Population	2 500 000	2 700 000
Contractors	284	228
Number of contractors/10 <sup>4</sup> capita	1.2	0.9

<sup>1</sup>Hussein, 1979.

Table 2  
Data concerning DSW disposal in Alexandria, 1981

	%
<u>House treatment</u>	
Wrapping of waste in paper	47
Water draining	15
No treatment	38
<u>House storage</u>	
Plastic containers	40
Galvanized iron containers	43
Plastic bags	12
Refuse chutes	5
<u>Monthly charge to contractors</u>	
Up to 0.2 LE	9
More than 0.2 LE and up to 0.5 LE	84
More than 0.5 LE	7

## Household Practice and Attitudes

DSW disposal practices and attitudes towards solid waste problems were studied by submitting a questionnaire (Annex 1) to people with different standards of living in Alexandria. The results are presented in Tables 2 and 3.

Table 2  
Data concerning DSW disposal in  
Alexandria, 1981

Attitude	%
Current frequency of collection in winter	
- daily	44
- every other day	44
- other	12
- no opinion	-
Preferred collection frequency in winter	
- daily	78
- every other day	15
- other	5
- no opinion	2
Current frequency of collection in summer	
- daily	58
- every other day	29
- other	13
- no opinion	-
Preferred collection frequency in summer	
- daily	89
- every other day	7
- other	2
- no opinion	2
Attitude toward refuse chutes	
- yes	46
- no	50
- no opinion	4
Preference of collection by private sector	
- yes	47
- no	46
- no opinion	7
Preference of collection by public sector	
- yes	46
- no	47
- no opinion	7

Attitude		%
Preference of plastic bags	- yes	84
	- no	14
	- no opinion	2
Acceptance to carry wastes to communal containers	- yes	37
	- no	62
	- no opinion	1
Most important side effect of solid waste	- vectors	18
	- bad odour	18
	- bad scene	15
	- ethical	11
	- pollution	15
	- diseases	17
	- traffic hindrance	6
Attitude toward waste problem	- could be delayed	4
	- needs urgent action	77
	- indifference	19
Readiness to increase monthly charge	- yes	77
	- no	18
	- no opinion	5

### Optimization of Collection and Transfer of Domestic Solid Waste

Data shown in Table 1 indicate that private sector DSW collectors, with their present working capabilities, cannot cope with the increasing load of solid waste generated partly as a result of the population increase. In addition, the number of workers decreases each year. In order to find the best method of collection of solid waste, four proposed systems were examined in addition of the current system.

- (a) The same collection method as at present except that kerb collection replaces door-to-door collection.
- (b) Kerb collection by manual-load non-compactor trucks.
- (c) Kerb collection using manual-load compactor trucks of the Public Cleansing Department (PCD).
- (d) Collections by mechanical-load compactor trucks of PCD of waste from communal containers filled by the residents.

Three different areas, representing three standards of living in Alexandria, were selected for study of the above systems. The following parameters were taken into consideration for system appraisal:

- Time needed to empty the waste container at the door of each apartment about 10 s/container.
- Time needed to empty the collected waste into the cart; about 30 seconds per building.
- Time needed to go up and down in the building.
- Time required to move from one building to the next; about two minutes.
- Time used to sort waste: one hour.
- Time taken to travel to and from the dumping site: one hour.
- Manpower needed to carry out these systems efficiently throughout the city.
- Number of carts or vehicles needed.
- Total number of apartments in the city: 560 000.
- Volume of communal container:  $1.7 \text{ m}^3$
- Time needed to empty each container: 5 minutes.
- Travel time from container site to another: 10 minutes.
- Travel time to or from the dumping site: 30 minutes.
- Time spent at dumping site: 10 minutes.
- Cost per apartment per month, cost per caput per month, and cost per ton of waste were calculated from the following data:
  - (a) Donkey cart
    - capacity:  $6 \text{ m}^3$
    - amortization over 10 years: 5 LE/month.
    - feeding cost of the donkey is nil as it is fed on food waste.
  - (b) Non-compactor trucks
    - capacity:  $8 \text{ m}^3$
    - amortization over 5 years: 83 LE/month.
    - one driver and one crewman: 120 LE/month.
    - running cost: 110 LE/month.
  - (c) Compactor trucks for manual loading
    - volume  $9 \text{ m}^3$  compression ratio of 3, capacity  $27 \text{ m}^3$ .
    - amortization over 5 years: 333 LE/month.
    - one driver and one collector: 120 LE/month.
    - running cost: 110 LE/month.
  - (d) Compactor trucks for mechanical loading
    - volume  $27 \text{ m}^3$ , compression ratio 3, capacity  $81 \text{ m}^3$ .
    - amortization over 5 years: 1000 LE/month.
    - one driver and two collectors: 180 LE/month.

- running cost: 220 LE/month.
- maintenance cost: 20% of total costs.

The benefit per apartment per month, benefit per caput per month, and benefit per ton of waste were computed from the following:

- monthly fee: 0.33 LE per apartment + selling of saleable items (see Table 4) minus costs, giving net benefit per apartment per month, net benefit per caput per month, and net benefit per ton of waste.

**Table 4**  
Prices and percentages of saleable items,  
Alexandria, 1981

Item	Price (LE/ton)	Weight (%)
Paper	23	12.6
Rags	15	2.0
Bones	10	1.8
Glass	23	0.7
Metals	15	0.7
Plastics	15	0.4
Garbage	6	78.1

**Table 5**  
Cost-benefit of domestic solid waste management systems  
Alexandria, 1981

System Cost- benefit, LE/year	I	II	III	IV	V
Benefit	3 432 000	3 744 000	4 056 000	3 744 000	3 744 000
Cost	1 248 000	936 000	936 000	1 248 000	1 248 000
Net benefit	2 184 000	2 808 000	3 120 000	2 496 000	2 496 000

- N.B**
- I = Current system of DSW management, with door-to-door collection.
  - II = First proposed system of DSW management, with kerb collection (a).
  - III = Second proposed system of DSW management, with kerb collection using non-compactor trucks (b).
  - IV = Third proposed system of DSW management, with kerb collection using compactor trucks (c).
  - V = Fourth proposed system of DSW management, with compactor trucks from containers (d).

Table 6  
The performance of the domestic solid waste  
management systems,  
Alexandria, 1981

System		I	II	III	IV	V
Parameter						
No. of apt. that can be collected in 8 man-hours		376	615	3199	3519	9529
Total time per apt.,(s) <sup>a</sup>		67	41	8	7	3
Benefit per apt. per month <sup>b</sup>	LE	0.56	0.53	0.52	0.54	0.54
Benefit per caput per month <sup>b</sup>	LE	0.11	0.12	0.13	0.12	0.12
Benefit per ton of waste <sup>b</sup>	LE	10.70	11.40	9.50	9.50	9.50
Cost per apt. per month <sup>c</sup>	LE	0.21	0.13	0.12	0.19	0.18
Cost per caput per month <sup>c</sup>	LE	0.04	0.03	0.03	0.04	0.04
Cost per ton of waste <sup>c</sup>	LE	3.90	2.50	2.10	3.40	3.10
Net benefit per apt. per month	LE	0.35	0.40	0.40	0.35	0.35
Net benefit per caput per month	LE	0.07	0.09	0.10	0.08	0.08
Net benefit per ton of waste	LE	6.80	8.90	7.40	6.10	6.40

**N.B.** I = Current system of DSW management.

II = First proposed system of DSW management (a).

III = Second proposed system of DSW management (b).

IV = Third proposed system of DSW management (c).

V = Fourth proposed system of DSW management (d).

<sup>a</sup>Total time needed is the time required to collect DSW, sort it, and transfer it to the final disposal site.

<sup>b</sup>Includes monthly fees and price of saleable items.

<sup>c</sup>Includes salaries, amortization of equipment, and running costs.

The summary of the results obtained from evaluation of each system is presented in Tables 5 and 6. In order to evaluate these systems precisely, the following process was used (JICA, 1981).

- Selection of the factors to be evaluated.
- Each system was evaluated for each factor.
- Relative orders of importance ( $W_i$ ) must be decided for the factors.
- Marks were to be given for each system regarding each factor.
- The following scoring formula was used:

$$A_j = \sum_{i=1}^n W_i \cdot S_{ij} \quad (1)$$

where:

- $A_j$  = total score points for the system j.
- $W_i$  = weight of importance for the factor (i) in the decision-making.
- $S_{ij}$  = subscore point for the factor (i) and the system (j).

#### Method

- Step 1. Give a value for relative importance of the factor (i) in the decision-making, e.g. from 1 to 10 where 1 mark was given for the least important factor and 10 marks were given for the most important factor.
- Step 2. Calculate the weight of importance ( $W_i$ ) of the factor (i) in the decision-making, which equals
 
$$W_i = \frac{\text{the given mark of the factor (i)}}{\text{the total marks given to all factors}}$$
- Step 3. Give a subscore point ( $S_{ij}$ ) for each factor (i) and system (j), e.g. from 0 to 10 where 0 is given to the least favourable system and 10 is given to the most favourable system.
- Step 4. Calculate the product ( $W_i \cdot S_{ij}$ ) for each factor (i) and system (j).
- Step 5. Calculate the total score point ( $A_j$ ) from equation (1) for each system.
- Step 6. Compare the total scores ( $A_j$ ) for all systems. The system having the highest score is the one of choice.

The results of the evaluation are illustrated in Tables 7 and 8. It is evident that the second proposed system has the highest score and is the best one, especially if the trucks are replaced by the rear-loaded compactors instead of the non-compactors.

Table 7  
Systems evaluation\*

Factor (i)	System (j), subscore			
	1	2	.....	j
First factor $W_1$	$S_{11}$	$S_{12}$	.....	$S_{1j}$
Second factor $W_2$	$S_{21}$	$S_{22}$	.....	$S_{2j}$
Third factor $W_3$	$S_{31}$	$S_{32}$	.....	$S_{3j}$
⋮	⋮	⋮	⋮	⋮
nth. factor $W_n$	$S_{n1}$	$S_{n2}$	.....	$S_{nj}$
Scores ( $A_j$ )	$A_1 =$ $\sum_{i=1}^n W_i \cdot S_{i1}$	$A_2 =$ $\sum_{i=1}^n W_i \cdot S_{i2}$	.....	$A_j =$ $\sum_{i=1}^n W_i \cdot S_{ij}$

Note:

$$1. W_1 + W_2 + W_3 + \dots + W_n = 1$$

$$2. S_{11} + S_{12} + S_{13} + \dots + S_{1j} = 1$$

$$3. A_1 + A_2 + A_3 + \dots + A_j = 1$$

$$4. A_1 = \sum_{i=1}^n W_i \cdot S_{i1} = W_1 \cdot S_{11} + W_2 \cdot S_{21} + W_3 \cdot S_{31} + \dots + W_n \cdot S_{n1}$$

\* Source: JICA, 1981.

**Table 8**  
**Evaluation of different systems for domestic solid waste management**  
**Alexandria, 1981**

Factor (i)	System (j), subscore <sup>1</sup>				
	I	II	III	IV	V
Resource recovery <sup>2</sup> 6/30	8/40	9/40	10/40	6/40	7/40
Feasibility 7/30	4/36	7/36	7/36	8/36	10/36
Economic <sup>3</sup> 8/30	7/41	10/41	10/41	7/41	7/41
Social acceptance <sup>4</sup> 9/30	10/35	7/35	7/35	7/35	4/35
Scores (A <sub>j</sub> )	0.197	0.215	0.220	0.187	0.180

Note: <sup>1</sup> See footnote Table 7.

<sup>2</sup> Marks from Table 6.

<sup>3</sup> Marks from Table 7.

<sup>4</sup> Marks from Table 3.

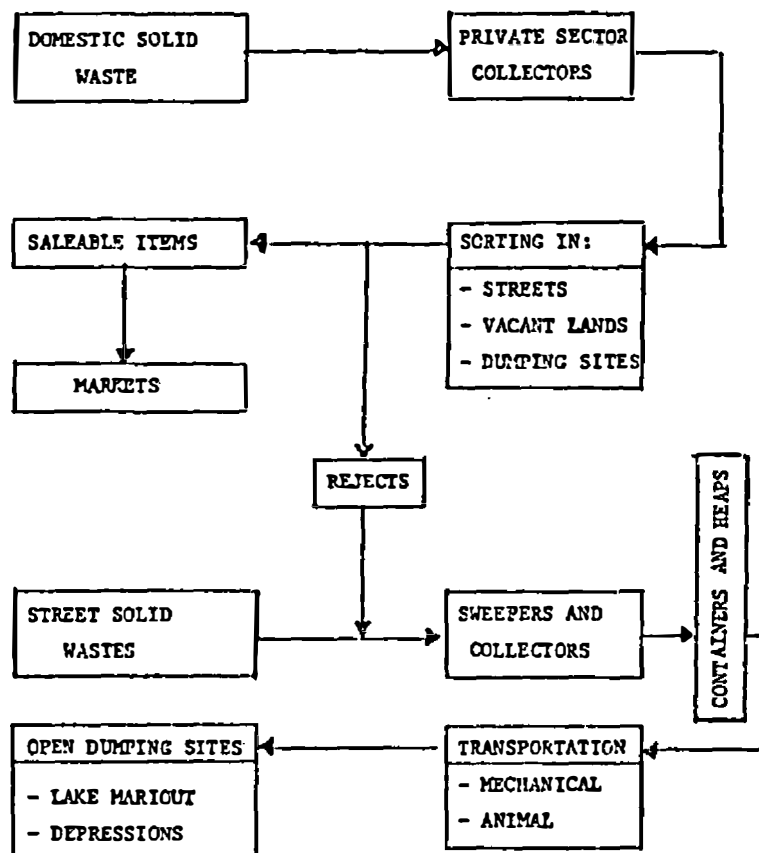
## STREET SOLID WASTE (SSW) MANAGEMENT

Solid waste generated from streets, i.e. dust, leaves, etc. and DSW not collected by the private contractors is collected by the various district PCD. The system involved is shown in Figure 1.

### Street Waste Collection

Street waste is collected manually or swept, into baskets. The waste is carried on tricycles and hand carts to the various types of containers and collection sites.

Figure 1  
Flow diagram of solid waste management,  
Alexandria, 1981



### Street waste sites

Sites of street solid waste are:

- (a) Waste heaps on street corners, in markets and gardens where enough space is not available for containers.
- (b) Stationery containers made of concrete or metal located mostly on pavements. They are emptied manually on to non-compactor trucks.
- (c) Compactor containers located in places which take the following conditions and/or considerations into account:
  - available land area;
  - available space for trucks to enter and exit;
  - effect on the traffic;
  - presence or absence of DSW collection services; and
  - amount of waste generated.

These containers are found on wide vacant sites, serviced by wide streets, and in areas of high street waste generation rates, which is the case in localities lacking a DSW collection service.

- (d) Transfer stations: There are few transfer stations in Alexandria and they are located on vacant pieces of land away from residential areas. SSW is transferred by tricycle and hand carts as well as by donkey carts. There, DSW is sorted and the valuable items are balled to be sold. The residue, mainly food waste, is sold for composting to nearby farms.
- (e) Dump sites: In Alexandria, disposal sites are located along the shores of Lake Mariut, where wastes are openly dumped. The distance between the different sections of the city and the dumping sites varies between 3 km and 26 km. Most of these distances were regarded as economical for direct haul rather than indirect haul using transfer stations. However, in Alexandria it was found that indirect haul could be economical as will be seen later.

### Transportation of street waste

Waste in heaps is collected by non-compactor trucks of different types as well as shredders. Waste in containers is lifted by compactor trucks using a hydraulic hoist mounted on top of the truck. For dead animals, there is a special trucks equipped with manual crane. No special trucks are available for bulky waste. Some areas which have narrow streets are serviced by mule carts. The transportation system in Alexandria is mostly direct haul.

### Routing System of the Public Cleansing Department

The current SSW managment has three main routing systems:

1. The compactor trucks follow certain routes determined by the location of the containers they serve. These routes are side enough to allow passage and manoeuvre of the trucks. Usually they follow the same route every day.

2. The non-compactor trucks follow certain routes along which street sweepers have collected SSW into heaps. These trucks can travel in areas which have only moderately wide streets. The daily route may be changed according to the local conditions and/or solid waste amount. This routing system is more flexible than that of the compactor trucks, as the containers are difficult to move and have to be emptied by hydraulic hoist.
3. Mule carts operate in the narrow streets and alleys where waste has been heaped.

The amount of solid waste collected by the trucks in comparison with the amount found in streets is illustrated in Table 9. Data presented in Table 9 indicate that the capacity of PCD trucks is more than sufficient to cope with the solid waste generated from houses and streets. The reasons for accumulation of solid waste in streets are:

- collection of industrial solid waste;
- collection of waste from construction and demolition operations; and
- collection of waste from restaurants and hotels.

All these activities are illegal.

Table 9  
Efficiency of Public Cleansing Department Trucks,  
Alexandria, 1981 and 1982

	1981	1982
DSW thrown into street, tons/d <sup>1</sup>	408	600
SSW (tons/d)	464	700
Total (tons/d)	872	1300
Capacity of transportation system (tons/d)	2056	2056

<sup>1</sup> This is the amount of DSW from the 56% of apartments not served by the private sector.

#### Cost-benefit of street solid waste management

Data shown in Table 10 represent the cost-benefit of SSW management in Alexandria. This table indicates that SSW management can support itself financially.

Table 10  
Cost-benefit of SSW mangement,  
Alexandria, 1981

	LE/year	%
Cost: - Labour costs	3 305 752	77
- Depreciation of trucks	512 000	12
- Running costs	73 125	2
- Administration costs	389 088	9
<b>Total</b>	<b>4 279 965</b>	<b>100</b>
Benefit from selling reclaimed land <sup>1</sup>	8 500 000	

Cost of management/ton of waste =

$$\frac{4\,279\,965 \text{ LE}}{872 \text{ tons/day} \times 365 \text{ days}} = 13.4 \text{ LE/ton}$$

<sup>1</sup> Area reclaimed each year = 170 000 sq.m. at 50 LE/sq.m.

#### Choice between direct transportation and indirect transportation

In Alexandria, most SSW is transported directly to the dumping site. Two sections of the city were chosen in order to study the feasibility of indirect transportation, i.e. with transfer stations to which non-compactor trucks carry their loads, and from which compactors haul them to the final disposal sites. These two sections had different characteristics, so as to test the effects of the different parameters on the performance of both methods. The cost of different methods of transportation of SSW from each section to the site was estimated as shown in Table 11. From this table, it is evident that the distances from both sections to the disposal sites (4.6 and 15.3 km) are less than the economical distances set for use of transfer stations in, for example, European cities. Salvato, 1972, stated that a distance of less than 17.7 km one way was considered economical for direct haul; however, Marks and Liebman, 1970, said that 9.7 km one way was the maximum economical distance for direct haul. The mean times taken to travel from the centre of Section A (25 minutes) and of Section B (45 minutes) were less than those regarded as the maximum time for the use of direct haul (55 minutes, Wilson, 1977). Despite these facts, the cost per 1000 km per m<sup>3</sup> for the direct transportation of SSW in Alexandria (0.13 LE for Section A and 0.07 LE for Section B) was found to be more than that for the indirect method (0.07 LE for Section A and 0.04 LE for Section B). The main causes for such differences between the methods in Alexandria as compared with cities in other countries could be due to:

- street conditions: traffic speed is lower in Alexandria, traffic hindrance is greater, and street pavements are not satisfactory;
- salaries are much lower;
- fuel is cheaper.

Item	Section		A	B
<u>Grand total for indirect method</u>				
Total SSW hauled	m <sup>3</sup>		9720	8310
Grand total km	km		2671	6093
Grand total cost	LE		1938	2262
Cost/ m <sup>3</sup> of SSW	LE		0.20	0.27
Cost/km	LE		0.73	0.37
Cost/1000 km · m <sup>3</sup>	LE		0.07	0.04

#### CONCLUSION

#### Calculation of the manpower, trucks, and other equipment required for solid waste management in Alexandria

These requirements, calculated mainly for collection and transportation, are presented in Table 12 for both DSW and SSW management.

Table 12  
Manpower, equipment and cost required  
Alexandria, 1982\*

Item	DSW	SSW	Total
Total number of trucks	228	48	276
Total number of workers	456	3 328	3 784
Total cost, LE/year	1 028 000	3 675 000	4 703 000

\* These figures were calculated only for collection and transportation.

#### Solid waste disposal

Considering the various solid waste disposal methods, sanitary landfill has proved to be the best method for the time being in Alexandria. The trench method may be recommended when no cover material is available near the disposal sites. The running and maintenance cost at the disposal site would be 1 137 00 LE per year and the staff needed on site would be about 100 persons.

Table 11  
Comparison between direct and indirect transportation of SSW  
Alexandria, 1982

Item	Section		A	B
<u>Direct</u>				
Mean distance to disposal site	km		4.6	15.3
Mean time to disposal site	min		25	45
Mean time spent at disposal site	min		10	10
Mean round trip time	min		261	307
No. of trips/day			4.8	4.1
Amount of SSW transferred/month	m <sup>3</sup>		7920	8310
km hauled/month	km		1498	4059
Total cost	LE		1946	2216
Cost/m <sup>3</sup> of SSW	LE		0.20	0.27
Cost/km	LE		1.30	0.55
Cost/1000 km m <sup>3</sup>	LE		0.13	0.07
<u>Indirect</u>				
Mean distance to transfer station	km		0.5	1
Mean time to transfer station	min		2	4
Mean time spent at transfer station	min		5	5
<u>From collection sites to transfer station</u>				
Mean round trip time	min		33	38.5
No. of trips/shift			12	12
Total number of shifts needed			102	95
SSW/total number of shifts	m <sup>3</sup>		9720	8310
km/total number of shifts			1346	2299
Total cost	LE		1325	1356
<u>From transfer station to disposal site</u>				
Mean round trip time	min		90	130
Number of trips/shift			4.7	3.2
Total number of shifts needed			31	39
km/total number of shifts			1325	3794
Total cost	LE		613	906

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Cost/km	LE		1.30	0.55
Cost/1000 km m <sup>3</sup>	LE		0.13	0.07
<u>Indirect</u>				
Mean distance to transfer station	km		0.5	1
Mean time to transfer station	min		2	4
Mean time spent at transfer station	min		5	5
<u>From collection sites to transfer station</u>				
Mean round trip time	min		33	38.5
No. of trips/shift			12	12
Total number of shifts needed			102	95
SSW/total number of shifts	m <sup>3</sup>		9720	8310
km/total number of shifts			1346	2299
Total cost	LE		1325	1356
<u>From transfer station to disposal site</u>				
Mean round trip time	min		90	130
Number of trips/shift			4.7	3.2
Total number of shifts needed			31	39
km/total number of shifts			1325	3794
Total cost	LE		613	906

**Performance norms of solid waste management in Alexandria**

Different norms concerning solid waste management, actual and optimum, are shown in Table 13.

**Table 13**  
**Norms of solid waste management**  
**Alexandria, 1981**

Norm	Current	Optimum
Total population	2 700 000	
Total number of apartments	560 000	
Total street surface area $m^2$	17 500 000	
SSW/ $m^2$ street surface area, g/d		40
<u>SSW:</u> Sweepers	2070	3160
Foremen	55	211
Inspectors	33	53
Directors	6	7
Director-General	-	1
Drivers	125	48
Crewmen	-	120
Hand carts	177	1580
Compactor containers	1039	1230
Trucks	101	48
Street surface area/sweeper, $m^2$	11000	7200
Sweeper/10 000 caput	8	12
<u>DSW:</u> Collectors	800	149
Donkey carts	190	570
Collector/10 000 caput	3	6
Collector/1000 apartments	1.4	2.7
Carts/10 000 caput	0.7	2.1
Carts/1000 apartments	0.3	1.0
Total sanitary labourers	2870	4650
Sanitary labourers/1000 capita	1.1	1.7

This work was carried out in Alexandria University (High Institute of Public Health) with the financial support of WHO/EMRO from 1981 to 1983. Since then a research grant has been awarded to continue this work as a pilot study in other cities in the Region. In this connection thanks are due to Dr Ahmad Hussein, a student carrying out this research under the writer's supervision and working for his doctorate degree on this subject.

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Questionnaire

DSW sanitation and attitudes of citizens towards solid waste problems

1. District:
2. Quarter:
3. Street:
4. Building no.:
5. Apartment no.:
6. Number of occupants:
7. Method of house treatment of waste:  
wrapping ( ), straining ( ),  
separation ( ), others ( ), none ( ).
8. Storage method:  
plastic containers ( ), galvanized iron containers ( ),  
plastic bags ( ), others ( ), none ( ).
9. Current frequency of collection in winter:  
daily ( ), every other day ( ), other ( ).
10. Preferred collection frequency in winter:  
daily ( ), every other day ( ), other ( ).
11. Current collection frequency in summer:  
daily ( ), every other day ( ), other ( ).
12. Preferred collection frequency in summer:  
daily ( ), every other day ( ), other ( ).
13. Attitude towards refuse chutes:  
yes ( ), no ( ).

14. Preference of collection by:  
private sector (    ), public sector (    ).
15. Would you like to use plastic bags - offered by the governorate  
at little charge - to collect your solid waste?  
yes (    ), no (    ).
16. Are you ready to participate in carrying your solid waste to  
communal containers or to the front of your building if this  
will help in solving the problem?  
yes (    ), no (    ).
17. If yes, do you prefer collection at:  
door of the building (    ), OR  
placed by the occupants in communal containers (    ).
18. In your opinion, what is the most important side effect of  
accumulation of solid wastes:  
vectors (    ), bad odour (    ), bad scene (    ), ethical (    ),  
pollution (    ), diseases (    ), traffic hindrance (    ),  
others (    ).
19. Attitude towards the solid waste problem:  
could be delayed (    ), needs urgent action (    ).
20. How much do you pay? (    ) LE.
21. Are you willing to pay more to improve the situation?  
yes (    ), no (    ).

14. Preference of collection by:  
private sector ( ), public sector ( ).
15. Would you like to use plastic bags - offered by the governorate at little charge - to collect your solid waste?  
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13. Attitude towards refuse chutes:  
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TREATMENT AND DISPOSAL METHODS  
COMPACTING - SHREDDING - INCINERATION - DISPOSAL  
AT SEA

by  
Professor E.A. Glysson\*

I BALING (COMPACTING)

Baling or compacting utilizes high pressure to reduce the volume of the refuse. It does not change the physical or chemical nature of the waste. The bale produced is easy to handle, transport and place in a landfill. Landfill results in very few voids, less litter and blowing paper, reduced vector population, reduced potential for fires, less need for cover materials; no compaction equipment is needed and it is very stable.

Equipment

Balers can be classified into three types:

1. Heavy metal scrap baler, adapted to solid waste processing from the scrap metal industry. These operate at very high pressures, 3500 to 5000 lb/in<sup>2</sup>. The refuse does not require preprocessing and no tie wires are needed. They are batch fed.

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2. Paper baler, medium pressure, batch fed; preclassification is required to remove oversize objects; tie wires are needed. (1000-3000 lb/in<sup>2</sup>).
3. Hay baler type - low to medium pressure, continuous feed; pre-shredding is required; tie wires are needed (1000-3000 lb/in<sup>2</sup>).

### Operation

In general the solid waste is fed to the baler in batches, by weight or volume, such that the initial cavity is filled. The baler ram then compresses the contents along one of the three dimensions until the ram pressure reaches a predetermined level. The bale produced will have two of its three dimensions fixed with the third being variable depending on the nature and amount of material being baled. The finished bale is ejected from the machine by the ram which supplies the final compression.

The need for tying the bale depends on the final pressure that the bale is subjected to. Medium and low pressure baling requires tying while high pressure bales generally do not. A choice must be made between the cost of the energy and heavy equipment for high pressure baling versus the cost of tying the bales. High pressure bales are usually available only in high capacity units (50 ton/h capacity).

### Bale stability and density

The final stability and density of the bale will be a function of several factors: the operation of the baler itself, the amount and nature of the wastes, i.e. moisture content, and the time since the formation of the bale. The baler operation includes pressure and time

of pressure application. Waste characteristics include moisture content, elasticity, size of components, percentage of grass or leaves and so on. There will also be a certain amount of spring-back in the bale after it leaves the baler.

The final density of the bale will be a function of the ram pressure. High pressure balers ( $> 3500 \text{ lb/in}^2$ ) can produce bales of solid waste weighing  $1700 \text{ lb/yd}^3$ . Moderate pressures result in bales of  $1000 \text{ lb/yd}^3$ . There is an accompanying reduction in volume as shown in Figure 1.

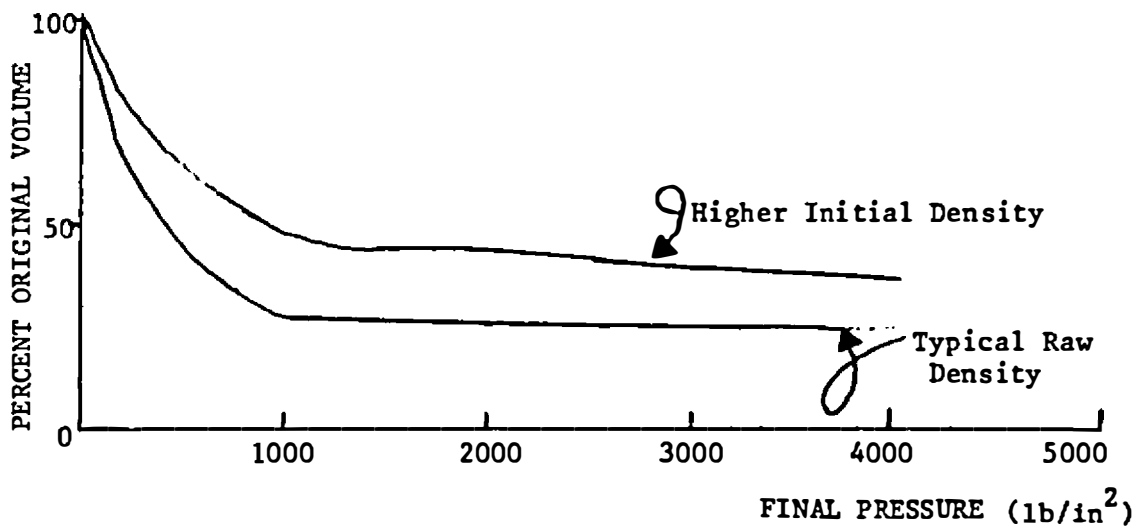


Figure 1. From reference (1)

<sup>1</sup>Hartz, K.E. "Solid Waste Shredding, Separation and Baling"  
Environmental Engineering Handbook. McGraw-Hill.

Moisture content of the refuse has considerable influence on the stability of the bale. Up to 30% moisture (dry weight basis) the stability increases as moisture increases but above 30% moisture the stability starts to decline. Stability is affected by large amounts of grass or leaves (above 50% by weight) or more than one tyre in a bale.

The spring-back effect occurs after the bale leaves the baler. It is an expansion of the material in the bale and takes place over time. Hartz (1) indicates that the bale will expand 7% in the first hour after release, 25% in one day after release, 26% in one week, thus most of the expansion will have occurred after one week.

#### Economics

The estimated cost of baling is US\$6-10/ton but these figures are very tenuous and more precise information should be obtained from equipment manufacturers who can also recommend motor horse power requirements for different situations.

#### Advantages

The advantages of baling solid wastes prior to disposal are as follows:

1. Increased density -1000 - 1700 lb/yd<sup>3</sup> reduces volume occupied in landfill.
2. Bales are easier to transport.
3. Most materials can be baled, especially by heavy duty balers.

4. Costs are comparable with other types of processing.
5. Bales fill sites usable for other purposes sooner due to less settlement.
6. No odours, flies, litter and less chance of fire at bale fill.
7. Less cover material required.
8. Less equipment needed at bale fill for compaction and cover.

#### Disadvantages

There are some disadvantages associated with baling solid wastes:

1. Additional costs added to disposal.
2. Recovery of materials from bale for recycling precluded.
3. Baled refuse will eventually produce gas and leachate in the same manner as other landfilled refuse and the same precautions must be taken.
4. Excessive moisture (>30%) and excessive amounts of grass, leaves will result in unstable bales.

## II SHREDDING

Shredding (milling) of solid waste is a process utilized as an essential part of resource recovery and has applications prior to landfilling. Shredding:

1. improves homogeneity
  - (a) moisture
  - (b) particle size;
2. improves handling characteristics;
3. improves separation of components;

4. Reduces ultimate volume by
  - (a) improving compactability
  - (b) improving spreading characteristics
  - (c) reducing voids due to bottles, etc.

### Types of Shredders.

#### Dry Shredder

Hammer mill: consists of a horizontal or vertical shaft that supports hammers which are either fixed or pivoted within a strong enclosure. These hammers are rotated at high speeds and serve to break up the solid waste material to a small enough size to be able to pass out of the machine through a set of openings which serve to establish the final size of the shredded material. The pivoted type of hammer is the most commonly used form and the hammer mill is the most commonly used type of shredder.

Rotary shear: consists of a pair of horizontal shafts with rotating shearing units which turn in opposite directions to one another causing the waste material to be torn and sheared apart as it passes between the rotors. It is a low speed device and is becoming more widely used.

#### Wet Shredders

Hydro pulper: a modification of the machine used to make paper - utilizes water and a high speed cutting blade in the bottom of the unit to put the solid waste into a slurry. Particle size is controlled by the size of the openings in the exit plate at the bottom of the unit. All non-pulpable material such as

metal is rejected out of the side of the unit. These units are not in common use with mixed municipal refuse.

#### Others

Rasp: Rasp mills consist of a large rotor on a vertical shaft which carries heavy rasping arms which bear on a large perforated plate. Obstructions are attached to the plate and as the rotating arms move the solid wastes over the plate within the enclosure of the rasp mill the waste passes over these obstructions and is reduced in size. This process continues until the particles are small enough to pass through the holes in the plate. These devices are more commonly used in Europe in connection with compost plants.

Flail mills: are light-weight relatively high-speed machines which are usually designed to tear open bags of refuse and break bundles of materials and to provide some mixing action. They consist of a rotor shaft to which are attached free-swinging rods or chains. The chains or rods flail the refuse as the shaft is turned. Due to its limited effectiveness there is little justification for its use.

#### Design and Operation

Due to the more common application of hammer mills in solid waste processing the discussion of design parameters will be limited to that type of shredder. Hammer mills were originally designed to process homogeneous friable material, utilizing the impact of the hammers to break up the material. Since solid wastes are heterogeneous and contain only about 25% brittle

materials (2) there are differences in the design considerations for this type of material.

#### Particle size distribution

Particle size distribution of incoming material is as significant a variable in the comminution process as the subsequent size distribution of the ground product is to the success of eventual processing stages. The size distribution of incoming material is very difficult to control and can vary widely. A comparison of raw residential refuse by Trezek and Savage (2) indicated that a range of 90% cumulative passing between 12 and 25 inches could be expected.

More attention has been given to the measurement of the ground product size distribution. Studies have concluded, (1) (2), that the particle size distribution can be mathematically described by a Rosin-Rammler relation of the type

$$Y_x = 1 - e^{-(x/x_0)^n}$$

where:

- $Y_x$  = the cumulative decimal fraction passing a given screen size  $x$
- $X_0$  = the size at 63.2% passing
- $n$  = the index of distribution

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<sup>2</sup> Trezek, G.J. and G. Savage. "Results of a Comprehensive Refuse Comminution Study" Waste Age Magazine, July 1975, p. 49.

The 63.2% passing-screen size is considered to be the characteristic particle size. For a given characteristic particle size  $X_0$ , the power consumption per ton of refuse can be projected. Also the grate bar spacing versus characteristic particle size can be predicted and from the data the proper motor size and grate bar spacing can be determined for a desired characteristic particle size  $X_0$ .

Based on curves shown below developed by Trezek and Savage (2) and also from Vesilind and Rines (3) the following type of design values may be obtained.

Assume 20 tons/hour of residential refuse is to be shredded to a characteristic particle size of one inch ( $X_0$ ).

Using the graph the grate bar spacing would be 4.5 inches and the specific energy would be 11.5 kwh/ton.

$$11.5 \text{ kwh/ton} \times 20 \text{ ton/h} = 230 \text{ kw.}$$

$$\frac{230}{0.7457} = 308 \text{ hp.}$$

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<sup>3</sup> Vesilind, P.A. and Rines, A.E. Unit Operations in Resource Recovery Engineering. Prentice Hall, p. 123.

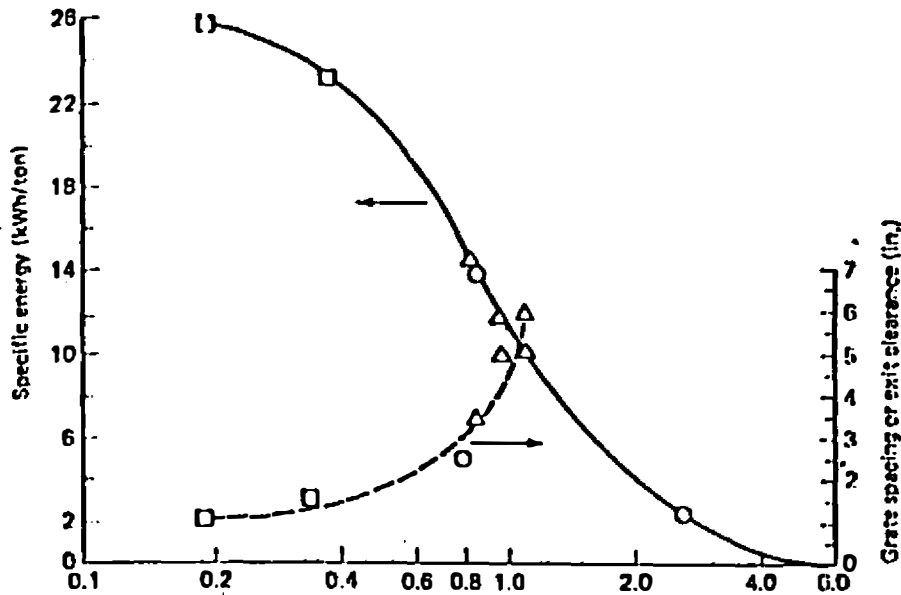


Fig. 2 Characteristic Particle Size ( $X_0$ ) inches.  
From Vesilind and Rines (3)

A larger motor would be specified to accommodate losses etc. The example assumes residential refuse and is pertinent for that type only.

There is much more information available on shredder selection and analysis which should be consulted by the designer. Design considerations such as speed, motor horse power requirements and rotor inertia must all be included.

The rotor inertia is usually expressed as  $WR^2$  where  $W$  is the weight or mass of the rotor assembly and  $R$  is the radius to the hammer mill tips. (This is not the accurate measure of rotor inertia but serves as a convenient parameter for comparative purposes).

same time controlling the entrance of air. The charging hopper which is kept full by the crane at all times extends from the charging floor down to the end of the grate - a distance of ten or more feet. It is usually as wide as the furnace and four feet or more long. The inner surfaces are of steel plate, water-cooled to allow the refuse to slide smoothly down into the furnace. The basic requirements of the feeding system are to provide a continuous flow of refuse to the furnace and to protect against burnbacks of fire out of the chute into the pit area and to control the unwanted entrance of air.

The furnace or combustion chamber itself is where the actual burning takes place. In the past many of the furnaces were lined with fire brick to sustain the high temperatures. Modern design however has shown the use of the watertube wall configuration to be much more effective in many ways. (This design consists of tangentially welded boiler tubes forming the walls and roof of the combustion enclosure). By using the water wall configuration less excess air is needed which formerly was required to control the furnace temperature to protect the fire brick. Less slagging occurs and there are no fire bricks to maintain and replace. Higher operating temperatures can be maintained which results in better burn-out and less combustibles in the residue.

The design of the combustion chamber should provide for the three Ts of incineration: time, temperature and turbulence. This means that there must be time enough for the refuse to be dried, heated and burned, turbulence is required to mix the evolved gases and air for complete combustion and temperatures of a sufficiently high value to produce complete oxidation of the

combustible in the fuel. These three components are interdependent and are also related to the condition and characteristics of the refuse, the furnace configuration and air supply. It is usually considered necessary to maintain temperatures in the combustion zone of about 1400-1800°F (800-1000°C) and a rule-of-thumb for rectangular furnaces calls for about 25 ft<sup>3</sup>/ton-d (0.67 m<sup>3</sup>/t) of combustion chamber volume. Also a heat release rate of between 12 500 and 25 000 Btu/ft<sup>3</sup>·h (between 4.6 x 10<sup>5</sup> and 9.2 x 10<sup>5</sup> kJ/m<sup>3</sup>·h) (3) is common.

Individual combustion chambers of 250 to 300 tons/d capacity are common with some units sized to handle 500 tons/d. Large incinerators are built with more than one combustion unit to allow for flexibility and maintenance.

The grate system is used to support the burning refuse and to move it along through the combustion chamber. Another important responsibility of the grate system is to provide the proper agitation of the refuse to promote thorough combustion and passage of under fire air. This agitation should not be excessive to avoid excessive particulate entrainment into the gas stream.

There are several grate systems available; they are: reciprocating, rocking, travelling, rotary kiln, reverse reciprocating and multiple rotating drums. There may be variations and combinations of these as well.

The determination of the grate area used may be approximated by the following (3):

$$\text{grate area} = \frac{\text{solid waste to be burned}}{\text{grate burning capacity}}$$

In this respect the following chart (1) shows machine requirements for four general categories.

CHART NO. 1: From reference (1)

<u>Category</u>	<u>Composition</u>
Household	Paper, cardboard, bottles, cans, garbage, lawn trimmings.
Medium	Small crating, small appliances, small furniture, bicycles, tree trimmings, occasional auto tyre.
Bulky	Stoves, refrigerators, washers, dryers, doors, mattresses, small rugs (9 in x 12in), chairs, sofas, tree limbs, smaller trucks tyres.
Heavy	Demolition rubble, logs, stumps, automobile parts.

The following items should be excluded from all swing hammer mills regardless of  $WR^2$ :

1. items which are likely to explode such as propane or butane bottles, gasoline cans, etc.;
2. large, thick-walled metallic objects such as gas cylinders, pressure vessels, etc.;
3. heavy wire rope and heavy industrial chain in lengths greater than circumference of rotor;
4. large blocks of plastic or rubber;
5. heavy truck and earth moving vehicle tyres;
6. long dense rolls of wovens such as industrial carpeting, tarpaulins longer than rotor circumference, long pieces of conveyor belting, etc.

<u>Category</u>	<u>Minimum hp/ton*</u>	<u>Minimum WR<sup>2</sup></u>
Household	10	25 000 lb-ft <sup>2</sup>
Medium	15	50 000 lb-ft <sup>2</sup>
Bulky	25	100 000 lb-ft <sup>2</sup>
Heavy	70	180 000 lb-ft <sup>2</sup>

Based on information in Chart No. 1 (1) and with refuse that contains various kinds of material the required shredder horse power may be estimated if the percentages of each of the four waste categories is known.

For example: 50 ton/hour of refuse containing

70% household	0.7 x 10 = 7.0 hp/ton
20% medium	0.2 x 15 = 3.0
19% bulky	0.09 x 25 = 2.25
1% heavy	0.01 x 70 = <u>0.7</u> hp/ton
	12.95

12.95 x 50 = 647.5 hp.

The next larger size motor would be specified and a rotor with a WR<sup>2</sup> of 180 000 lb-ft<sup>2</sup> would be called for to provide for the heavy waste to be shredded.

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\* ratings are for nominal 3 inch particle size; i.e. 90% of material passing 3 inch square opening.

Particle size requirements

Particle sizes of different magnitudes are needed for different purposes. They may be summarized as follows:

1. RDF (Refuse-derived fuel)
  - . 1in size - suspension burning
  - ≈ 2in - 3in for fixed bed combustion
2. Magnetic separation - course shred ≈ 6in
3. Air classification medium 3in - 6in
4. Landfill - prevent blowing paper, 80-90% passing 2in size.

Operational problems

1. Materials handling - getting the solid waste into and out of a shredder is difficult. Entrance velocities must be great enough to penetrate the ring generated by the tips of the swinging hammers to avoid the refuse simply riding on the tips as they spin. Conveyor belts are subjected to severe abrasion and wear.
2. Hammer mill refuse is very difficult to shred, containing much material that is abrasive and resilient. In fact, a shredder is a self-destructive machine being able to sustain the stresses placed on it only because it is more rugged than the material being shredded. Frequent maintenance is required to replace the hammers and other interior parts. As the hammers wear the clearance between them and the grate bars increases which results in larger particle size and partial plugging using more energy for shredding.
3. Fires and explosions - caused by the presence of containers of flammable material (gasoline, paint thinner, etc.) in the

refuse. Sparks and heat are generated by the rapidly rotating hammers and explosions have caused serious damage to the shredder and the building enclosing it. Designs for releasing sudden high pressure without structural damage are required on shredders and flame suppressor systems are also available.

4. Dust - shredding of refuse can produce tremendous amounts of dust which must be controlled for various reasons: health, house-keeping, instrument and equipment operation and explosion hazard to name several very important reasons. Proper enclosure and venting hoods with air cleaning equipment to remove the dust particles prior to exhaust are needed. The use of face masks by the operators may also be required.

U.S. Occupational Safety and Health Act (OSHA) limits dust inhalation to  $15 \text{ mg/m}^3$  of total dust over an 8-hour day. Limited studies have found dust levels in shredder installations 3 to 7 times this level (3).

5. Noise: The level of noise around the hammer mill can be quite high. Noise around a 3 ton/h hammer mill was measured at 95-100 dBA (decibels on the "A" scale) (3). Much of the noise is a low-frequency rumble but there is considerable impact noise as well. OSHA limits noise to 90 dBA over an 8-hour working day. The corresponding level set by US-EPA is 85 dBA. These values would indicate that ear protection should be worn by shredder operators and noise reduction should be a part of the shredder installation design.

### Advantages

The advantages of shredded refuse over non-shredded refuse when placed in a sanitary landfill are as follows:

1. No flies
2. No rodents
3. No odours
4. No blowing paper (except plastic film) if size is  
= 2 in - 3 in
5. Easy to spread and compact
6. Higher density when finally in place (1200 lb/yd<sup>3</sup>)
7. No daily cover needed
8. Does not sustain fires
9. Easy for trucks to travel over
10. More uniform and less subsidence
11. Improved aesthetics.

In addition it should be noted that shredding either as a single stage or in two stages is usually an integral part of mechanical resource recovery operations. It has also been used as a means of preparing large bulky combustible items for incineration where the resultant volume reduction may be as much as 90%.

### Disadvantages

Many of the operational and maintenance problems of shredders discussed may be considered to be disadvantages; they will be summarized here.

1. Shredding adds to the cost of disposal (8 to 12 dollars/ton)

2. Leachate and gas production in the landfill show an increased rate of generation - not an increase in total amount produced.
3. High maintenance type of equipment needs regular upkeep - rule-of-thumb: for every eight hours of shredder, eight hours of maintenance.
4. Needs standby equipment to accommodate the possible lack of availability due to maintenance requirements.

### III SCREENING

Separation of refuse components is done for a variety of reasons. These may include resource recovery, protection of equipment and improved operation, and better quality of final product.

There are several screening devices but only a few will be dealt with here.

#### Hand sorting

This is the most elemental yet most effective method available. Any given separation may be provided depending on the market for materials and separation objectives. The two goals may be summarized as salvage and protection. Design parameters for hand picking from a conveyor belt are: belt width 24 in for picking only on one side, 36-48 in for picking from two sides, belt speed 30 to 40 ft/min (3).

#### Trommel screen

The trommel is a revolving screen made up of a perforated drum and is the most popular screen for processing municipal

waste. The drum or cylinder with holes in it is inclined, mounted on its side and the refuse is fed into the upper end. As the cylinder rotates the refuse tumbles and rolls and the particles which are smaller than the openings fall through and out of the waste stream. Rotation of the drum is about 10-15 rpm. The main advantage of the trommel is that it is resistant to clogging.

Design parameters as presented herein will be more empirical than theoretical. Separation by trommel is accomplished by allowing the refuse in the screen to tumble around until the pieces smaller than the holes find a hole and fall out. The tumbling motion may be of two kinds (3):

1. Cascading
2. Cataracting

The difference between the two is that the cataracting motion results when the drum rotates fast enough so that the material actually leaves the surface of the drum and tumbles through the air (parabolic trajectory) back to the bottom of the screen, while in the cascading motion, refuse simply rolls down the layer of refuse heading up. Cataracting motion produces the greatest turbulence and should produce the highest separation efficiency. Critical speed is that speed such that the refuse is just held on the wall of the screen by centrifugal force (1).

$$N_o = \frac{1}{2\pi} \sqrt{\frac{g_o}{R}}$$

where:  $N_o$  = critical speed

$g_o$  = acceleration due to gravity

$R$  = radius of drum

Designs differ but it appears that diameters may range from 6 feet to 9 feet or more, length 12 feet or more, (a trommel should not be less than 2 diameters in length (1)), detention time should be 30-60 seconds, at least so that 5 or 6 revolutions of the refuse may occur within the drum before exiting (3). Drum speed should be 30% to 45% of critical speed or about 10-15 rpm. Another rule-of-thumb indicates that the recovery is greatest where the load rides one-third of the distance to the top of the drum (3).

For estimating electrical needs, a value of one horse power per ton per hour capacity can be used, increasing to the next larger size motor available (1).

The utilization of a trommel screen ahead of a shredder allows the removal of a good deal of the glass without shattering it to the extent that occurs in the shredder. If refuse-derived fuel is to be produced the early removal of the glass before it is imbedded with the paper etc., reduces the ash content and the abrasive character of the final product tremendously. This will reduce the wearing of the hammers in the hammer mill caused by the abrasion due to the glass in the mixed refuse.

#### IV INCINERATION

The combustion of mixed municipal refuse under controlled conditions is the general definition of incineration.

Incineration should be considered as a means of volume reduction since there are still residues to dispose of. The volume reduction accomplished should be 85-90% assuming complete combustion of the combustibles. (Weight reduction may range from 70-80%).

The discussion following will be organized in a manner commensurate with the schematic shown. Initially it is assumed that quantities of waste in excess of 200 tons/d are to be burned.

#### Refuse receiving area

The collected refuse is delivered to the incinerator plant which must provide facilities for these trucks to empty efficiently for return to the collection route. The usual procedure is to provide a large storage pit into which the refuse is discharged. This pit has a capacity of from 2 to 3 days or more accumulation of refuse and serves as a storage reservoir of refuse so that the furnace may continue burning throughout the 24 hours of the day even though refuse collection is completed in less time than that. Also it may be important to be able to burn continuously 7 days a week, when collection is only done on 5 days. The pit is constructed of durable materials, armoured to protect the walls from damage from the crane bucket and other heavy objects. The tipping area (where the trucks empty) may or may not be enclosed but environmental considerations are best protected by enclosure. It must be designed so that it is large enough to allow the required number of trucks to enter the tipping area, to empty simultaneously, and then to leave efficiently to avoid long delays at the tipping area.

### Transfer crane

As was stated earlier the solid wastes are discharged from the collection vehicles into a large storage pit. The refuse must be moved about within the pit to make room for more incoming refuse, mixed to make a more uniform fuel and finally transferred to the furnace for burning. All of these important functions are carried out by the transfer crane. This crane must have a capacity of 2-5 yd<sup>3</sup>, be of a high-speed, heavy-duty type which is arranged so that it can reach all parts of the pit. Approximately 50% of its operating time will be spent mixing and moving refuse while the other half is spent feeding the charging hopper of the furnace. The usual style of crane employed is a travelling bridge crane with an enclosed operator's cab either travelling with the crane or in a central location where the full operation can be seen. Since the continuous operation of the combustion process depends on the operation of the crane it is usually necessary to have a standby unit available at all times for reliability. The bucket used may be either a grapple, clam-shell or orange peel type.

### Furnace (combustion system)

Incinerator furnaces may be classified in a number of ways; among them are: (i) batch or continuous feed; (ii) refractory or water wall; (iii) grate systems. The discussion provided herein will be limited to the continuous feed type since this is the type most widely used for large (>200 tons/d) units. A continuously fed furnace is designed with a charging hopper to provide a means of continuously introducing refuse while at the

The ordinary design values for grate burning capacity for municipal solid waste are about 50 to 70 lb/ft<sup>2</sup>·h (240 to 340 kg/m<sup>2</sup>·h). Another grate loading parameter is the Btu/ft<sup>2</sup>·h (heat release) which commonly ranges between 250 000 and 300 000 Btu/ft<sup>2</sup> of grate/h (2.8 x 10<sup>6</sup> to 3.4 x 10<sup>6</sup> kJ/m<sup>2</sup>·h) (3).

The manufacturer's stipulations relative to specific requirements for each of the various types of grates must be considered.

Combustion air is another important component of the furnace design. An ample supply of oxygen is required to complete the chemical reactions involved in the combustion process. The exact amount of oxygen required for burning the waste is known as the stoichiometric air requirement. Any additional air is known as excess air and is generally expressed as a percentage of the stoichiometric requirement.

Air is supplied as under fire and over fire air. The under fire air is admitted through the grates and cools them in addition to supplying air for combustion. Over fire air is introduced through the top and sides of the combustion chamber above the fuel bed and provides air for the combustion of the volatile gases and to produce mixing and turbulence for complete combustion.

Various furnace configurations will have different air requirements and variations of the split between under fire and over fire air with the range from 25-100% under fire. It would seem reasonable for approximately one-third to be put under fire with the rest above the grates.

The amount of excess air provided is an important factor since it influences the furnace temperature and the volume of exiting

gases passing through the air cleaning phase of the furnace. Theoretically the maximum temperature in the combustion process is obtained only when the stoichiometric amount of air is supplied. If more air is introduced the temperature is reduced in proportion to the amount of excess air. This effect is utilized to control the temperature in a refractory lined furnace and thereby protect the fire brick. Up to 200% excess air is sometimes required whereas in a water wall furnace the excess air may only amount to 50-100% of the theoretical amount (3).

Air requirements are provided by fans which deliver the air to the various points of application under pressure.

#### Residue (ash)

Due to the presence of a certain amount of non-combustible material plus a small percentage of unburned combustible material the incinerator is not a method of final disposal but a volume reduction process. The amount of unburned combustible material will be at a minimum (<5%) in a well designed and operated incinerator while the non-combustible content will reflect any preprocessing such as metal recovery that occurred. If no preprocessing occurred the residue may comprise 20-30% by weight or 10-15% by volume. This material must be quenched upon leaving the grate since it is very hot and may contain burning material. (Still burning material should be minimized if the furnace is well designed and operated.) This is done by introducing water to the ash hopper in which the residue is collected or dropping the hot residue into a bath of water from which it is removed by a drag conveyor.

From this point the residue is disposed of, usually by land-filling. The recovery of metals and use of the ash for fill material is being practised at some locations.

#### Gas cleaning equipment

The gases leaving the combustion chamber may be very hot (1400-1800° F) and contain particulate matter. The gases must be cooled and the entrained particles removed. The gas temperature entering many air cleaning devices cannot exceed 450-500° F. Cooling may be accomplished by utilizing water in various ways which will require large quantities of water (rule-of-thumb, 2-4 pounds of water for every pound of refuse burned) or the heat may be removed by passing the gases around a series of boiler tubes as is done in a water wall furnace. Such a waste heat boiler may be able to produce steam at the rate of from 1 to 2 lbs of steam/lb of refuse incinerated and 60-70% of the heat generated may be recovered following a refractory combustion chamber (3).

The air cleaning equipment employed is mainly responsible for removal of particulates. Other constituents of combustion, CO, NO<sub>x</sub>, and SO<sub>x</sub> are usually rather low from incinerators burning MSW (3).

There are several types of air cleaning devices which may be considered. Cyclones, wet scrubbers of several kinds, bag filters and electrostatic precipitators make up most of the list.

In general cyclones are not able to remove enough of the fine particles to meet the air emissions standard.

Wet scrubbers may have trouble in removing the required amount of particulates but do have the ability to remove certain water-soluble gaseous pollutants. They do require substantial power to attain high efficiencies, and utilize large amounts of water which require treatment.

Bag filters are being designed now which can sustain the high gas temperatures (750° F) and are being considered for possible use at incinerators.

Electrostatic precipitators have been the most common devices used at incinerators where they have met the air quality standards. They are expensive and require careful control of influent gas temperatures (450-500° F) and have other problems but they have also shown that they are able to meet the effluent standards.

#### Water treatment

Water is utilized in a number of ways in a large incinerator operation. If a water wall combustion chamber is utilized then the water will have to be demineralized and de-aerated in the same manner as boiler feed water. If a wet scrubber is utilized then the particulates removed from the gas stream will in turn have to be removed from the water before it can be recirculated or discharged, pH adjustment will also be necessary. By treating and reusing as much water as possible, considerable savings in water costs can be realized depending on the cost and availability of water.

## V OTHER TYPES OF COMBUSTION DEVICES

### Modular units

These units are generally prefabricated combustion units designed for 50 tons/d. or less. They are often batch fed by means of a hydraulic ram which pushes the refuse from a charging hopper into the end of the furnace. The combustion of the refuse utilizes a controlled-air approach whereby the refuse as received is burned in a primary combustion chamber in a reducing atmosphere (insufficient oxygen for complete combustion) which tends to reduce the particulate emission. The gases from the primary chamber are then burned in a secondary chamber where an excess of air is provided with vigorous turbulence to ensure that all the gaseous and particulate matter is burned. Auxiliary fuel such as gas or oil may be required to assist in the combustion process.

The modular unit is usually designed to operate less than 24 hours a day; some have grate systems which move the refuse forward through the primary chamber while others require shut-down for removal of the residue. The weight reduction reported is about 68%, volume reduction 93% (3). Waste heat recovery systems can also be provided on the modular incinerator. This type of unit is well suited to small community use and use by industry.

### Fluidized bed

The fluidized bed incinerator consists of a bed of sand contained within a refractory lined enclosure supported on a perforated plate through which air at a high enough velocity to lift the sand is introduced. The sand is preheated and then the fuel (in this

case pulverized solid waste) is introduced. The combustion of the waste occurs in contact with the fluidized sand maintaining a bed temperature of 1400-1600°F. The solid materials stay in the bed until they become small enough and light enough to leave with the exiting gases as particulates or they may build up in the bed until the excess material is drawn off to maintain the bed level. The sand acts as a heat source and heat sink and provides a fly wheel effect to maintain combustion conditions as the waste characteristics vary. Some common dimensions of these units are: reactor diameter 20-50 ft, sand depth 1.5 to 10 ft and air velocity in the bed 5 to 7.5 ft/s.

Fluidized beds have been successfully utilized in burning various types of liquids, sludges and gaseous organic wastes. Municipal solid waste must be shredded to a fine particle size prior to its introduction into a fluidized bed reactor. Experience with the utilization of the fluidized bed to burn municipal solid waste is very limited and much more needs to be known before any conclusions can be drawn.

## VI PYROLYSIS

The process of pyrolysis is the destructive distillation of the organics in the waste material. The process is carried out under high temperatures in an environment lacking in or devoid of oxygen. The products resulting from the process are a gaseous fraction, a liquid fraction (oil) and a solid fraction (char).

Typically, during the pyrolysis of municipal solid waste, organic compounds are converted to pyroligneous acids, fuel gases, water and char. An analysis of pyrolysed municipal solid waste products (3) noted that a ton of municipal solid waste pyrolysed at approximately 1600°F yields the material shown in the table below.

Products of Pyrolysis @1600°F

Gas	18 000	ft <sup>3</sup>
Liquid	144	gal.
Tar	0.5	gal.
Ammonium sulfate	25	lb
Solid residue	154	lb

(From reference 3)

The gases produced in the process consist primarily of hydrogen, carbon monoxide, methane and ethylene in that order of abundance. The mixture of these gases is a good fuel with a heat content of about 2750 to 4400 Btu/lb of solid waste. About 1100 Btu/lb of heat is required to make the process self-sustaining; the remaining gas fraction becomes available as a by-product of the process (3).

The reactor also produced liquid products, oil and tars, pyroligneous acids and water. The oils and tars can be used as fuel stock products while the pyroligneous acids are chemically complex mixtures.

The solid residue or char is a light-weight carbonaceous material which has a fuel value from 5500 to 9350 Btu/lb and a very low sulfur content (3). This char material may be used as a fuel after briquetting or for other purposes.

The pyrolysis process is a complex one with many variables which affect the operation, character and composition of the final products. In general it may be stated that with other conditions being held constant, as the temperature of pyrolysis increases the gas content increases proportionately while the amount of acid, tars and char decreases. The operating temperature influences not only the quantity of the gas but also its quality (3).

There are several different pyrolysis systems available. No attempt is made herein to describe them but rather to indicate the nature of the process. With further advances in technology and with greater emphasis placed on energy conservation pyrolysis should become a process to be considered.

## VII OCEAN DISPOSAL

The topic of ocean disposal of solid wastes raises several questions:

1. Will the solid waste discharged into the ocean remain on the bottom or float and eventually wash ashore?
2. In either case what will be the effect?
3. Will the flora and fauna of the sea water in the area of disposal be affected? If so, how?
4. Is this an economical means of disposal considering the resource recovery and environmental aspects as well as simply immediate costs?

Some practical aspects of ocean disposal are as follows. The permanent submergence of solid waste eliminates the objectionable features of floating debris, etc. This requires increasing

the density of the solid waste by compression to a degree at which it will sink to the bottom of the ocean and stay there. The required density is about  $66.5 \text{ lb/ft}^3$  or  $1800 \text{ lb/yd}^3$  (4).

The problem has been, and remains, of finding the means of applying the required pressure to obtain the refuse densities needed. Densities in excess of about  $55 \text{ lb/ft}^3$  are difficult to obtain in an open hydraulic press due to the extrusion of liquids from the wastes.

Another possibility has been suggested and that is to push the baled refuse down a tube which projects 30 to 50 feet below the water surface. This method would pressurize the waste and not require particularly complicated equipment (4).

Not all waste components respond well to compression; plastic items do not remain compressed and submerged (4).

The major uncertainty relating to the pressurization approach to disposal at sea is the question of how long the compressed material will remain submerged. With the passage of time decomposition may take place resulting in gasification to the extent that the bale swells and breaks so that the material will resurface (4).

The question of the ecological effect of the waste material on the immediate area over a long period of time has to be considered.

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(4) Golucke, C.G. and McGauhey, P.H. "Future Alternatives to Incineration and their Air Pollution Potential". National Conference on Air Pollution, 1966.

SANITARY LANDFILL -  
OPERATION AND MAINTENANCE

by

D.H.G. Tollemache\*

In the background paper we have already discussed sanitary landfill, and referred to Frank Flintoff's book, which shows simple means of landfill, using low-cost equipment and showing how landfill can be carried out manually.

The foregoing showed us the principles of sanitary landfill, and the methods with simple equipment which are particularly suitable for the smaller towns and rural areas in the EMR.

This present short paper is intended to follow on from what has already been said in the background paper, and to deal with other practical aspects of sanitary landfill.

The term "sanitary landfill" originally American, has come to be the chief way of describing "controlled tipping" which definition was used in Britain. This was derived from the original description "constructive tipping", used by Bradford City, where the best early example of this method was demonstrated by the construction of the well-publicized Odsal Stadium at Bradford. It was the example of this magnificent reclamation project that concentrated people's minds on the great advantages that sanitary landfill/constructive or controlled tipping had over the stinking, rodent- and fly-infested mess that "dumping" had caused in the

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past, not to mention the smell of burning and the air pollution of smoke too.

We re-emphasize that sanitary landfill involves depositing the wastes in layers of no more than 2 m, covering the deposited refuse after compacting with 25 cm of earth, and finally compacting again after covering. This must be done daily, and the operators must ensure that all the refuse is completely covered and sealed. The object of this cover, which effectively closes the refuse in earth-covered cells, is:

- (i) to prevent fly emergence;
- (ii) to prevent rodents burrowing into the materials tipped, and even if they do enter, to make it easier to see where they have entered so that steps can be taken to dispose of them;
- (iii) to keep the heat of the natural fermentation in, so that pathogenic organisms and fly larvae are killed; and
- (iv) to keep the fire risk down; in sanitary landfill the refuse is never tipped to a greater depth than 2 m before sealing with cover; should fires occur, this method helps to limit them to one cell and so makes it easier to isolate fires.

The tip is then, of course, covered with its final cover of fertile earth so that agricultural crops or trees can take root. The thickness of this final cover will depend on the crop, but should be at least 45 cm.

Types of landfill most likely to be suitable in the EMR Countries

1. Desert sites

Here it is necessary to find areas which have deep sand or poor earth to a depth of at least 2 m without an aquifer below. This is usually possible, since many of the areas near the sea are inherently unsuitable for boreholes, due to the salinity of the water. There are two methods:

(a) A trench of some 2 m in depth is excavated by means of a JCB or similar machine, or by means of a tractor and front-end loader, either wheeled or tracked. This method is adequately described by Flintoff on page 142 of WHO's Publication "Waste Management in Developing Countries".

(b) The cut -and-fill method

This is sometimes used in Britain for small sanitary landfill sites. In Britain, as already stated, the county authorities are responsible for refuse disposal, and the district or borough councils for refuse collection. If the county authorities were to insist on the collecting authority sending their collection lorries more than the agreed mileage (which varies from county to county), they must pay for this extra transport by reimbursing the collecting authority (the district or borough council).

For this reason, although large tips are very much more economical to operate than small ones, the disposal authorities sometimes require to have small landfill sites near small out-lying towns. Often natural landfill sites (such as disused quarries) are not available at a suitable distance from the

town. In these cases, where soil conditions allow, the disposal authority will send out an excavator to dig a pit, which will last for, say, 2-3 years.

Such a pit will be excavated to a depth of some 2-5 metres and to a width which will accommodate all the collection vehicles that are likely to tip at one time. The excavated earth is stock-piled at the sides and ends of the excavation, the shape of which should preferably be rectangular and the length as required for the quantities. After the excavation, only a simple tractor and front-end loader or small bulldozer will be required on site. In villages, no machinery will be required where the operation is small enough to be done manually.

The dug pit is filled with refuse, covered and compacted in the same way as in a natural quarry (to be described further). The cover is taken from one side or one end to cover the refuse tipped into the pit. Later, further refuse is tipped above the level of excavation and spread out from the area of the dug pit to make a smoothly formed hill with shallow contours above the existing ground level.

It may be interesting to note, though not applicable in EMR countries, that such hills of refuse have been made for use as skiing slopes in Canada, and one of the advantages of this method is that there is a minimum amount of leachate, since the heat of fermentation in the tip evaporates much of the moisture, and the hill formation sees to it that rain does not enter the refuse when the tip is finished and closed. Such a method is also valuable in EMR countries where there is thought to be any danger

of polluting underground waters, as the rains will not have passed through the refuse to produce a large quantity of strong, polluting leachate.

Such a method may also prove to be of considerable advantage to smaller towns in EMR countries. The writer wishes to remind readers of the "district" methods referred to under "collection" in the background paper - where a district can help smaller towns with their waste management problems by loaning them equipment.

#### Calculation of earth cover required for landfill

Refuse tipped 2m deep will be consolidated and settle to approximately 1.5m. If we use 25 cm cover on each 2 m layer (settling to 1.5 m), and also cover the "flanks" and finally top cover the tip, with 45 cm, we shall need a volume of covering material approximately equal to 30% of the volume of the excavation filled with refuse. As a converse, a pit of, say, 20 000 m<sup>3</sup> will provide sufficient covering material to receive approximately 55 000 m<sup>3</sup> of compacted refuse, with some 15 m<sup>3</sup> (plus cover) in the pit one has dug, together with, say, 40 000 m<sup>3</sup> of compacted refuse above ground level and spread over and landscaped around the pit.

#### Allowance for cover essential

We should note here that, whatever the type of site one plans to use for landfill one must ensure that covering material amounting to some 25-30% of the volume of the tip is available.

## 2. Quarries, valley ends and ravines

It is most important that these be filled in layers from the bottom up to avoid steep slopes from which the cover would be eroded by winter rains. It is also necessary to arrange drainage before starting to tip in such a way that streams are diverted so that they do not enter the tip.

A road must be made to the lower level to within 2 m of the bottom (in quarries there is usually such a road already). If the road is already in existence, and we are on the floor of the quarry, we must start by making a "finger" or a cell (See Flintoff, pp. 116-121 and Figures 19 and 20) of the width required for all the lorries likely to tip at the same time.

Refuse is tipped, pushed out and compacted on a gentle slope which the bulldozers can climb, to a height of 2 m, which becomes the tipping face, and is advanced as tipping proceeds. This slope is, of course, finally covered in the course of completing the further layers.

## 3. Marshes and tipping into water

The writer did not come across the need or desire for information on tipping into marshes or water during his visit to EMR countries, but it would seem quite likely that such areas might be suitable for improvement near some EMR low coastlines. Flintoff mentions the problems of odours caused by  $H_2S$  when refuse ferments anaerobically, and how this can be overcome by forming dykes with inert wastes and pumping the areas dry before filling with refuse. Refuse has been tipped into inland ponds. This

causes pollution problems which have been overcome by blowing air through the water. However, except in exceptional situations with no alternative sites available such complications should be avoided, and raw refuse is now seldom tipped into water.

#### The utilization of old landfill sites

When an old tip site is full, and the material in it is fully degraded to an extent that disturbing it no longer produces odours (about seven years), the material could be removed and used as an organic fill, after screening, to form dykes, or indeed, to improve the desert.

Careful tests would have to be done initially to ensure that it was safe from the health point of view, and secondly to judge whether there was any fertility left in the decomposed materials of sufficient value to justify the cost of removal. This activity may, in certain circumstances, be worthwhile - for instance, to create a new landfill site near the city from the old one, at the same time making use of the old fill. Such cases may be rare, but as a possibility this should be borne in mind, since it economises both on land required for Sanitary Landfill Sites and also on land otherwise requiring excavation in order to produce covering material.

#### The sanitary landfill of pulverized refuse

Pulverized refuse, as referred to in our Background Paper, has the advantage that no intermediate cover (every 2 m) is required, but a final top cover must be given.

It also has the advantage that there are no voids and a denser tip - although tips formed with the use of steel wheel compactors give the same density. Pulverized refuse does not blow about so readily, and the pulverized refuse can be composted if formed into windrows. This is both an advantage where compost is required and also in those cases where one requires to tip into a marsh and raise the levels. After a period of simple composting the BOD will be reduced by half, and the problem of water pollution will likewise be reduced by approximately half too.

#### The sanitary landfill of toxic wastes

This problem has not yet been reported on, to the writer's knowledge, in the EMR countries, but may have been. In fact, strict controls should now be legally enforceable and to protect the environment it is essential that particular care be taken to ensure that chemical and other toxic wastes do no damage to the environment. If toxic wastes are to be disposed of, landfill operations must be particularly well controlled.

#### Secure landfill

The site for a secure landfill must not be above aquifers, and must have at least 20 m of filtering earth or sand. The bottom of the tip must be impermeable or made so with clay (or percolating at no more than  $10^{-7}$  cm/s ). The toxic wastes must be tipped in such a way that those which might react together are in different cells.

Should it be necessary to tip seriously toxic wastes or dangerous chemicals, whilst landfill was thought to be a secure

method, it must be undertaken with great care, with pretreatment and packaging where necessary, under responsible control and regulations which require careful daily records to be kept. In all cases, chemists' opinions should be sought before tipping toxic wastes, and their advice must be adhered to as to whether the wastes are safe in the landfill proposed, or must be tipped in the special secure landfill. Recent findings in Britain emphasize the need to pretreat certain toxic materials before landfill, often by incineration.

Such a secure landfill need not be large, and must be kept especially for toxic wastes (after pretreatment, where recommended) which the chemist advises should not be tipped in the main landfill.

#### Inherent problems of sanitary landfill and their avoidance

Whilst sanitary landfill is, and will undoubtedly continue to be, a main method of disposal because it is cheap, it can be criticized for the reasons that follow, all of which can be avoided to a greater or lesser extent with care and if proper attention is paid to the problems.

1. It wastes materials that could be re-cycled or from which energy could be gained. Only where it is reclaiming land and improving the environment can it be said to utilize wastes.
2. Inevitably, paper and plastics blow about in high winds. It is necessary to avoid this by using wire mesh screens.
3. If the bottom of the tip is wet, or there is a high rainfall, much methane will be produced. When the tip is well compacted, there is a danger that this methane can move laterally

and damage trees when it emerges, or even cause explosions in buildings into which it percolates. However, in some large tips the methane is extracted by pumping it out so that it can be utilized, and in others, trenches are dug around the tip to prevent the methane entering nearby buildings.

Because of the foregoing, some European countries and some experts recommend that pretreatment such as pulverization be carried out before tipping in sanitary landfills.

In the EMR countries, the foregoing dangers are unlikely to be serious ones, except in tips near large towns. It is always important to choose sites and use techniques that will produce the best results from landfill, and avoid its disadvantages and dangers.

There is, however, a present tendency - though a slow and gradual one - to move from sanitary landfill to forms of treatment which utilize wastes, and where it is economical, it is to be applauded and should have our enthusiastic backing.

#### The sanitary landfill of cesspit emptyings

The use of sanitary landfill sites for the disposal of cesspit emptyings and sewage sludge is acceptable as a temporary measure whilst other means of sewage disposal are being developed, but, as with toxic wastes, particular care must be taken to see that the leachate does not enter aquifers. Advice should always be obtained from the specialists in sewage disposal and the hydrogeological department to ensure that the Landfill site is not overloaded.

The preferred method is to excavate trenches in old tips, where the materials have desiccated and are absorbent. The liquids then seep through the old refuse, leaving only the solids from the cesspit sewage.

Particular care must be taken to see that there are no fly problems, but this method is far safer from the fly point of view than tipping the cesspit emptyings, widely scattered, over the top of the tip and uncovered, as the writer saw in one instance. The same precautions should be taken with paunch manures from the abattoirs.

Finally, before preparing this Paper, the writer talked to a number of colleagues and consulted recent books and papers on the subject of Landfill. Nowhere, in the writer's opinion, is there a clearer description of the basic principles on practices than in The Management of Solid Wastes in Developing Countries.

This covers almost all aspects including finding the site, leachate, water-filled sites, etc., and the writer feels that there is little he can usefully add, other than the previous notes he has already made, except to again strongly recommend the study of Chapter 14 to those participants who have to operate landfill as the best sedentary study they can possibly make.

Thereafter, it would seem most useful for us to see the film, kindly made available by the US Environmental Protection Agency.

Note: See Appendix for Model Conditions for Landfill Sites and Treatment Plants.

## APPENDIX

## MODEL CONDITIONS FOR LANDFILL SITES

Working Plan 1

No deposit of waste shall take place unless, at least one month previously, a working plan, giving details of the proposed conduct of operations at the site, has been submitted to the Waste Disposal Authority; and the licence holder shall notify the Waste Disposal Authority of any proposed change in the actual conduct of operations from the proposals shown in the plan, as altered by any previously notified changes, at least one month before the proposed change is implemented.

Comments

This condition enables details of operations on the site to be settled later, without delaying the decision on the application, and the provision concerning changes allows some flexibility as operations progress. There should be full consultation between applicant and the Waste Disposal Authority early in the application process before the working plan is drawn up - and afterwards if necessary. But as a result of legal advice, the condition does not provide for approval by the Waste Disposal Authority at a later date of the working plan or subsequent amendments to it. If in the end, the plan or proposed amendment were unacceptable to the authority (or indeed if an operator did not adhere to the

plan) it would be open to them to deal with the matter by modifying the conditions attached to the licence, in accordance with Section 7 of the Act. In general, it will often be better for matters which the authority regards as really important in a particular case to be dealt with by a condition rather than in the working plan. The following are matters which will commonly be appropriate for inclusion in a working plan:

- (a) Details of any site preparation work to be carried out, including steps to prevent water pollution. (But it may sometimes be more appropriate for these to be the subject of a separate condition.)
- (b) Average daily intake of waste, with a proportional breakdown into types where appropriate. (Often it is desirable to control the ratio in which different wastes, e.g. solid and liquid, are tipped, even though maximum permitted quantities are specified in condition 2 below.)
- (c) Direction of working (to take account of factors such as the prevailing wind).
- (d) Phasing of filling and site restoration. (The number of layers that are envisaged in each phase of filling should be indicated. To facilitate settlement and dispersal of any gases a period of at least six months and preferably twelve months should be allowed before a further layer is added.)
- (e) Maximum width of the working face. (This should be stated and should be related to the number of vehicles using the site at peak periods.)

- (f) Details of seasonal, bad weather and emergency tipping areas. (It may be appropriate to provide for separate areas to be filled in summer and winter, to avoid filling near occupied properties in the summer, and to preserve an area near the site entrance for use in bad weather or to designate an area for emergency use.)
- (g) Particulars of sources and reserves of covering material.
- (h) Location of the site control office.

The working plan should also show how the deposit of any waste with special properties, such as hazardous wastes and pulverized fuel ash, is to be integrated at the site.

#### Working Plan 2

The types and quantities of wastes deposited daily at the site shall not exceed the following.....

(To be specified according to the needs of the case.)

#### Comments

The types of waste for which the site is considered suitable should be specified in all cases. Often it will be necessary to specify maximum quantities of different types (e.g. solid and liquid wastes, domestic waste and particular industrial wastes). Where it is important to control the proportions in which a mixture of wastes should be deposited, this can be done by condition rather than as a feature of the working plan as suggested above.

Working Plan 3Site preparation and works

No deposit shall take place unless a road has first been provided within the site. This shall be constructed to the following specifications and shall run from the site entrance to the site control office. The road shall be maintained to the reasonable satisfaction of the Waste Disposal Authority.

Comments

It is preferable for this condition and for most of the other conditions in this section to set out the Waste Disposal Authority's requirements. The site road envisaged in this condition should preferably permit two-way vehicular traffic and should lead to the site control office which should itself be located far enough from the entrance to allow vehicles to queue within the site and not on the highway. Ideally, the road should be metalled although this will not always be necessary. In determining the length and width of the road account will have to be taken of the number of vehicles using the site and the location of the wheel-cleaning equipment (see condition 4) and the need to avoid obstructions and bottlenecks particularly at the site entrance.

Working Plan 4

No deposit shall take place until suitable wheel-cleaning equipment has been provided. This equipment shall be properly maintained and used (position specified by the Waste Disposal Authority).

Comments

If wheel-cleaning is to achieve its purpose it must be carried out on a hard surface adjoining the main site road so that once vehicles have had their wheels cleaned they do not have to travel over muddy surfaces. To avoid obstruction at the site entrance and to ensure that facilities are being operated and used properly they should preferably be located near to the site control office. The condition should normally specify the position.

Working Plan 5

No deposit shall take place until a site control office has been provided on the site.

Comments

The nature of the site control office required under this condition will depend upon the size of the site and the scale of operations. On some sites a small portable office will suffice. At others, however, a more substantial control centre may be necessary, possibly linked to weighbridge and wheel-cleaning facilities. The actual location of the site office is a matter

to be settled within the context of the working plan (see condition 1).

#### Working Plan 6

No deposit shall take place until a site identification board of durable material and finish has been displayed at the site entrance, showing the hours when the site is open and giving the name of the site, the name, address and telephone number of the operator (and his local agent) and of the Waste Disposal Authority responsible for issuing the site licence.

#### Working Plan 7

Tanks used for the storage of liquid shall be bunded. They shall be of a type and construction suitable for the wastes they contain and shall be labelled to show their contents.

#### Comments

The extent to which this condition is applied will depend on the nature of the liquid and the situation of the tanks and, particularly for explosive, inflammable and toxic substances, on safety and health factors.

#### Working Plan 8

No deposit shall take place until watercourses on the site have been diverted, culverted or otherwise protected to the reasonable satisfaction of the Waste Disposal Authority.

Working Plan 9

No deposit shall take place until surface drainage water from surrounding higher land has been diverted from the site.

Working Plan 10

No deposit shall take place unless subsidiary site roads have been provided as follows. These shall be maintained to a reasonable standard.

Comments

It is important that vehicles travelling to and from the working face in all weathers should not have to be driven excessive distances over unfinished surfaces.

Working Plan 11

No deposit shall take place until a suitable weighbridge or other weighing facility has been installed at an appropriate point on the site.

Comments

This is desirable and probably essential on larger sites in order to provide the management with the information on the quantities and types of waste received which is required under standard condition 28.

Working Plan 12

No deposit shall take place until suitable facilities have been provided for storing and maintaining equipment used on the site.

Comments

This could cover items such as a fuel storage tank, a tool store or a building for the servicing and repairing of equipment.

Working Plan 13

No deposit shall take place until movable screens have been provided at intervals near operational areas having regard to wind direction so as to ensure that paper and other materials are contained on the site. Materials arrested by such screens shall be removed and disposed of as necessary to maintain the efficiency of the screens and the tidiness of the site.

Comments

This will only be necessary on sites where the type of waste being disposed of makes wind nuisance likely.

Working Plan 14

No deposit shall take place until gates and fencing have been provided to the following specifications. They shall be maintained to the reasonable satisfaction of the Waste Disposal Authority, and all reasonable precautions shall be taken to prevent unauthorized access to the site.

Comments

The extent of the fencing and security measures required by this condition will depend on the size and location of the site, the nature of operations and the waste being deposited. Ideally, entrance gates should be wide, lockable and located at least 12 yards from the highway with the layout providing good sight lines for vehicles leaving the site. Where practicable, site entrances and areas where landfilling is actually taking place should be fenced. This is particularly important where toxic wastes are being deposited or lagooned. In determining the need for fencing, however, waste disposal authorities should taken into account any natural barriers that might exist. Other precautions to prevent unauthorized access might, on larger sites, include the provision of security patrols.

Working Plan 15

No deposit shall take place until lighting has been provided on the site as follows, to facilitate the use of the site during the hours of darkness.

Comments

The extent of the site lighting to be provided under this condition will again depend on the size and nature of the site but could include the provision of portable light units and fog flares as well as lighting for site roads: the appropriateness of such a condition will be influenced by the likelihood of members of the public gaining access to the site.

Working Plan 16Site Operation

The site shall be adequately manned and supervised during working hours.

Working Plan 17

Solid waste shall be compacted and formed into a layer as soon as possible after deposit and not later than at the end of the working day on which the waste is received.

Comments

The broader question of how landfilling is to be phased is a matter to be settled within the context of the working plan (see condition 1). Comprehensive guidance on landfilling is contained in the Report of the Working Party on Refuse Disposal, HMSO 1971. Depending on the size and nature of the landfill the provision of Part III of the Mines and Quarries (Tips) Regulations 1971 may be relevant as regards stability; the Health and Safety Executive will advise.

Working Plan 18

The layer of waste shall be formed in one or other of the ways described in condition 20 below using suitable compaction equipment with a blade or some other appropriate levelling device.

Comments

Depending on the size of the site and the scale of operations it might be appropriate to specify the equipment which is to be used.

Working Plan 19.

The depth of a layer of waste shall not after initial compaction exceed 2-5 metres (8 feet).

Working Plan 20.

Waste shall either

(a) be deposited on the surface of the site behind the face and partially compacted by a tractor or other compacting machine before being pushed over the face, or it shall

(b) be deposited on the ground forming the base of the site or on a previous layer in front of the face and shall be formed into a compacted layer by being pushed upwards and driven over by a tractor or other compacting machine.

Working Plan 21.

Before covering, working faces and flanks shall be compacted to form gradients not steeper than 1 in 3.

Working Plan 22.

Material used for landfill other than that which is wholly non-putrescible shall, subject to the traction needs of vehicles operating at the working face, be covered progressively with suitable non-putrescible or stabilized material throughout the working period each day, so that by the end of the day all exposed surfaces including the flanks and face shall have been covered to a depth of not less than 15 centimetres (6 inches).

Comments

Although a minimum depth of 15 centimetres (6 inches) cover is being specified in this condition, covering material should, ideally, be spread so that it is on average not less than 23 centimetres (9 inches) thick. The thickness of covering material on layers formed solely of pulverized waste need not be as great.

Working Plan 23

All large articles such as furniture, crates and hollow containers likely to cause voids shall be crushed, broken up or flattened and covered each day by other wastes in such a position that they are not within one metre (3 feet) of the surface or two metres (6 feet) of the flanks or face.

Comments

This is with prejudice to the health and safety precautions which may be required under the Health and Safety at Work Act 1974; e.g., for cylinders which have contained flammable liquids or gases under pressure, this condition would not be appropriate.

Working Plan 24

Waste other than inert material shall not be deposited in water.

Comments

Although it is possible to deposit waste other than inert wastes in water the precautions necessary to avoid undesirable consequences will normally be extremely onerous; in most cases the practice is better avoided.

Working Plan 25

Not less frequently than once a week any loose waste which may be lying on the site shall be gathered and disposed of in such a way as to keep the site tidy.

Working Plan 26

No waste material shall be burnt within the boundaries of the site, and a fire at the site shall be regarded as an emergency and immediate action shall be taken to extinguish it. All outbreaks of fire shall be notified forthwith to the disposal authority.

Comments

Persons on the site should be instructed as to the procedure to be adopted in case of fire, including evacuation and fire-fighting, in consultation with the Fire Authority and the Health and Safety Executive as the case may be.

Working Plan 27

Precautions shall be taken to deal effectively with any vermin and insects on the site.

Comments

The requirements of this condition can best be achieved if the operator adopts a programme of regular site inspection and regular pest control, paying particular attention to any area where cracks have appeared in the covering material. Steps should be taken to ensure that landfill surfaces are level to avoid ponding which

could give rise to the breeding of insects. In hot weather it may be necessary to treat loads of waste before deposit to prevent flies being brought in. At the commencement of landfilling it may be advisable for an operator to make arrangements with the local Environmental Health Department for rat control procedures so that rat infestation may be recognized and safe and effective methods for dealing with such may be practised. Operators should check at the time what other legislation applies, e.g. on fumigation procedures and use of pesticides.

Working Plan 28

A record shall be kept of the types and quantities of waste deposited.

Comments

Waste should be categorized as indicated.

Working Plan 29

The terms of the site licence shall be made known to any person who is given responsibility for the management or control of the site and a copy of this shall be displayed at the site control office.

Working Plan 30

Site roads shall, in dry weather, be sprayed with water to suppress dust.

Comments

Depending on the materials being used for landfill it may, in some circumstances, be advisable for this condition to be extended to include other operational areas as well as site roads.

Working Plan 31

When landfilling commences top-soil stripping shall be carried out in stages and only to the extent necessary to maintain a reasonably adequate area for landfilling at any one time. Top-soil thus stripped shall be retained on the site for use as final cover.

Working Plan 32

Animal carcasses and waste consisting wholly or mainly of animal or fish waste or other obnoxious materials shall be deposited in front of the working face and immediately covered with other waste material so that the obnoxious material is not within one metre (3 feet) of the surface and two metres (6 feet) of the flanks or face.

Working Plan 33

Each layer of waste and covering material shall be laid to a fall to encourage surface water run-off.

Working Plan 34

Until final restoration, completed areas of landfilling shall be graded and maintained in a tidy condition and where necessary action shall be taken to control or destroy weeds.

Comments

Weed growth and soil erosion might be prevented on completed plots awaiting reuse by sowing suitable grasses. Other requirements covering restoration will possibly have been incorporated in the planning permission relating to the site, though it may be appropriate in some cases for licence conditions to provide for phased restoration of the site while disposal activities are still in progress.

Working Plan 35

The final layer deposited shall be subject to the minimum compaction and shall, to a depth of not less than one metre (3 feet) be kept free of materials likely to interfere with final restoration or subsequent cultivation,

Comments

This condition is intended for application where land is to be restored for agricultural use. A less stringent requirement as regards depth of final layer will be applicable where some other use is intended for the site. For grassing, a thickness of 15-25 centimetres (6-10 inches) may be sufficient, depending on the type and thickness of the underlying primary cover. Where the supply of top-soil for final cover is insufficient, it may be

possible to use compacted refuse, or de-watered sewage sludge mixed with top-soil.

Working Plan 36

Not less than 14 days notice shall be given to the Waste Disposal Authority of the date on which landfilling is to commence or recommence in the event of a temporary cessation for a period in excess of three months.

Working Plan 37

Any temporary cessation of operation for a period in excess of three months shall be notified to the Waste Disposal Authority.

Additional conditions on the disposal of pulverized fuel ash

Working Plan 38

Before any deposit of pulverized fuel ash takes place at the site, water sprays shall be provided to the reasonable satisfaction of the Waste Disposal Authority and these shall be used when necessary to maintain the waste in a damp condition and so control emission of dust.

Working Plan 39

Proper provision shall be made for blanketing and binding the surface of completed deposits of pulverized fuel ash.

Working Plan 40

Each deposit or stack of pulverized fuel ash shall be inspected at least once a week by a suitably qualified person for signs of stack instability and to ensure that proper procedures are being followed and that deposit is taking place as provided for in the working plan.

Comments: 38-40

Conditions 38-40 take account of the special properties of pulverized fuel ash. This emerges from power station boiler plant as a fine and, to some extent, chemically inert powder which flows easily. It is disposed of either as a slurry or in a conditioned state (i.e. with the addition of a prescribed quantity of water). In either case, given correct treatment, it settles into a stable mass. Some of the ash is very light and can become wind-borne if the surface of deposited material is exposed and allowed to dry. However, dust can be prevented by suitable treatment. The Health and Safety Executive has responsibilities for the stability of certain tips and may therefore have comments on the appropriateness of these conditions in the particular instance.

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BIOLOGICAL PROCESSING  
COMPOSTING AND HYDROLYSIS

by

D.H.G. Tollemache\*

PART I BIOGAS

What is biogas?

Biogas is the name for the anaerobic fermentation of organic wastes to produce methane gas ( $\text{CH}_4$ ).

The process is well known because anaerobic fermentation has been studied since 1808, when Davy produced methane, carbon dioxide ( $\text{CO}_2$ ) and traces of nitrogen, hydrogen and hydrogen sulfide ( $\text{H}_2\text{S}$ ) from a mixture of water and farmyard manure, which he collected in a flask, in a laboratory experiment.

Methane is the gas produced by the decomposition of organic wastes in marshes, and the "Will o'the Wisp", a phenomenon in which gas bubbles explode with a blue flame, had been observed by country folk at night, without their understanding the reasons, for centuries.

Anaerobic fermentation has been used as a process to purify sewage sludge, from settled sewage, and as a source of power to run the machinery at the sewage works, since the early part of the century.

Methane is the gas which is often called "natural gas", and is found when an oil well is drilled, showing that anaerobic fermentation took place many centuries ago and the gas has been locked well below the surface, often under high pressure.

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Solid Wastes Management

The production of biogas from solid wastes

Although some attempts were made to produce methane from solid wastes during the 1920s by Lord Iveagh in England, and later by Imhoff in Germany, it was not until the Second World War that much practical progress was made.

The work of Lesage, Aliet and Mignotte in France, and Aceya in India, encouraged the building of many very small, simple plants by farmers.

Many of these plants used animal manure and straw - though some, in India, used solid waste in villages together with human excreta. There were some 1000 plants in France during the war, and there are still many such small plants in India and Kenya.

Such plants work well in a hot climate, but the gas production is very low in the winters of Northern Europe, just at the time when the gas is needed. This led to the disuse of small plants in temperate climates, as soon as there was no longer such a shortage of fuel as there was during the war.

The new interest in the methanization of organic manures has only recently started to show in university studies and pilot plants. It has arisen because of the increased cost of fuels.

The early small plants generally used relatively solid manures, pressed into the gasification silos, to get as much dry matter as possible into a given volume of plant, which was then covered with water.

The modern thinking is to "fuel" the plants with "chopped" organic manures sufficiently wet to be pumpable. This avoids the labour which killed the early, small, labour-intensive plants.

Such modern plants, which are very similar to the digestors used at sewage works, can be insulated, and some of the gas produced can be used to keep the digestors at a temperature where gas production is higher.

The effect of temperature on the daily production is considerable:

1 ton of manure at 10°C produces approximately 0.050 m<sup>3</sup> gas per day  
 1 ton of manure at 15°C produces approximately 0.150 m<sup>3</sup> gas per day  
 1 ton of manure at 20°C produces approximately 0.300 m<sup>3</sup> gas per day  
 1 ton of manure at 24°C produces approximately 0.615 m<sup>3</sup> gas per day  
 1 ton of manure at 25°C produces approximately 0.700 m<sup>3</sup> gas per day  
 1 ton of manure at 30°C produces approximately 1.500 m<sup>3</sup> gas per day  
 1 ton of manure at 35°C produces approximately 2.000 m<sup>3</sup> gas per day  
 1 ton of manure at 37°C produces approximately 2.460 m<sup>3</sup> gas per day

One ton of the dry organic fraction of refuse will produce approximately 39.0 m<sup>3</sup> per ton at 60°C, and 27.0 m<sup>3</sup> at 30°C. Obviously the time taken to obtain the gas varies, being some ten days at 60°C, when most of the gas is given off in five to eight days, and thirty days at 35°C, when most of the gas is given off in fifteen days. It is safer to work at the lower temperatures which do not need to involve the design in the complications of heating the digester, under EMR conditions.

The process itself is slightly exothermic (600 calories per m<sup>3</sup> of gas produced), thus the fermenting mass is hotter than the air

or ground temperature, but not sufficiently exothermic to overcome the cold of Northern Europe.

#### Examples of modern plants

At the time of writing this paper, the writer has unfortunately been unable to obtain production figures on the new plants. He hopes to have slides of some for the Workshop. Some have not yet been published, but it is known that there is a sophisticated plant using animal manures at Aberdeen University, with insulation, and heated by burning a proportion of the gas produced. The manure from any animal is suitable, but obviously the number of animals required to produce a given amount of gas will vary roughly in proportion to their live weight and the nature of their feeding.

There is also a 100 ton-a-day pilot plant at Pompano Beach, Florida, using the organic fraction of household waste after the removal of metal cans, glass and plastics. This is very promising.

There are many simple plants of a new design in the Canada/USA border region, some with insulation, used to overcome the smell from factory farms and also to produce "free" gas for the farmer.

The latter plants are incredibly simple, and consist of a pit dug just outside the animal "feed lot" house. This is lined with heavy PVC and is covered with a "balloon-like" cover with stiff sides tied to the bottom, so that the stiff sides act as a water seal and the gas, rising through the semi-liquid animal manure, is trapped by the "balloon" cover. The manure, at about 96% H<sub>2</sub>O, is pushed into the end of the pit between the stiff sides of the cover and the side of the pit (there is greater clearance at this point)

and expels the same volume of manure from which the gas has been extracted - or at least partially extracted - at the other end. The gas collected in the "balloon-like" cover is sometimes fed to a small gasometer, where it is stored and which maintains the desired water gauge pressure for feeding to the gas appliances in the farmer's house. The smell of  $H_2S$  can be removed by passing the gas through bog iron.

The gas is about 60%  $CH_4$ , 25%  $CO_2$  and 5% other gases, including hydrogen and  $H_2S$ . Hence, it has a calorific value halfway between methane, or "natural gas", and coal gas, or about 6000 calories per  $m^3$ , suitable, in fact, for most gas appliances.

Internal combustion engines will run off the gas; petrol engines can be modified by replacing the carburettor with a simple air/gas mixing valve. Compression ignition engines can become dual fuel engines, using a little diesel to cause the ignition.

A plant with an average "animal feed lot" holding animals with an approximate live weight of 50 tons will produce about 140  $m^3$  of gas per day.

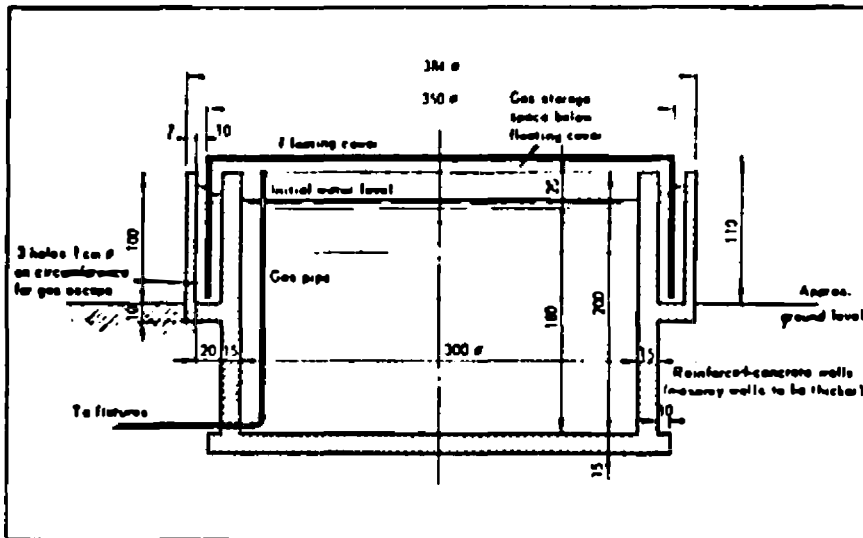
What is the potential of the biogas process in solid waste management?

1. Small, simple plants (figure I): We have got into the habit of thinking that "big is beautiful", but many small plants could make a contribution, not only in factory farming (where the writer came across a need in Cyprus), but for factory wastes (canning factories, bagasse from sugar production, etc.), and in small villages, where some 80% of the population of the EMR live. Separation at source, as mentioned in the Background Paper, would be necessary to remove the cans, glass and non-biodegradable items such as plastics.

Figure 1

Simple methane plant such as used in France during the Second World War

METHANE RECOVERY ON FARMS AND IN VILLAGES  
 CROSS-SECTION OF MANURE DIGESTER WITH FLOATING COVER FOR GAS-HOLDER



All measurements are in centimetres.

# REFCOM - REFUSE CONVERSION TO METHANE

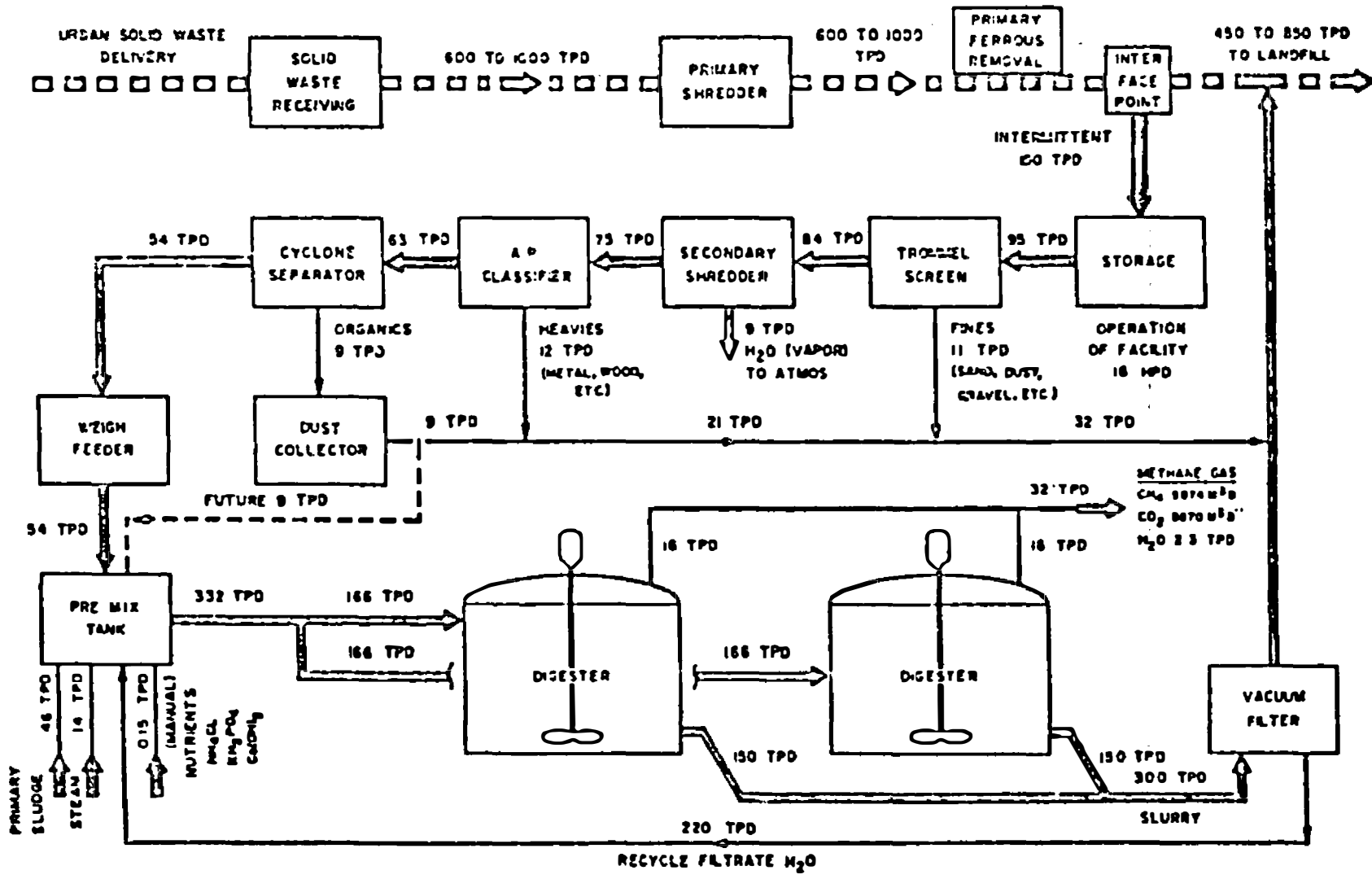


Figure II 100 ton-a-day biogas plant, Pompano Beach, Florida.

2. Larger facilities (figure II): such as the Pompano Beach, Florida, 100 ton-a-day pilot plant. This system, which looks very promising indeed, has the great advantage that it will be far easier to find finance for this than for a composting plant. One knows (as already stated in the Background Paper) that one can sell gas - one does not know that one can sell compost. Here we have a process that produces both compost (anaerobically made) and gas. The anaerobic compost can be burnt, but one feels that it would be best used as compost.

The only problem with this process in the EMR countries is that the balance sheet would not show up so well as it would in Europe (although the capital costs would be lower, since simpler plants are required in hotter countries), because the fuel cost, with which the gas production would be compared, is not generally at world prices in EMR countries.

3. Biogas from old landfill sites: As has been mentioned in the sanitary landfill paper, methane gas has, in some cases, been a trouble and a danger in landfill sites. In some cases trees on the border of landfill sites have been killed by the gas, and in several cases explosions have occurred due to gas seeping into buildings close to such sites.

Precautions have had to be taken in many cases in the USA. When such precautions (the digging of trenches to isolate the gas from nearby houses) have had to be taken, it occurred to the engineers that they might advantageously "tap" the gas and utilize it at a not much greater cost.

A landfill site can, after all, be similar to a very large methane digester, if the soil is of an impervious nature (clay), if it is finally covered with a well compacted clay-like soil, and the site is waterlogged. In countries where the soil temperature is above 15°C in particular, a great deal of methane will be produced for many years. There will be much methane gas in the interstices of most old landfill sites. Production can now be encouraged, whereas in the past it has been discouraged. Several old landfills are being exploited in the above way in the USA, and one in London.

The amount of gas available will not be of a sufficient quantity, nor pure enough, to feed into the National Natural Gas Grid System (natural gas, also CH<sub>4</sub>, is 1000 BTU, whereas the methane from landfills will contain CO<sub>2</sub> and be about 700 BTU per ft<sup>3</sup>). Nonetheless, the quantities are significant and certainly sufficient to encourage use by factories needing cheap fuel for high energy demand processes.

The work of extracting the gas is, moreover, justified in many cases from the safety point of view.

Most sites from which the gas is being extracted were land-filled quite normally, and boreholes were made in the landfill to extract the gas. If it were intended to fill a landfill specifically for gas extraction, as has been done in some cases, the landfill would be filled to encourage gas production and easy extraction.

#### How to encourage methane production in a landfill

In the above case, the landfill would be made with clay-puddled sides, trenches filled with materials to retain voids and act as gas

reservoirs, and the final cover would be of puddled clay, or even have a plastic impervious membrane under the top cover to retain the gas. Finally, water would be run into the landfill to ensure anaerobic conditions.

#### The production potentials

Unless the landfill site has been especially managed with the object of maximum methane recovery in the manner described above, it will not, of course, yield the maximum production of some 300 m<sup>3</sup>, which might have been expected from a plant for each ton of the organic matter - in fact, one could not expect more than 1/10 this quantity. Studies are underway in the USA which will provide enough findings for a rough estimate of the likely gas production to be made. It is hoped that these will be available for discussion at the Workshop.

However, the writer knows that in one case in Britain, estimates of gas production from a 70 acre (28 ha) landfill, 18m deep, will be very approximately 4 m<sup>3</sup> per minute, or around 5750 m<sup>3</sup> per twenty-four hour day - sufficient for a fairly large factory or some 1000 EMR family houses. This is the average expected for ten years. The daily production would be greater but the period shorter under the hotter EMR conditions.

At present, one can say that this is a worthwhile exercise under some circumstances, and that tests on a tip (by bore holes) would have to be undertaken to make an estimate of the likely gas available.

A landfill site can, after all, be similar to a very large methane digester, if the soil is of an impervious nature (clay), if it is finally covered with a well compacted clay-like soil, and the site is waterlogged. In countries where the soil temperature is above 15°C in particular, a great deal of methane will be produced for many years. There will be much methane gas in the interstices of most old landfill sites. Production can now be encouraged, whereas in the past it has been discouraged. Several old landfills are being exploited in the above way in the USA, and one in London.

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Conclusions

1. There are as yet too few practical examples of biogas plants, or the use of biogas produced from solid wastes, to say that this is a method proven by experience. Nonetheless, from what is known already, it seems very probable that the method has potential, and could be of benefit in one form or another in EMR countries in the future.

2. Because the new generation of the large plants, based on the Pompano Beach 100 ton-a-day pilot plant, is not yet available, and because these may prove too expensive for EMR countries, where fuel prices are below world prices, it would seem that the smaller plants for the special conditions of factory farms and wastes from factories may, at first, be of greater interest.

It also seems probable that these small plants will be of value to the small villages and rural communities, where electricity is not available, due to the costs of distribution.

3. In such circumstances, it would seem worthwhile considering small methane plants to dispose of and utilize animal and human manure and solid wastes. The writer, who designed and erected such a small plant in England in 1950, can assure the delegates that such plants are comparatively inexpensive, can be made from local materials, and are very simple to erect and operate.

With benefit of recent findings both in India and the USA, and under EMR climatic conditions, they should be effective and useful - useful enough to justify a pilot plant, where a need for gas is found and the other conditions are correct.

Finally, biogas should be considered as a possible solution, or part-solution, when planning future solid waste treatment in the EMR countries.

## PART II COMPOSTING

The writer has been an enthusiast for municipal composting - the utilization of urban wastes in agriculture - for many years, and believes this to be the obvious first method considered as likely to be the most suitable for refuse treatment in the EMR countries, provided it can be done in a way that suits the economy of the country concerned.

Again we refer to Flintoff's excellent chapters on composting in "The Management of Solid Wastes in Developing Countries". The writer is presuming that delegates have read Chapters 16, 17 and 18. This will absolve him from repeating what Flintoff has said so well, and allow him instead, after defining "composting", to concentrate on those aspects of composting, sometimes in combination with other forms of waste utilization too, which he considers most appropriate in EMR countries.

### 1. What is composting?

Composting is the natural degradation of organic matter brought about by bacteria, actinomycetes and fungi, under mainly aerobic conditions.

Municipal refuse has all the elements required by the organisms which cause the fermentation: carbon, nitrogen, phosphorus and potash, and the micro-nutrients essential for the growth of micro-organisms. Much of the carbon serves as a source of energy for the organisms - it is burned up and expired as  $\text{CO}_2$ . This releases much heat, so the process is strongly exothermic, and causes a heat rise in the composting refuse, which has the advantage that it kills the pathogenic organisms present. This process is really the other side of the coin to the anaerobic process in biogas, which we have previously studied, producing methane gas, which is far less exothermic. Not only are all the necessary nutrients available, but all the micro-organisms are present, "free, gratis and for nothing". Several studies have been done to prove that the purchase of special cultures is quite unnecessary - in fact, if one provides the right conditions for the micro-organisms, they arrive and thrive. If special cultures are purchased but the conditions do not suit, they die.

Aerobic composting is the same process as that which breaks down organic materials on the forest floor and turns this into leaf mould. It is the same process that causes farmyard manure or tipped refuse in a sanitary landfill to heat up as it does, but efforts are made to speed up the process. Whereas in sanitary landfill we compact the refuse to exclude air (other than that in the interstices of the materials - which causes the initial heat-up), in the composting process we ensure that there is ample air and moisture so that the process proceeds as quickly as possible.

The procedures in the composting process are now well known, after studies at Berkeley, Savanna, Birmingham and many other universities. The amount of air and moisture required is known, and it is known that whilst the bacteria break down the sugars, starches and amino acids most effectively, it is the fungi and actinomycetes that best break down the cellulosic materials. We know that the former generally multiply best at thermophilic temperatures and that the latter are most effective at mesophilic temperatures. Thus it is now possible for process plant designers, with the advice of microbiologists, to design mechanical plants which create the right conditions for composting to proceed efficiently.

## 2. History of composting

Before man settled in static communities he left his solid wastes and excreta and urine scattered around the earth. This made for soil fertility, since all the wastes were broken down in the same natural way. Aerial photographs have shown that the fertility around human settlements was greater than elsewhere, not only because of the animals which man kept, but also because of his own wastes.

The idea of using municipal wastes to benefit agriculture was stated early in this century by far-sighted enthusiasts, both to overcome the health hazards of disposing of night soil and solid wastes, and to turn these into fertilizers. Both were intractable and difficult to dispose of alone; mixed together and composted they produced an excellent organic fertilizer.

Sir Albert Howard, working with Jackson and Ward at Indore in India, was one of the first pioneers to compost night soil and municipal refuse together. He was followed by Van Vuren and Krige in South Africa.

The Dutch firm V.A.M. found that because of the change in the character of municipal refuse, Dutch farmers no longer used sorted municipal wastes on the land as they had done previously. It was V.A.M., before the Second World War and since, who showed that municipal composting could help refuse disposal and also provide fertility for the farmer. They did so in spite of Holland being a country in the temperate region, which is not a part of the world which produces the best type of refuse for composting; nor does the land need or benefit from organic manure as much as the arid soils in the hot countries of the EMR.

### 3. Early types of composting plants

The plants created by V.A.M., developed by Mr Van Meeran and his colleagues, were simple and effective. They are still used and still produce compost which is as good as that produced by modern plants.

Two processes were used: the Van Meeran process and the Dorr Oliver Rasp process.

In the former process, refuse is brought to isolated places - Mielo and Wjeister - by rail, dumped at the side of the line, wetted, heaped by grab cranes and turned as necessary. After fermentation is finished, the fermented refuse is taken to a factory, and the contraries are removed by magnetic separators, ballistic separators and screens.

The process cannot be used with sewage sludge, nor near a town, and depends on the operator of the plant knowing when to turn the refuse and so aerate it, and when to add more moisture, the amount to add being judged according to the rainfall at the time. The process requires the operators to understand the "art".

The Dorr Oliver Rasp system could be set up nearer towns. It involved pre-separation of contraries from a moving belt, the extraction of metal cans by a magnet, and the fine grinding of the refuse to turn this from a heterogeneous mass into a more homogeneous condition. This grinding put more air into the interstices of the materials, and so the heat-up and the composting proceeded much more quickly; there was less of a fly problem and less smell, whereas when the material in the Van Meeran system was turned there could sometimes be a smell of  $H_2S$  because the inside of the heap had become anaerobic.

In the Dorr Oliver process, after the heat-up in the windrows, the composting refuse was screened and ballistically separated to remove glass, stones, etc. It was then sold to horticulturalists whilst it still had heat in it, and used as a "hot-bed" manure.

#### 4. The second period plants and the problems with composting

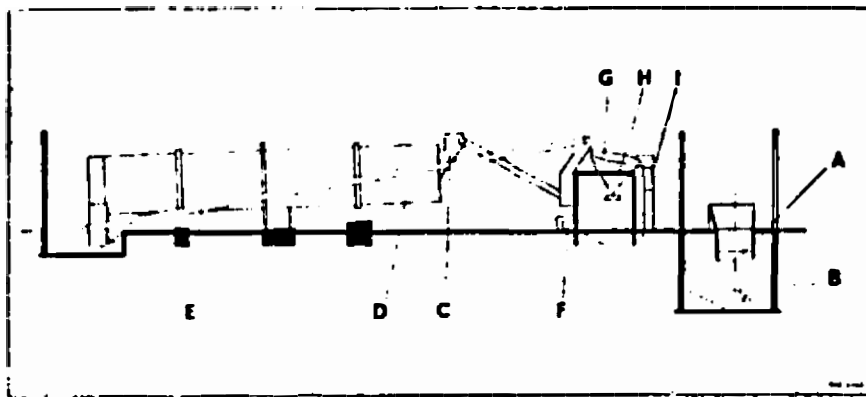
The modern plants were developed from the experience gained by V.A.M. and from the better understanding of the process gained from the scientific studies already referred to.

There were two main types of plant:

- a. The outdoor windrow composting plants, which were intended to be an improvement on the Dorr Oliver type of V.A.M. plant, but in

Figure III  
An early example of a rotating drum-type composter

DIAGRAM OF DANO "BIO-STABILIZER" PLANT  
AT EDINBURGH, SCOTLAND\*



\* After diagram in the *Dano Corporation Bulletin*, by kind permission of the Corporation

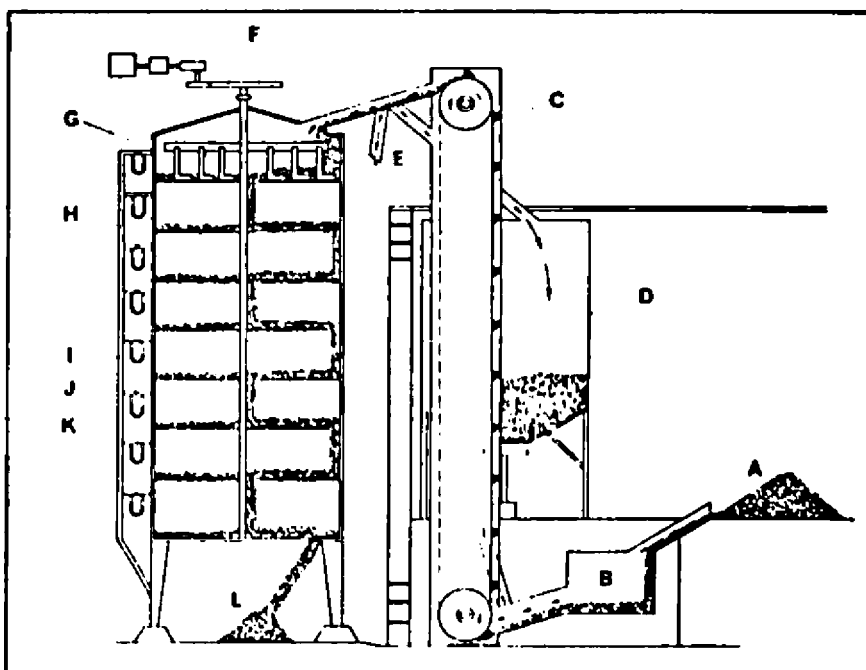
- A receiving hopper
- B conveyor belt for crude refuse
- C device for feeding material into Bio-stabilizer
- D Bio-stabilizer
- E conveyor belts for transferring material from Bio-stabilizer to screen
- F hopper and equipment for cans and scrap metal
- G screen
- H conveyor belt for taking away screened compost
- I chute for tailings from screen

At this plant, 20 tons of refuse, with sewage sludge added, are processed per day.

Figure IV

An example of one of the many makes of  
tower-type composters

DIAGRAM OF LARGE-SCALE DIGESTER PLANT  
AT LANSING, MICH.\*



\* After Snell, " by kind permission of the  
publishers of the Consulting Engineer

- |   |                         |   |               |
|---|-------------------------|---|---------------|
| A | raw refuse-sorting unit | G | ploughshares  |
| B | grinder                 | H | air pipe      |
| C | bucket conveyor         | I | manometer     |
| D | storage tank            | J | orifice plate |
| E | by-pass                 | K | deck          |
| L | rotating mechanism      | L | compost       |

The raw refuse is taken by bucket conveyor to and from the storage and dewatering tank to the top of the digester and is then slowly dropped down the decks of the unit.

which the refuse was fully composted in the windrows by turning until the composting process was completed and the compost mature. Thereafter, the compost was screened to remove plastic and other non-biodegradable items.

A promising, more recent improvement is the Laxa "Block" windrow system developed by Dr Gunnar Housenious, with air sucked and blown alternatively from under. This avoids some turning, and greatly saves on the area needed.

b. The enclosed or high-rate/fully mechanical composting plants. These are of two main types:

- i. The rotating drum type (Figure III) of which the Dano, invented by Kai Peterson, was the first, and
- ii. The tower plants (Figure IV).

The rotating drum has been very successful throughout the world. It consists of a drum some 3.5 m in diameter and some 25 m in length. After hand sorting in some cases (though this is now, usually, avoided by pulverization and screening) to remove salvage and uncompostible items, and magnetic separation to remove metal cans, the refuse is fed into the drum, often together with sewage sludge. Because of the rotation, the refuse is broken down and becomes more homogeneous. Air is blown into the drum and the fermenting refuse heats up. The retention period is anything from two to six days. The compost is screened before it leaves the drum to remove large items which have not been broken down, and again more finely to remove plastics and non-biodegradable items. It is then generally put in windrows, where

the composting process is finished by means of turning and aerating in the windrow area: thereafter it is often screened a second time to remove small plastic particles and sometimes ballistically separated to remove any glass and stones remaining.

Tower plants: There have been many manufacturers of this type of plant: Earp Thomas, Fairfield Hardy, Carel Fouché, John Thompson and others. The refuse, after pre-sorting, metal removal and pulverization, is fed into the top floor of the tower (most plants have five floors) where, in most of the plants, it is continuously or intermittently turned by ploughs. Air and the necessary moisture are added to keep it in an ideal state of fermentation. It is then dropped to the next floor, and so on until it emerges at the bottom. Thereafter, it is again screened and ballistically separated to remove contraries.

Other types of plants were developed as compromises between windrow composting and high-rate composting plants. Some have developed into successful plants, notably the omnium d'assainissement type; others have failed, mainly due to inadequate machinery and corrosion problems, because the steaming, composting refuse encourages rusting.

There are examples of most types of plant in the EMR countries: some good, some not so good. The country that has been most successful with composting is Brazil. EMR plants visited by the writer are in Abu Dhabi, Dubai, Egypt, the Libyan Arab Jamahiriya and the Syrian Arab Republic; there are excellent plants in Lebanon.

5. Problems which arose with the second generation plants and composting in general

Much enthusiasm was engendered amongst the public by over-optimistic newspaper articles in the same way as with regard to re-cycling. In the early plants, the machinery was often inadequate, and the metal was often inadequately protected against corrosion.

Composting was undertaken by municipalities before adequate studies had been made. The wrong type of plant was often bought for the prevailing conditions, and, more frequently, it was wrongly sited. The siting of a plant is one of the most important considerations; it can make a plant either economically successful or a failure.

It was thought that composting could make a profit in its own right by the sales of compost. In Northern Europe, where much of the land is covered with some 100 mm of grass and grass roots, and hence has sufficient organic manure, compost was not in great demand - labour costs are high, and it was cheaper for the farmers to use inorganic manures.

One of the causes of failure was that manufacturers made over-optimistic claims as to the speed of composting, and plants gave a lower output than was claimed. Early on, some companies endeavoured to sell special inoculums, to speed up composting; as stated earlier, university studies showed that these were valueless.

In consequence there was for some time much disappointment, and many composting plants have failed to satisfy their purchasers. But some, which are run by enthusiasts, who have made an effort to sell

compost and who took trouble to maintain their plants, have succeeded. Composting has been more successful in hotter countries with organic refuse and arid soil conditions, than in the temperate climates of Northern Europe.

6. The current position regarding compost plant efficiency

During the last two decades, composting plants have been improved. The machinery is now much more substantial and adequate for the purpose. The processes needed to make good compost are now well known, and adequate plants are available. City authorities wishing to compost can be sure that if they purchase a composting plant, site it correctly and run and maintain it properly, it will work well: with the essential proviso that a full and proper study has first been made of all the relevant local conditions, and the right choices and decisions have been made.

7. Remaining problems with financing composting and organizing sales of compost

Composting municipal wastes is a hygienic means of disposal. It lowers the cost of sewage sludge disposal and increases the national wealth by increasing the fertility of the land. Because much of the urban waste consists of the organic and waste food products or paper products originally grown on fertile land, it is a valuable and proper way of re-cycling wastes.

But usually the plant has to be bought and run by the municipality, and unless they can sell the compost to defray the extra costs over controlled tipping or sanitary landfill, whilst the benefits still accrue to the nation, the municipality will be out of pocket.

Further to the foregoing, many composting plants are expensive and difficult to finance. Whereas it is known that energy will sell, it cannot be known for certain that compost will continue to sell at an economic price. Like most businesses, the future economic success depends on future demand and price. For this reason, composting plants may require to be, and must in many cases be, at least partially financed by the State.

8. Further reasons why composting has not developed as quickly as at first hoped by "enthusiasts"

There is a tendency for consultants to "play safe". They often mention those disadvantages which are only true in some cases, but can be overcome if the right course or design is used. For instance, we have read that "compost is usually considered to be only a soil conditioner and not a fertilizer." This is totally wrong, causing misunderstanding. A material that brings fertility can rightly be called a fertilizer. Certainly compost does: a recent test showed that municipal compost produced 14 700 kg. of grape juice from 1 ha., whereas the inorganic fertilizer dressing alone produced only 8 600 kg. per ha. on the control plot. What is meant is that organic fertilizers are always much lower by percentage in nitrogen, phosphate and potash than concentrated inorganic fertilizers, but much heavier dressings are used.

They should say this, and should not decry compost, which not only contains NPK and trace elements, but also has organic values which, with or without extra inorganic fertilizers, are necessary and of great benefit to soils - particularly on the sandy soils and under the arid conditions of the EMR countries.

### Heavy metals

A more recent "scare" sometimes brought up is the attention paid to the danger of heavy metals in composts made from sewage sludges and urban wastes. It is said, often with no further explanation, that these can be taken up by plants and, particularly with cadmium, damage man's health. Dr Knoll of Guisenheim and Dr Gunnar Housenius at Låxa have found that plants grown on land fertilized with compost high in heavy metals take up less heavy metals than soils fertilized with inorganics lower in heavy metal.

The writer is currently studying this subject in order to thwart this damaging "scare" story. It can be said at this stage that there is no chance of such damage being done to crops in the EMR countries. Such problems will only arise in industrial countries, where the sewage works take in effluent from plating works. It is, of course, essential that plastics and metal cans be removed before composting, so that these do not contribute to the problem. If this is done, there is no danger under EMR conditions.

### 9. Other means of disposal necessary

One reads in critical literature that composting disposes of only part of the refuse disposal problem. This is often mentioned "baldly", without pointing out that salvage (metal boxes in particular) is removed, and that what still has to be disposed of, such as the total "overs" from the final ballistic separators and screens, has already been through a pathogenizing process and can be tipped anywhere. Moreover, composting can be integrated with the use of

the high calorific fraction for burning as RDF or in cement kilns, in which case the process gives almost 100% total disposal. Plants can and should be designed to achieve this.

10. The future of composting in the EMR countries

So we can say that composting, if it can be financed, is an ideal means of waste treatment in the EMR countries. We must emphasise that most careful studies should be done before embarking on a scheme.

11. Methods that should be considered

The simple methods and sheet composting with the organic fraction of refuse

The writer is of the opinion that too little attention has been paid to simple methods of putting organic wastes back on the land. Such methods, as stated in the Background Paper, have been used with success under desert conditions, and were used in Holland before the advent of the V.A.M. composting plants referred to earlier.

Separation at source

We will refer to this method of separation, which is now likely to come into vogue, more fully in the Resource Recovery Paper. In smaller communities, the people can be supplied with two dustbins. They should put the compostable fraction into one, and the inorganic and non-compostable fractions into the other.

Sheet composting

The organic fraction can be ploughed into the desert.

a) Tests will be necessary with organic fractions, (preferably seeding/weight tests) to ensure that the organic fraction has degraded sufficiently not to cause nitrogen starvation, before planting.

b) With the low calorific fractions from refuse-derived fuel plants.

The same can be done with the heavy low calorific fraction from heat recovery and waste-derived fuel plants. This fraction will amount to some 40% of the total refuse. As already stated this is a suitable method to combine with burning the high calorific fraction in cement kilns, etc.

c) From a pulveriser.

Likewise, sheet composting can be carried out using pulverized refuse from which the metals have been removed, but it will also be necessary to screen out the plastics, thus amounting to the same procedure as b) above. Alternatively, where this is not done, pulverized refuse can be landfilled, not in deep layers, but in layers of around 0.5 m thickness on average, to landscape eroded or infertile land. If the plastics have not been removed, it should then be covered with 0.30 m of earth or sand. By this method, large areas of desert and poor land can be greatly improved for forestry or other agricultural uses.

12. The modern composting plants, both windrow and high-rate

These are either tower, drum, windrow, or high-rate enclosed plants such as already described, but there has been a considerable improvement in the machinery, which is generally now much more substantial, provided a good make is chosen.

The best of the high-rate plants now make more mature compost than the older plants because, at least in some cases, the aeration and the flexibility of treatment are now improved. However, although high-rate plants claim to make compost in five to eleven days, this must be "taken with a pinch of salt". There is, as yet, no easy, quick standard test of maturity.

13. Maturity of compost

To make fully mature compost it is generally necessary to have a windrow system after the high-rate plant. Thus, where this is needed, the advantage of a smaller area requirement for the high-rate enclosed plant over the windrow plant disappears. However, it is always possible to site the high-rate plant on a relatively small area near the load collection, and transport the immature compost elsewhere or direct to the farms, where it can mature.

Stabilized compost is essential. It must have gone through a heat process that kills pathogenic organisms and makes it unattractive to flies. Mature compost is only necessary where it is to be put on growing plants or seedlings, or ploughed into the ground to be planted - immature compost can be used as a mulch between established fruit trees or bushes, at the end of the growing season, so that it will have broken down before the next season starts.

#### 14. Maturity tests

Compost is considered to be mature when 75% of the carbon is biodegraded or when the C:N ratio is below 15:1. As stated, a simple standard test has not yet been evolved or generally accepted. The seedling/weight test against a control, using beans, which are susceptible to immaturity (and heavy metals, too), is advisable before selling compost for general use on land where crops grown from seed are farmed. This avoids the danger of the farmer being disappointed the first year and talking to his friends so that compost gets a bad name and sales are affected.

In hot countries, such as those of the EMR, where organic manures degrade quickly and are quickly oxidized, this matter is not so serious as in temperate lands. Thus the importance of ensuring maturity is not so vital, provided the farmer is aware of the dangers. Of course, the second crop in the land manured with immature compost is not affected, for by then the organics will have matured in or on the land.

#### 15. Conclusions and recapitulation

The refuse in EMR countries is very suitable for compost-making. Composting is a suitable method for EMR countries, and is probably saleable, though sales surveys should be done.

Those EMR countries without oil can consider simple forms of composting without heavy capital costs. The lower calorific fraction (the heavy fraction) from refuse-derived fuel plants, which will be of interest to EMR countries who do not have oil, can be composted or used for sheet composting at little extra cost, whilst the higher calorific fraction can be used as a fuel.

A compost plant should be designed so that it is an almost 100% refuse disposal plant, and almost no landfill is required. This can be done by using salvage and combining the process with some heat recovery system, such as the burning of the high calorific fraction in a cement kiln.

It is most important that a composting plant be sited correctly, so that it saves travel for the collection vehicles. In some cases, the first part of the plant can be sited near the load centre of collection, and the second part convenient for transport to the compost user. (It then has the advantage of a transfer station as well as of a composting plant).

In all cases the choice of a plant, and as importantly, its siting, must be studied in all aspects before a decision is made, because whereas a good choice can be of great benefit to the community, the wrong plant sited badly can be an expensive mistake.

### PART III THE HYDROLYSIS OF CELLULOSIC WASTES

Paper and other cellulosic wastes can be hydrolyzed under pressure and at high temperature ( $230^{\circ}\text{C}$ ) in the presence of an acid catalyst (0.5% sulfuric acid -  $\text{H}_2\text{SO}_4$ ) to produce sugars, hexoses and pentoses, which can be fermented by micro-organisms to produce useful industrial chemicals, including ethanol, acetone and petrol substitute.

The production of ethanol from 1 ton of separated paper will be in the region of 0.2 tons. Since ethanol is worth approximately £250 a ton, this will yield £50 worth of ethanol from each ton of paper.

Waste paper is a very fluctuating market at the moment, with a price around £30 a ton, and the merchants only interested in the best quality and no soiled paper.

One of the criticisms of resource recovery plants is that the waste paper market has a very critically narrow band of supply and demand. The price drops and there is no demand with a 10% increase in supply or 10% decrease in demand. The critics fear that re-cycling will flood the market.

For the above reason, any process such as hydrolysis that can produce a product which is known to be in firm demand, such as petrol substitute, is very welcome indeed, because there is an assured market for petrol more than for anything else one can think of.

This process will, therefore, when fully developed, help to overcome the need for countries who salvage large quantities of paper to set up their own paper carton and insulating board industries to avoid the fluctuating world waste paper prices and the transport costs. The latter is the only other way of making paper recovery on a large scale economical.

The present means of hydrolyzing paper is at the laboratory bench scale pilot plant stage, and the work is being done by Dr Andrew Porteous at the Open University, Milton Keynes, England, to whom the author is indebted for the likely production figures.

## INDUSTRIAL SOLID WASTE MANAGEMENT

by

Professor E.A. Glysson\*

The management of industrial solid waste involves wastes from materials which are being utilized for manufacturing a product, wastes generated by shipping and packaging operations and wastes from extraction operations, to name just a few possible types and sources. The point is that every industry produces wastes which are peculiar to that industry at that location. The following is an attempt to organize a discussion on the subject that can apply to as many industries as possible without becoming specific to any one.

## I. SOURCE REDUCTION

The single most effective method of managing industrial waste is to collect and reuse as much as possible of the potentially waste material so that it never becomes waste. This may mean reorganizing the way a given process is presently operating or other rather drastic measures, but the economic justification is in the reduction in costs of materials and avoidance of disposal costs. This is particularly significant if the materials to be thrown away are classified as toxic or hazardous.

A. Recycle scrap material for reuse

When collecting scrap material it is important that different types of materials be kept separated to maintain the purity of the recycled materials. This

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concept is as true for scrap paper as it is for scrap metal, depending to some degree on the type of reuse to which material is to be put.

Recycling may be done in-house, directly back into the product stream, or the material may be resold for reuse by others. The supplier of a material may be better able to reprocess it if necessary.

B. Salvage for reuse for other purposes

- Recovery of combustible waste for use as fuel.
- The waste recovered to be used as raw material for new or different products. Examples:
  - fly ash used in cinder blocks
  - old tyres made into door mats
  - shredded newspaper made into insulation.

## II COLLECTION AND STORAGE

Collection of industrial waste material should be accomplished as soon as possible to remove the waste from the work place where it may occupy needed space, cause accidents etc. This may be done in a number of ways, depending on the amount and type of waste. The responsibility for the waste removal should be clearly identified and that person or persons given the necessary equipment and time to accomplish the task. If several different types of materials are involved, bins or some other suitable container clearly labelled as to waste content should be provided so that the collection operation can maintain the necessary identification and separation.

Storage of the waste material on site may be necessary for a period of time. Depending on the material involved, storage may need to be under cover and volume reduction may be indicated. Volume reduction usually can best be provided by baling, or shredding followed by baling, again depending on the material involved. Perhaps baling will render the material weather-resistant so it can be stored outside. Protection from the weather may also be provided by covering with plastic sheeting.

### III. SLUDGES AND RESIDUES

Many times the industrial waste will be in the form of sludges and tank bottom residues which must be properly managed and disposed of. The following is a brief outline of the techniques available for dealing with this type of material.

#### A. Biological treatment

1. Aerobic
2. Anaerobic

#### B. Chemical treatment

1. Fixation with material such as lime or some other solidifying agent
2. Neutralization

C. Physical treatment

1. Drying
  - a. Vacuum filter
  - b. Sludge press
2. Thermal
  - a. Incineration
  - b. Wet Oxidation

The overall objectives of the various processes listed above in the brief outline are to, in some manner or other, concentrate and incorporate the waste in such a way as to facilitate the removal of any water it may contain. The end result will be a solid which will lend itself to ultimate disposal without undue damage to the environment. The most suitable final form for disposal is an inert solid since the objective of final disposal is to provide a permanent separation of the waste from the rest of the environment such that no adverse effects can occur.

IV. ULTIMATE DISPOSAL/SECURE LANDFILL

The development of a secure landfill for industrial waste materials must include provision for an impervious liner, a leachate collection and removal system, an impervious final cover and a system of monitoring wells to detect any leachate which is leaking out of the landfill.

## RESOURCE AND ENERGY RECOVERY

by

D.H.G. Tollemache<sup>\*</sup>

Resource and energy recovery needs some defining: what exactly do we mean? The dictionaries tell us that:

Definition

Natural resources are of two kinds: renewable and non-renewable, and that resource is bounded by the concept of utility. If we do not know how to use a resource, it is not much use to us - so resource estimates change with technology and our ability to use it. The value of a resource also changes with our need to use different resources at different periods of history.

The reasons for resource recovery

At this moment in history, the world is getting shorter and shorter of non-renewable materials, many of which are thrown away and become solid wastes. Solid wastes also have a value as energy to replace fossil fuels, which are also expensive and likely to get more so, and are also a non-renewable resource.

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Solid Wastes Management

### Findings

It has been found that after pulverization, screening and air classification, roughly 50% is of a light, relatively high calorific value, and roughly 50% of a heavy, lower calorific value. The high calorific value fraction can be burnt or biodegraded to produce energy, and the lower calorific fraction can be composted (or possibly biodegraded to provide energy and compost) to grow heavier crops and hence increase resources.

Both fractions also contain salvageable materials such as: from the higher fraction, paper, rags, plastics, etc., and from the heavier fraction, glass, metals, bones, etc.

### Competition between salvage(or resource recovery)and energy recovery

Since we cannot both burn the paper and plastic and also salvage them, we must decide which process is of the greater value to us. Our decision will depend upon the nature of the wastes, the proportions of the various materials, the cost of the processes, and whether one country has a good supply of fossil fuels or not. In fact, the choice depends on a) our needs and, b) the economy.

The heavier lower calorific value fraction also contains salvageable materials: metals in particular, which can easily, and usually must be, removed or they make the process more difficult. When separation is essential to the process, or cheap and easy to carry out, the separation is justified even if the salvaged materials are not particularly valuable, and vice versa.

Figure I  
Average contents of Swedish municipal solid wastes

	Water content %	Percentage by weight	Percentage by volume	Approx. value		Energy demand on conversion from semi-manufacture		Caloric value kcal/kg
				SEK/t recycled	SEK/t of waste	kW·h/t of raw material	kW·h/t ton of waste	
Ferrous metal	6	5	6	150.00	9.00	6900	600	-
Paper	50	16	75	200.00	100.00	2300	200	3100
Miscellaneous plastics	9	11	7	150.00	13.50	8000	250	8000
Glass	10	21	3	50.00	5.00	3200	350	-
Compostable material	22	45	8	20.00	4.40			1800
Incombustible	3	20	1	-	-			-
<b>Total</b>	<b>100</b>	<b>22</b>	<b>100</b>	<b>130.00</b>				<b>2600</b>

This percentage of course varies enormously with different refuse analyses.

### Choices

Our choice lies between obtaining energy from all that will burn, removing only items which will cause a problem, and removing all that we can sell. It is possible to burn 96.6% of everything except the extracted metal, if we use the refuse as a supplementary fuel with coal. If we salvage everything that we can sell, we will have at least very approximately 25% of heavy fines left to dispose of or compost.

### The systems available and the history of resource and energy recovery systems

Resource recovery, re-cycling and energy recovery have been widely publicized and have caught the public's imagination. The impression given is that it is something new, and almost that "there is gold in them there dustbins".

Specialists are described as "the new prospectors" mining "ore" from the wastes. This public enthusiasm is to be encouraged, but the realities must be faced. Resource and energy recovery are not new, and are still relatively difficult and expensive.

In 1896, the Chelsea (London) incinerator pre-sorted the refuse by hand and salvaged paper, rags, bones, glass, cullet and metals. It recovered heat from the remaining refuse, which heated the municipal baths and buildings. The ash was sold for brick-making. In fact, the engineer could truly say that he recovered everything except the smoke which went up the chimney.

In England in 1918, there were 102 incinerators; nearly all salvaged many items and ninety-six recovered the heat from the

refuse. There are now some forty incinerators, none of which recovers salvage and only four of which recover the heat. This is because labour is expensive now, and the market for scrap is erratic because of the Recession. They also went through another period - that of the "throw away society".

Until recently totters (rag and bone men) salvaged much scrap in England and in many countries families lived on the landfill sites, scavenging the refuse which they could use or sell.

The "throw away" period has now finished, and we need to utilize our wastes to salvage the resources in them and recover the energy from them.

Whereas in the past, the recovery was by hand and on a small scale, because most refuse went to landfill, now, where landfill sites are only available far from cities, it is sometimes necessary to have transfer stations. When this double-handling of wastes becomes necessary, resource and energy recovery systems may be economical. Usually, however, they must have high through-puts to be so.

The avoidance of allowing resources to get into the waste flow and quality of the recovery

It is most important that there should be a thriving reclamation or scrap industry to avoid recoverable materials getting into the waste stream .

A most important consideration is that resources should be recovered and used to their highest value. That is, for instance, that tyres should first be re-treaded before they are cut up as

rubber crumb or pylorized. Paper should be re-cycled as paper, then as cardboard, then as insulating board, and finally burnt or composted. Please note that we say "consideration" - sometimes, as explained earlier, for other reasons the lower use will be the most economical. Finally, old motor cars should be repaired, and cannibalized and used for spare parts before they are broken up and the various metals broken down for salvage. More will be recovered if this breaking down is done by hand (first stripping the aluminium and copper, separating the cast steel from the other heavy steels, and finally baling the sheet steel,) than if this is done mechanically.

However, to avoid the environmental problems of rusty car bodies littering the roads of some cities seen by the writer, it would seem worthwhile having a central fragmentizer, because this method makes for heavier, more valuable scrap from sheet steel than other methods do.

#### Separation of other materials by hand

There is currently much interest in Japan, Europe and America in resource recovery of materials at the source of their arisings - in the home, factory and shops. Pilot schemes are being costed whereby householders collect and store the paper, plastics, ferrous and non-ferrous metals, etc., separately before they are collected and mixed with other wastes in the "waste stream" itself, where their value is inevitably reduced by spoilage, and from which they are difficult and expensive to separate.

There are also such schemes as the "bottle bank" in which the public is encouraged to put bottles of each different colour into

separate compartments in special containers set around the cities. Whilst this system is better than allowing glass to get into the waste stream, it is not nearly so good as having a law making it obligatory to charge a deposit on the bottles and hence encourage their reuse.

#### The mechanical separation of resources from the waste stream

The interest in these processes has been engendered because of the evident shortage and high price of raw materials on the commodity market. Undoubtedly the supply of virgin materials will become less available and more expensive, since they are non-recoverable resources and their supply, thus, finite.

#### Warning on price of salvaged materials

However, the enthusiasm for recovery of materials has cooled considerably since the recession in Europe. Many authorities who previously collected waste paper, for instance, have ceased to do so, and some re-cycling plants, which it was hoped would be economical, are shut down awaiting the rise in prices of paper fibres, metal scrap and other materials.

Other plants are being developed which specialize in the separation of items, which, it is believed, will be in steady demand: for instance, the recovery of tin from metal cans, because tin now fetches some £7 000 a ton (or \$16 800). The writer does not wish to dampen the enthusiasm of the delegates for resource recovery, but he must point out that there is a message here too. When materials such as the tin or metal food containers become so

expensive, there is always the probability that an alternative material will be used in the future. This must be taken into account.

It is therefore essential to warn potential users that the plants they choose must be flexible, so that they can salvage those materials which are currently in demand and at a high price. Further, in general, plants must not only be capable of recovering materials, but of recovering the energy from waste, or making use of it by composting too.

#### The design of mechanical resource recovery plants

The methods are best explained by proceeding from the simplest to the most sophisticated:

1. The first element in all plants is the reception, feeding and size reduction section, in order to make it easier for the separation equipment which follows, for further, more sophisticated processes, to work. Figure II shows such a plant.

This, consisting of a pulverizer (without grids) is normally the first element in most recovery plants, and is also all that is needed for feeding cement kilns or chain-fed stoke grate boilers.

In some types of cement kilns it is necessary to provide a secondary pulverizer, because they require very finely ground refuse. In another instance (the Doncaster Plant for Materials and Energy Recovery) the use of a pulverizer is avoided before screening because there is a tendency for the paper to gain too much moisture during screening from the wetter fraction if

pulverized and a smaller pulverizer is used after screening to pulverize only that fraction of the refuse for which this is desirable.

There are advantages and disadvantages in both systems. The Doncaster plant now has cutters in the primary trommel to cut plastic bags.

This type of plant recovers ferrous metals only as materials and energy.

2. The second procedure (Figure III) in most plants is to screen and often to air classify the pulverized refuse. Sometimes the air classifier is relied upon to remove the metals, from which the ferrous metals are later removed by magnet; in other cases the ferrous metals are extracted before the air classifier, as in the Doncaster plant.

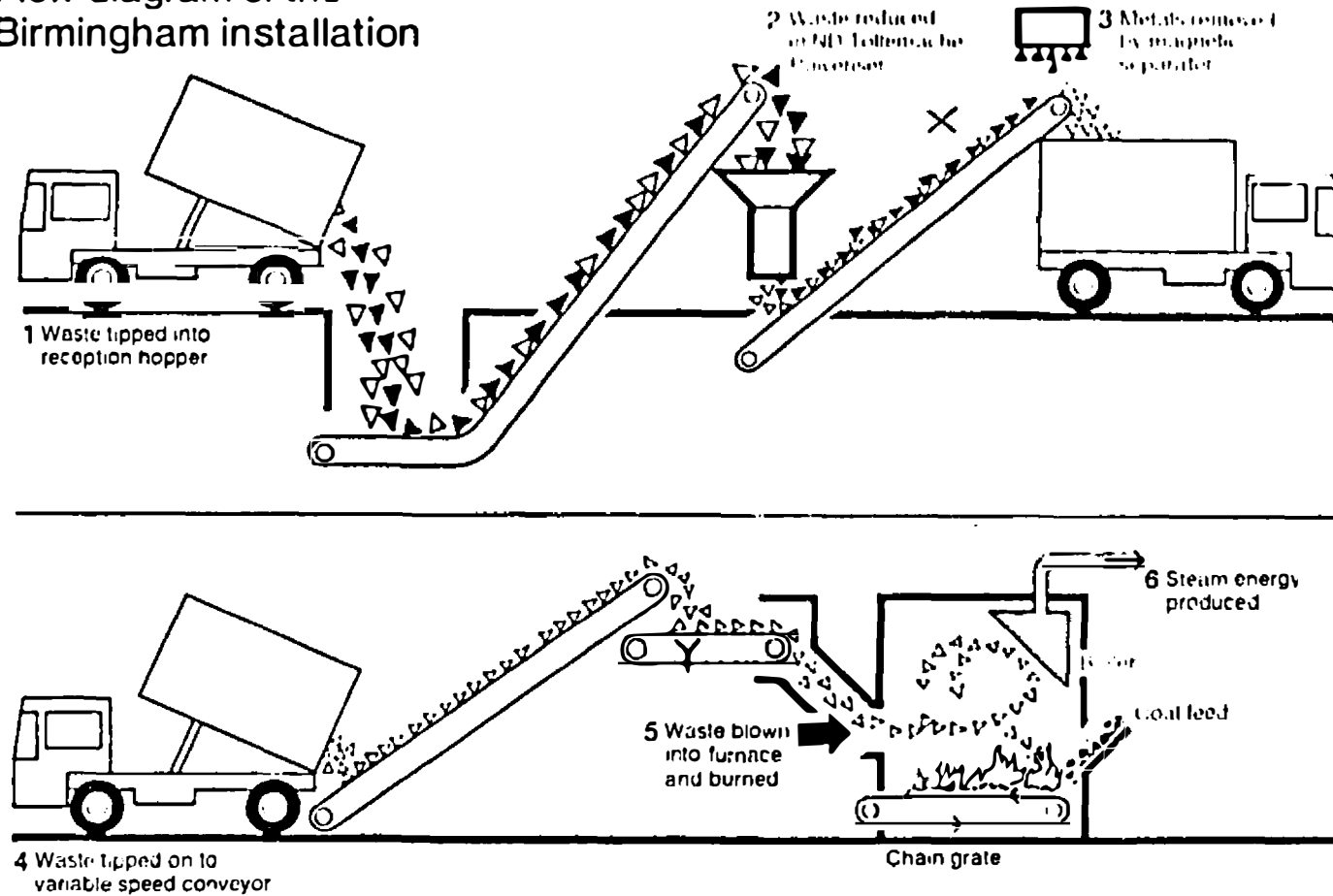
It will be noted that Figure III also shows two further procedures.

3. The refuse-derived fuel line with pelletization: This makes pellets from the high calorific fraction after further pulverization and drying. The advantage of this procedure is that the pellets can be made in summer and used in winter, and the pellets can be transported and sold to the public for use in many types of boilers.

It has the disadvantage that energy is used to dry the refuse (though waste heat can be used) and the pelletizer both uses power and is expensive to maintain. Hence the system is not so

Figure II

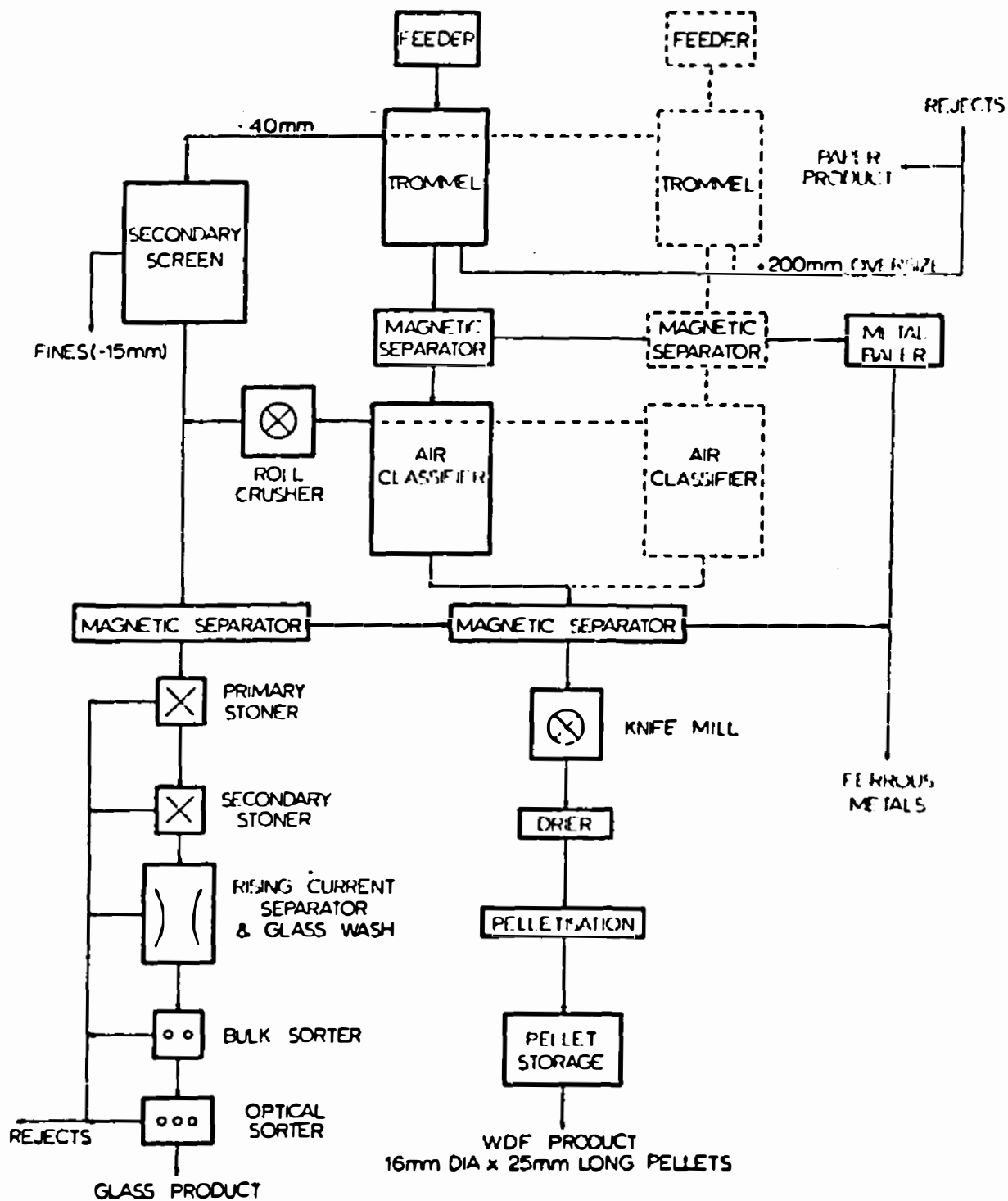
Flow diagram of the Birmingham installation



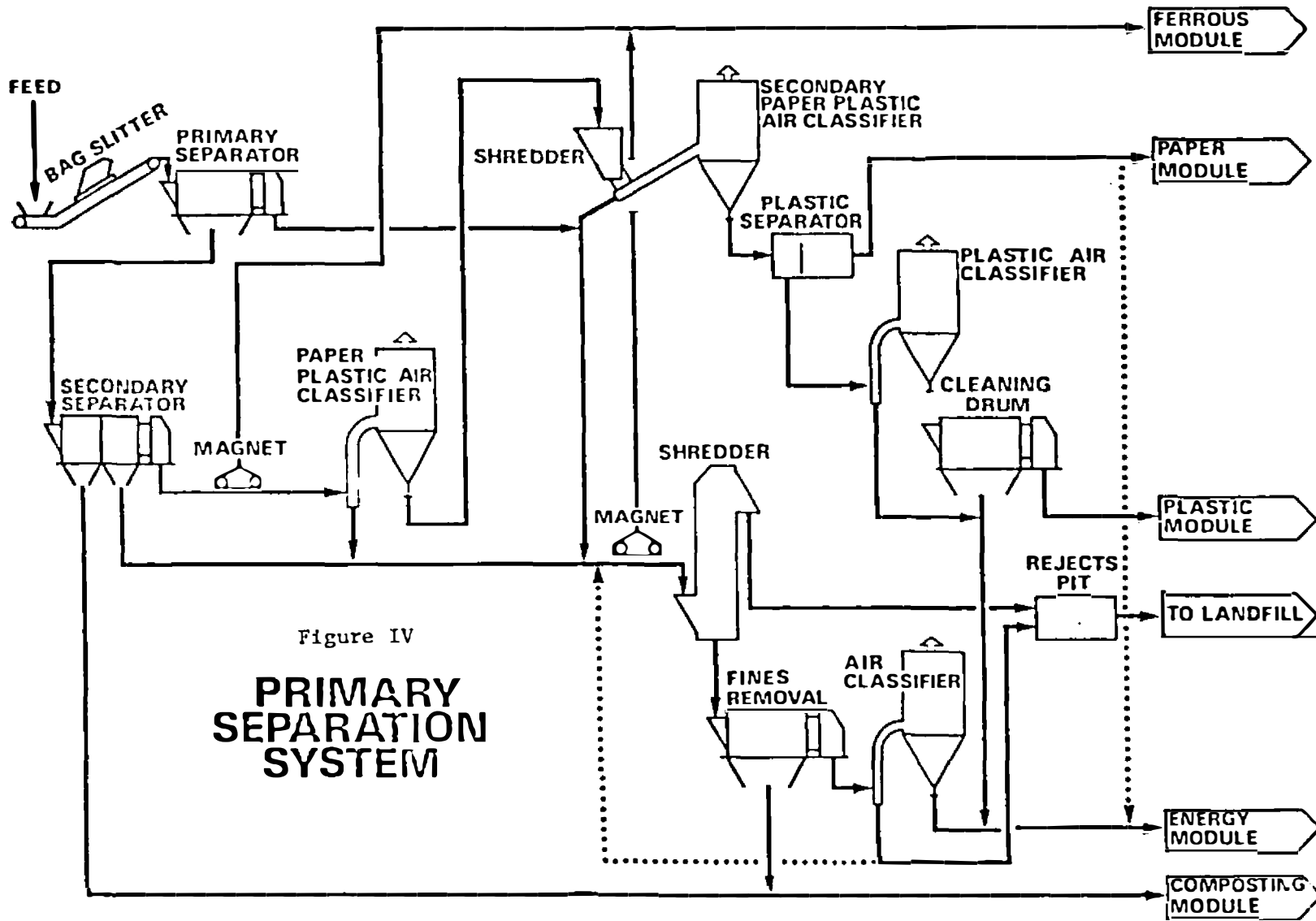
Note: It happens that this plant is split to suit the site. Normally conveyor "X" would feed onto conveyor "Y".

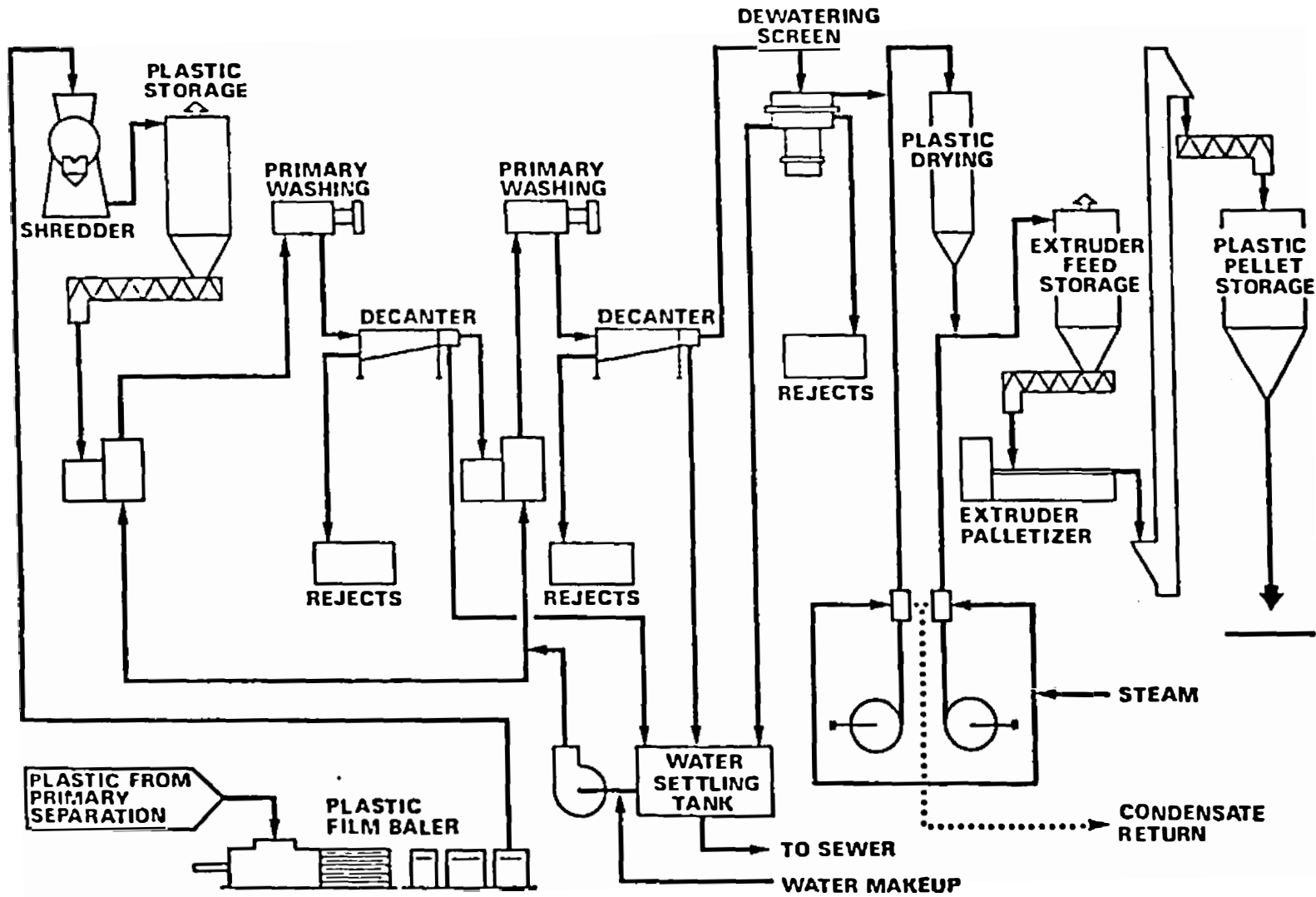
Figure III

# SCHEMATIC FLOW DIAGRAM



## DONCASTER RECYCLING PLANT





# PLASTIC PELLETS MODULE

Figure V

economical as an "in house" system such as that shown in Figure II, but is necessary where the conditions do not allow the Figure II system to be used.

It will also be seen that Figure III shows an additional line.

4. The glass extraction line: As has already been said, glass bottles ideally should not get into the waste flow. So the economics of this line, in the writer's opinion, is suspect.

5. The paper fraction line: Figure IV shows the primary separation system of the Sorain-Cecchini plant in Rome, and how the paper fraction is removed.

This plant has been operating since 1964, and is the most complete resource and energy recovery system in the world. In addition to the lines shown in the flow sheet, Figure IV, the vegetable and food items shown as the compostable fraction are actually divided into two streams, the second being an animal feed fraction which is steamed and made into pellets for chicken feed. This is unlikely to be economical in most countries.

6. The plastic fraction line: This is shown in Figure V. The plastic fractions can be separated by one or the other of the following two methods:

- i) The dry process: The paper and plastics, after size reduction, are blown up pipes with hot air in them, sufficiently hot to shrivel the plastics into balls - which are then denser and can be separated by air classification.

- ii) The damp process: The paper and plastics are put into a conditioner and mixed together. The plastics are more slippery, separate from the paper, which balls up and absorbs moisture. The paper is then heavier than the plastics and so can be separated by air classification.

Figure VI shows analysis based on the Italian refuse.

Figure VI - Refuse analysis

	Minimum	Maximum	Average
Paper	13.71	22.63	18.82
Wood and textiles	2.16	13.26	5.95
Plastic	2.50	5.00	3.68
Rubber	1.11	2.19	1.71
Metal	2.45	4.65	3.57
Glass	9.64	12.57	10.67
Organic matter	34.46	41.60	38.52
Screenings less than 20 mm	14.01	18.52	15.18

7. Other systems: The Sorain-Cecchini plant has been described because it is the most complete recovery plant in the world. All the other plants use the same principles, though naturally the flow lines and machinery differ in detail.

Energy recovery

Energy recovery can be by burning in:

- i) Cement kilns
- ii) Chain-fed stoke grate boilers
- iii) Fluidized beds

or energy can be recovered via the biogas system.

The economics of the system

It is quite impossible to give any worthwhile figures on the likely economics in EMR countries during these very inflationary times, and when EMR costs also differ so greatly from British costs, but the following will help to give the delegates some ideas on this subject:

Sorain-Cecchini claim that their process shows savings of 30 - 100% on the costs of the disposal otherwise needed. There is a big advantage in the lower energy requirement needed to manufacture aluminium, steel, glass, paper and plastic goods from recovered materials than from raw materials.

It is believed that waste-derived fuel can be produced in Britain at 7.2 pence per therm against 76.2 pence per therm for electricity and 13.4 pence per therm for coal, provided an allowance is made to the plant for its function as a disposal facility at current orthodox disposal costs via transfer station and landfill.

To obtain an economic balance sheet, it is essential to do a survey in each country under local cost and refuse conditions.

Special recovery opportunities

If we look back at the analysis of Dubai's refuse given in the Background Paper, we will see that 110 tons of timber appears in the refuse daily. This is a quite exceptional percentage, and requires special treatment, such as charcoal burning, in a non-capital-intensive way, because the supply will probably decrease. Likewise, any specially high percentages of recoverable resources should be treated in a manner that is deemed to be the best in the circumstances at the time.

Consideration for those contemplating resource and energy recovery systems for use in the EMR countries

The foregoing systems have been described to show what is available. It is unlikely that such complicated systems would be economical in most EMR countries.

Assuming that these plants will last twenty years, one has to estimate:

- a) What will be the nature of the refuse after, say, ten years?
- b) What will be the values of recovered materials and which will be economical to recover in, say, ten years?
- c) What is most needed by the country concerned? Does it wish to have an indigenous paper industry or steel manufacture?
- d) Is the need to save energy more important, or to increase the fertility of the lands?

- e) How do these processes fit in with the hygienic treatment and disposal of wastes under local conditions?

### Conclusions

In the writer's opinion, all the EMR countries he has visited have refuse which is ideal for composting, and the agricultural land could benefit from compost.

Those countries without oil require cheaper energy, and so the simple recovery of ferrous metals and the recovery of energy, via the cement kiln or furnace and boiler method, stands out as being most likely to be of advantage to the countries.

Further, so far as material recovery is concerned, good salvage and recovery at source would help all the countries economically, by encouraging indigenous industries, such as the production of paper products, probably salvaged at source.

Oil-rich countries are already composting - their need is to continue to improve the environment, agriculture and local industry, and so they should also consider the salvage of waste paper as well as steel scrap, both at source and from the composting plants.

## INSTITUTIONAL DEVELOPMENT, MANPOWER NEEDS AND TRAINING

by

Professor E.A. Glysson\*

## I INSTITUTIONAL DEVELOPMENT

The management of solid wastes involves collection and disposal operations which may be performed by the public or private sector. The institutional aspects of collection will be discussed separately from that of disposal; however, there is much in common between them.

A. The institutional arrangement for collection presents several alternatives of which the following are examples:

1. Cities may operate independently through an appropriate department such as the Department of Public Works.
2. Several cities or communities may organize into a regional authority or public corporation for the purposes of managing solid wastes, administratively independent from other agencies of their governments.

With these or other governmental arrangements there are several alternatives which may be established relative to collection. The following are examples:

1. Public ownership and operation, usually administered by some specific department, i.e. Department of Public Works.

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2. Private firms under contract. Contract is preferably awarded by competitive bid based on specifications as to type and level of service, length of contract, etc.
3. Private firms in open competition for the work in the same area. In some cases the area may be divided with exclusive franchises awarded to individual firms within each subdivision. Arrangements for payment for service are made with each customer by the collection firm. This approach is often used by industry and commercial establishments.

There are advantages and disadvantages with both the public and private sector.

Public ownership and operation of the collection system involves purchasing, operating and maintaining all the necessary equipment. It includes hiring, training and maintaining an adequate work force to perform required tasks along with all the necessary records, benefits etc. required.

Private sector operation of the collection system relieves the city of the above responsibilities and reduces the capital commitment to equipment and maintenance costs. Decision-making, adjustments in labour assignments and purchases of needed equipment are much more readily carried out by the private sector. Table 1 (Decision-Makers' Guide in Solid Waste Management, USEPA 1974 (SW - 127) p. 14-16) summarizes many of the advantages and disadvantages of these two alternatives.

Table 1  
 POTENTIAL ADVANTAGES AND DISADVANTAGES OF TYPES  
 OF PUBLIC AND PRIVATE OPERATION OF COLLECTION SERVICES  
 AND THE CONDITIONS THAT FAVOUR EACH

Alternatives	Potential advantages	Potential disadvantages	Conditions which favour alternative
<b>Public:</b>			
Municipal department	Tax-free Nonprofit Economies of scale Can institute separate collection for recycling Can institute mandatory collection City has administrative control	Monopolistic Lack of incentive to maximize efficiency Financing and operations often influenced by political constraints Frequently financed from general tax fund and subject to 1-year budgeting process Solid waste management often low-priority item in budget Labour pressures may result in inefficient labour practices and strikes Poor equipment replacement policies Policies of job-support inflate labour costs	Past history of unsatisfactory contractual operations for public services Public predisposition towards government operation of public services Quality of service provided more important criterion than economics

Table 1 (Cont'd)

Alternatives	Potential advantages	Potential disadvantages	Conditions which favour alternative
Public corporation or utility (usually serving a multijurisdictional or regional area)	Tax-free Nonprofit Economies of scale Self-financing. Multiple-year budgeting Operated independently of political structure Can institute separate collection for recycling Can institute mandatory collection	Monopolistic Labour pressures may result in inefficient labour practices and strikes	History of regional cooperation Rural or semi-rural area Area with rising costs
Private: Open competition	Competition may reduce costs Self-financing	Danger of collusion among haulers to reduce competition and keep prices high Cutthroat competition can result in business failures and service interruptions Overlapping routes, waste of fuel. Cannot institute citywide separate	Unacceptable alternative

Table 1 (Cont'd)

Alternatives	Potential advantages	Potential disadvantages	Conditions which favour alternative
		collection for recycling Lack of mandatory collection	
Controlled entry through use of permit system	Competition may reduce costs Self-financing	Subject to political abuse in the awarding of permits Creates oligopoly Overlapping routes, waste of fuel Can't institute citywide separate collection for recycling Lack of mandatory collection	Unacceptable alternative
Exclusive franchise via contract with local government	Competitive bidding for contract(s) helps keep prices down Can institute separate collection for recycling  Can institute mandatory collection City has administrative control	Danger of collusion in bidding	Flexibility is needed to make changes in operations that would result in labour savings and other cost reductions  Existence of qualified private contractors

Table 1 (Cont'd)

Alternatives	Potential advantages	Potential disadvantages	Conditions which favour alternative
Combination of public and private:	Municipal system and private firms under contract	Competition helps keep prices down Alternative available if either sector cannot deliver service because of strikes, for example Can institute separate collection for recycling Can institute mandatory collection City has administrative control	Public predisposition towards private sector involvement in public services Newly incorporated communities, or where population growth is outpacing ability of community to provide public services  Municipality is expanding through annexation or merger with other jurisdictions Changing from separate garbage and trash collection to combined collection

Table 1 (Cont'd)

Alternatives	Potential advantages	Potential disadvantages	Conditions which favour alternative
Competition between municipal system and private firms	Competition helps keep prices down	Overlapping routes, waste of fuel Can't institute citywide separate collection for recycling Lack of mandatory collection	Unacceptable alternative

A combination of public and private sector operations may be utilized. This may serve to stimulate competition which would tend to reduce cost while providing the refuse generators the level and variety of service they desire.

Leasing of equipment by the public or private sector is another alternative which may or may not be possible depending on the availability of leasable equipment. This alternative reduces the initial capital expenditure required and has many of the characteristics attributed to the private sector.

B. The institutional arrangement for disposal often involves more capital investment in land or equipment than collection which is more labour-intensive. For instance, a sanitary landfill requires a large investment in land and earthmoving machinery while a solid waste processing facility requires large investments in materials handling and processing equipment. The labour requirements of a disposal facility represent a smaller part of the total cost of the facility than do the other costs.

Both the public and private sector may own and operate the disposal facility or a combination of public ownership and private operation may be employed. The public sector may consist of a single city or be made up of a regional authority as mentioned earlier.

The ability of the private sector to raise capital and to acquire disposal sites may make this alternative very attractive. However, if private enterprise is not interested or is perceived to lack responsibility, the community may decide to own and operate its own facility. Many of the advantages and disadvantages of private versus public operation of disposal facilities are listed in table 2. (Decision-Makers' Guide in Solid Waste Management USEPA 1974 (SW-127) p.17).

Table 2  
 POTENTIAL ADVANTAGES AND DISADVANTAGES OF PUBLIC AND  
 PRIVATE OPERATION OF DISPOSAL FACILITIES,  
 AND THE CONDITIONS THAT FAVOUR EACH TYPE OF OPERATION

Alternatives	Potential advantages	Potential disadvantages	Conditions which favour alternative
Public	Tax-free Nonprofit Can obtain low-interest rates and/or government grants for capital-intensive systems	Community may not have expertise to operate sophisticated disposal facility	Public predisposition towards government operation of public services
Private	Local government does not need to raise capital Often easier for private firms to buy land for a disposal site	Community may have no control of prices if only privately operated disposal site is available Operator may base decisions on basis of financial reward rather than community needs Legal constraints may prevent signing of long-term contract Displacement of city employees Municipality must locate acceptable firm and negotiate contract	Borrowing power of community and/or voter approvals for bond issues needed for capital improvements in disposal facilities are limited or not available Flexibility is needed to make changes in operations that would result in labour savings and other cost reductions

Table 2 (Cont'd)

Alternatives	Potential advantages	Potential disadvantages	Conditions which favour alternative
			<p>Desire of local government to avoid administrative details in operation of disposal facilities</p> <p>Community lacks sufficient technical and management expertise for efficient operation of the type of advanced disposal system it would like to instal</p> <p>Territorial flexibility is needed to permit operation across political boundaries, where appropriate regional agencies do not exist</p>

## II MANPOWER NEEDS

At disposal sites such as sanitary landfill it is estimated that 4 to 6 labourers are involved with the disposition of 1000 yd<sup>3</sup> of refuse per day<sup>\*</sup>. Included in this group are the foreman, equipment operators, gate man, spotter, etc. Not included are any administrative personnel involved.

An overall project supervisor must be assigned to the operation of the landfill who is well informed on the environmentally acceptable methods of landfill operation, heavy equipment operation and general construction and drainage techniques. He will also have to be an efficient manager able to deal well with his personnel and the general public.

Qualified maintenance personnel will also be required for maintaining the heavy equipment involved.

Manpower requirements at processing plants such as shredders, balers or incinerators require specialized training relative to the type of operation. Incinerator manpower requirements are used as an example.

1. Scaleman - responsible for weighing all incoming material, recording same and issuing receipts. The records compiled here are used for billing in many cases.

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\*Pavoni, J.L., Heer, J.E., and Hagerty, D.J., Handbook of Solid Waste Disposal Materials and Energy Recovery. Van Nostrand Reinhold, 1975.

2. Crane operator - at least one per shift, responsible for moving refuse from pit to furnace charging hopper and for moving and mixing refuse in the pit. Must understand the general operation of the facility and the need for as uniform fuel feed as possible.
3. Tipping floor labourer - responsible for keeping the floor clean, assisting in spotting trucks.
4. Furnace operator - one for each furnace per shift, is responsible for the proper operation of the combustion system itself. This is the most critical of assignments since the flow of refuse, air and residue must be carefully maintained in the proper relationships for complete combustion while at the same time guarding the furnace from improper temperature and other damaging effects. This position requires very capable and well trained individuals.
5. Residue system operator - responsible for the efficient and continuous removal of the residue from the furnace. This may involve various quenching and conveying systems.
6. Maintenance personnel - The operation of an incinerator involves high temperatures, very abrasive and complex materials, a wide variety of equipment such as blowers, pumps, etc. and some very heavy equipment. Its continuous operation is essential to the handling of refuse and the maintenance personnel must be capable of keeping it in running order.

7. A supervisor is necessary to organize and direct all of the above personnel. This position requires a thorough knowledge of the incineration process, the various equipment involved along with the ability to organize and lead a work force to carry out the objective effectively. Dealing with the public will also have to be part of the responsibility of this position. He will also have to have some business managerial skills. As stated earlier the manpower requirements have been described using an incinerator as an example. Other processing plants will utilize similar types and numbers of employees depending on the type of process.

### III TRAINING

#### A. Public relations

Refuse handling personnel have the characteristic of being at a very close interface with the public. They are very conspicuous as they collect refuse and are at all times aware of the types of wastes being thrown away. (A great deal can be learned about society by studying its wastes). As a result it is important that solid waste handling personnel be aware of their public relations responsibility. They have the opportunity to present a favourable image or an unfavourable one depending on the training and deportment that they demonstrate.

**B. Safety**

Refuse handlers have a history of having the highest accident and injury rate of any single group. This is due to many factors including handling heavy material, being exposed to traffic, and the nature of the waste materials themselves. It is very important that adequate training be provided to all employees in the proper handling of receptacles, operating of equipment and use and wearing of safety devices. This aspect cannot be over-emphasized since the loss of time and human suffering as well as repair and replacement of equipment all indicate the importance of good safety instruction and practices.

**C. Care of equipment**

This section relates to the training of operators or users of equipment which involves instruction in its proper use and maintenance, not in the sense of repair but to check the various features such as air pressure in tyres, oil and other fluid levels, cleaning radiators, wiping glass, checking belts and lubricating parts, etc. All of this type of care will lengthen the life of equipment, reduce maintenance costs and keep equipment functioning more efficiently and effectively.

## LEGISLATION AND REGULATIONS

by

Professor E.A. Glysson<sup>\*</sup>

## I OBJECTIVES

The objectives of regulations for solid waste management should be to: (a) protect the public health, (b) protect the environment, (c) promote the development and construction of solid waste management and resource recovery systems which preserve and enhance the quality of air, water and land resources.

The various agencies set up to meet the objectives summarized above may also be given the responsibility of supporting and promoting these objectives by:

1. Providing technical and financial assistance to the various levels of government (regional and local) in planning and developing resource recovery and solid waste disposal programmes.
2. Promoting research for the development of new or improved solid waste management techniques. This includes innovations in methods of administration as well.

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3. Providing for the promulgation of guidelines to properly accomplish the above.
4. Promoting training of the individuals who will be charged with implementing the various programmes developed.

## II NATIONAL LEVEL

### A. Legislation

Legislation leading to solid waste management regulation at the national level is best if it is of the nature of policy-setting with regard to the general level of environmental protection which sets the tone for the laws and regulations formulated by the regional or local governmental units.

It may be required that the regional and local regulations be essentially equivalent to the federal law which provides for uniformity of waste management among the regions, but allows for some flexibility to accommodate local conditions.

Legislation dealing with air and water quality has traditionally been the first to occur. It is only relatively recently that laws dealing with solid waste have appeared. Technology applied to the problem of cleaning up the air and water has resulted in various sludges and waste streams which have had to be disposed of on the land. This has required that solid waste legislation and the definitions developed by it may have to consider such sludges and waste streams as part of solid waste along with the more traditional material. Such is the case with the current federal act of the United States.

We must deal with the problem of proper disposal of all our residues into three sinks: the air, water or land, and if the first two are not available we must use the third. These sinks are, however, not independent and completely separated from each other and what goes into one may find its way into either or both of the other two. We are beginning to gain experience with the problem of cleaning up polluted land disposal sites and are finding it to be more expensive and difficult than cleaning up the air and water in some cases.

Legislation relating to environmental quality is usually set forth in sections. The first section commonly spells out the objective of the legislation. The second section will include a series of definitions which are intended to define what is meant when the various terms are used in the legislation. This is a most important section of the legislation and it is also an important part of any regulations (rules) which are formulated to implement the legislation.

The following are examples of areas of concern in solid waste disposal that are addressed by legislation.

Floodplains - convenient location for industry and available for waste disposal, subject to flooding and erosion affecting water quality.

Surface water quality - rainfall and leachate improperly controlled may carry pollutants into nearby surface waters.

Groundwater quality - leachate which is improperly controlled may enter groundwater-bearing formations, resulting in serious damage to water resources.

Food chain crops - may be affected by land spreading of solid wastes (sludges) which contain certain chemicals or trace metals.

Air quality - may be affected by emissions from waste processing or from land disposal.

Safety - one of the many concerns here is the affect of bird hazard on aircraft and the relative location of landfills vis-à-vis airports.

A great deal of emphasis is placed on planning at the national level. Solid waste management plans are expected to determine what is being done with the waste at present and to develop satisfactory means of dealing with the expected waste generation in the future - perhaps up to twenty years. These plans are formulated by regional or local governments with financial assistance from the national level. The basis for this approach is that it requires (1) an appraisal of the present systems and management practice; (2) a determination of the amount and characteristics of the wastes generated;(3) a study of the future development expected for the area, i.e. population, industrial waste generation, etc.;(4) projection of the waste management needs in the light of data gathered and (5) methods for providing for that projected need - short-term (5 years) and long-term (20 years).

By developing a comprehensive solid waste management plan for an area it is expected that,if the plan is implemented and followed, the solid wastes can be properly dealt with.

#### B. Regulations

Regulations are the rules by which legislation is put into effect. They include definitions of what is meant and give more

specifics on exactly how the implementation of the legislation is to be carried out.

There are two approaches to formulating guidelines. One is to use operational standards. This approach sets forth technologies, designs and/or operating methods which are specified in such a way as to theoretically ensure the protection of public health and the environment. This approach promotes the usage of the best practical technology and the regulatory agency charged with environmental protection can easily determine compliance with the specified operating standard, the required type of treatment or standard being very specific. The major disadvantage of this approach is that compliance is generally not measured by determining the actual effects on the environment but rather as a "yes or no" situation as to whether the operational standard is met or not.

The other approach is based on performance standards which are developed to provide a given level of protection to the environment in the vicinity of the disposal site. Determining whether the facility is in compliance with performance standards is more difficult because the necessary actual measurements of the ground and surface water, air and land quality are difficult and costly to perform.

As a result of the characteristics of the two types of standards just described it is not uncommon for regulations to be a combination of the two. This is an attempt to assure adequate environmental quality and yet not be excessively difficult to test for compliance.

Examples of the type of regulation which might be applied to the areas of concern listed earlier are:

Floodplain - prohibit location of a disposal site within a 100 year floodplain unless adequately protected from flooding (1% chance of occurring in any year).

Surface water quality - might require adequate drainage to accommodate a storm equalled or exceeded once in 25 years of 24 hour duration.

Ground water quality - might require specific thickness of man-made or natural soil liner with a specific permeability; also monitoring of wells around the periphery of the waste disposal area to detect any change in the ground water quality.

Food chain crops - regulations would aim to limit the movement of heavy metals and synthetic organics from solid waste into soil used to produce human food chain crops. One of the more common concerns relates to municipal sewage sludges. Control might consist of limiting the amount of cadmium allowed to be deposited on the soil, depending also on the crop to be grown. The performance standard evaluation would include a determination of the heavy metal content in the leaves and grain which are harvested from the sludge-treated soil. If the level of cadmium was acceptable then the programme could continue.

Air quality - regulations would probably include specific amounts of particulate from the stack under standard conditions as operational standards for incinerators. Air quality sampling at the property line or in the area adjacent to the facility might be used as the performance standard.

Safety - conflict between birds and aircraft - the operational standard would be not to allow an airport runway within 10 000 feet of a landfill.

### III LOCAL LEGISLATION

For the management of solid wastes to be successful it must be successfully carried out at the local level. This is where the actual generation and collection occur. If the operation at the local level fails then all the plans and expectations set forth at the national level will be of no avail. Therefore the requirement of the higher levels of government must be translated into implementable measures to be carried out at the local level.

Each unit of local government must accept its share of the responsibility on behalf of its citizens to provide them with what they perceive as adequate solid waste management and environmental quality. The level of governmental services and maintenance of environmental quality may be set forth as laws pertaining to that community. This may constitute a list of city ordinances among which are those pertaining to solid waste management.

The list may contain ordinances which describe how the solid waste is to be managed by:

- a. the generator
- b. the collector
- c. the disposer

The ordinances are usually quite specific, designating the locations for storing the refuse, and the size and style of the container. They may specify how often the collections shall be made, who may make collections, type of vehicle, etc. There may be a lengthy list of definitions as to what is collectable and not collectable, such as the maximum size and nature of wastes to be collected and maximum weight of container.

There may be restrictions on who is allowed to make collections and licences or franchises may be authorized. These may provide some control over the collection process.

Rules which explain these ordinances may be prepared and distributed to the citizens within the city to inform them on how to prepare and manage their own waste material prior to collection.

The disposal of wastes which is in many cases carried out by the municipality will generally come under the regulations set forth by the national government as described under that heading. If there is a state government it may have jurisdiction over the cities' activities but the state regulations in most cases are usually basically equivalent to the national regulations while allowing for variations due to local differences.

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Reflecting the concerns of the times a great deal of attention is now being given to the management of that special division of solid waste identified as hazardous wastes. Dealing with this material involves the evolution of special legislation and regulations which have not been addressed herein.