Practical solid wastes management for developing countries

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PRACTICAL SOLID WASTES MANAGEMENT
FOR
DEVELOPING COUNTRIES

by

JOHN RODDY HOLMES
CEng FIMechE FICE MIRE

MASTER THESIS

Submitted in partial fulfilment of the requirements of the award of:-

Master of Science of the Loughborough University of Technology
1st January 1987

C. J.R. Holmes — 1987
ABSTRACT OF THESIS

PRACTICAL SOLID WASTES MANAGEMENT FOR DEVELOPING COUNTRIES

by

JOHN RODDY HOLMES CEng, FIMechE, FICE, MIEE

AIMS

This thesis sets out to demonstrate to city managers, planners, consultants and industrialists how the solid waste management techniques of the developed nations should be adapted to meet the needs of the big cities and towns in their countries. It emphasises that as these countries become industrialised there is much they can learn from the mistakes made in developed countries. The thesis seeks to demonstrate that being poor does not by definition mean dirty and that there are solutions that will work at every level of available resources and expertise. The thesis cautions against the indiscriminate application of Western technology but rather its careful adaption to the different circumstances of the developing world.

Technology

The scale of the problem and its environmental priority are analysed together with the nature of solid wastes. The available techniques of refuse collection, street sweeping, other auxiliary services, waste disposal policies and waste reclamation are examined. Particular reference is made to the adaption of Western waste reclamation techniques most appropriate to developing countries. The more important waste disposal techniques are examined and sensible policies defined for the treatment and disposal of industrial and hazardous wastes.

Photographs, Supporting Literature and Index of Industrial Topics

The thesis concludes with a selection of photographs, brochures and other material to illustrate the points made in this work as well as a schedule of the individual topics making up the complete work.

Key Words

Solid Wastes
Developing Countries
Waste Collection
Waste Disposal
Waste Reclamation
Hazardous Wastes
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A.1.

THE SCALE OF THE PROBLEM

AND

ITS ENVIRONMENTAL PRIORITY
THE SCALE OF THE PROBLEM AND ITS ENVIRONMENTAL PRIORITY

The large cities of the developing world have grown at a rate unimaginable in Western Europe. Africa boasts several multi-million population cities. Lagos, as an example, has increased its population from 1m to about 4m in the past decade or so. South and Central America have parallels, and in all these cities, as you can well imagine, there is a very substantial gap between the rate of urban development and the environmental and public health services necessary to maintain healthy and clean conditions for the populace.

Governments, however, are starting to realise the size and nature of the problem, and despite some early mistakes and premature investments in unsuitable technology and plant, the problem is being tackled with a proper appreciation of what is needed.

Public cleansing starts with simple and effective collection and street-sweeping services backed up by good maintenance and workshops. Only when all these have been satisfied and good sanitary landfill is impossible should a move be made to implement the higher technologies of composting and incineration. Regretfully, again and again one meets sophisticated plants irresponsibly sold to cities in the face of a total absence of more basic refuse collection and street sweeping services and a complete absence of skilled manpower to make the whole service operate properly.

Of necessity, western waste management services can only be applied to the more prosperous end of the spectrum, or where massive population concentrations give rise to problems that require extraordinary management solutions. The nature of waste, climate and social conditions are all very different, and it is not possible to import western technology or impose western standards without regard to these.

The four main aspects of any solid wastes management system are:

- Storage at or near the point of generation
- Collection of waste
- Street Cleansing
- Disposal of Waste

Each of these principal headings means a very different solution in various parts of the world and the wholesale imposition of western technology and public health expertise will not solve the problem. A 1974 seminar held in Bangkok and organised by the World Health Organisation listed the following impediments to the use of western methods in developing countries.
1. Climate and seasonal variation
2. Budget and foreign exchange limitations
3. Economy of the region
4. Physical characteristics of the cities
5. Social and religious customs
6. Public health awareness
7. Quality of management and technical capacity
8. The environmental standards required

Against this background, the seminar stressed that the solutions provided should bear in mind the following key issues:

1. Protection of health and the environment at a level of cost that can be sustained locally.
2. Development of systems based on local climate, physical, economic and social factors.
3. Production of efficient, indigenous tools and equipment.
4. The achievement of high productivity from labour and equipment, especially motor transport.
5. Education of the public.
6. Vocational and professional training for middle and top management.

Solid waste management cannot be considered in isolation. It is part of a range of environmental services and at whatever level of available resources and urban development it must take its place in a sensible priority listing against pure drinking water, drainage, sewage treatment and other vital services.

Health & Hygiene

One good book that considers the broader inter-relation between these matters is Water, Waste & Health in Hot Climates, edited by R Feacham, M McGarry & D Mara and published by John Wiley. Another is Sanitation in Developing Countries, edited by Arnold Pacey and produced by the same publisher. Acknowledging that the protection of the public is a much wider issue than the collection and disposal of solid wastes it is a fact that in many cities the administration of public health is united with waste collection and disposal. The literature of public health is comprehensive but it is necessary here, at least in outline, to define the interface between it and solid waste management.
To achieve this there is no better example one can choose but to study the Government of Singapore's Ministry of the Environment and its Environmental Health Division. Figure 1 illustrates the command and functional structure of Environmental Health Control and highlights the place of refuse collection and disposal within it. Figure 1 also illustrates the other activities such as sewage and drainage that partner solid waste collection and disposal in a total service to the public. In addition to waste the Environmental Public Health Division controls:

Quarantine
Research
Street Hawkers Traders
Training and Education
Food Shop Licences and Inspection
Cemeteries and Crematoria
Pests and Vermin
Mosquito and Malaria Control

Few countries possess Singapore’s wealth and opportunities and the author recognises that its achievements will, for the most part, be ideal aims rather than practical targets. To counter this the achievements of Colombo in Sri Lanka are worth study and these are set out later in the text. Colombo has to manage with far fewer resources but is blessed with an educated and committed population who achieve much with a fraction of Singapore’s wealth.

By way of further contrast the City of Birmingham in the U.K., a major industrial city with a population in excess of 1,000,000 has organised its environmental services to form a discrete department. With its own Chief Officer and elected committee its responsibilities are seen in this way:

Environmental Inspection
Communicable Disease Control
Housing Inspection
Pollution Control
Noise Control
Food Inspection and Hygiene
Supervision of some working conditions
Refuse Collection
Street Sweeping and Litter Control
Laboratory Services

In order to deal with this task the department is organised into four divisions:

1. Environmental Health
2. Urban Renewal and Housing
3. Refuse Collection and Cleansing
4. Scientific and Laboratory Services
The Environmental Health Division splits down into three further sub-divisions. These are:

- Environmental Inspections
- Environmental Protection
- Veterinary and Food Inspections

Looked at in more detail each sub-division deals with the following issues:

Environmental Inspection

The work here covers the inspection of food, particularly in shops, as well as public complaints on the quality and safety of food sold. Outbreaks of infectious disease are investigated in collaboration with the Medical Authorities. A disinfection service is operated and the sub-division advises the City's planners on the public health aspects of building developments.

Another vital role is the investigation of public health nuisances. Sampling water at public baths and similar places. Noise, smoke and pest control are other issues as well as a general supervision of cemeteries and exhumations.

Environmental Protection

This sub-division deals with domestic and industrial smoke control as well as the prevention and abatement of pollution from industrial processes. Noise levels from road and air traffic are monitored and this includes vibration nuisances. The Environmental Protection Sub-division maintains liaisons with scientific and academic bodies and keep the department up to date on all aspects of pollution control.

Veterinary & Food Inspections

This covers the inspection of meat and the supervision of slaughtering. The inspection of food, fish, fruit and vegetable markets. Also covered are animal kennels, pet shops and breeding farms. The sub-division works with the Ministry of Agriculture, Fisheries and Food and deals with the diseases of animals.
Urban Renewal and Housing Group

A special feature of the way in which Birmingham has organised affairs is the existence within the Environmental Health Department of a division dealing with the renewal of older stocks of housing in the City. The work covers housing inspections and repair, improvement grants, and advice to owners on the improvement of houses.

Refuse Collection and Cleansing

This familiar set of duties, the subject of this thesis, is also handled by the department. It involves all the various refuse collection and street sweeping services, the reclamation of waste materials and the emptying of cesspools and pail closets. The removal of litter, the collection and removal of abandoned vehicles and the removal of waste dumped on open land are also covered. The department did not (until 1986) deal with waste disposal. In England this is the responsibility of the County Council, the next higher tier of local government. This split in duties has been the law in England since 1974. Some more recent legislative plans have changed this situation. The metropolitan counties have been abolished (1986) and waste disposal has reverted to the control of the metropolitan boroughs.

Scientific & Laboratory Services

This unit gives the scientific back-up to the other three operating arms. Scientific analyses are carried out on smoke, fumes, dust and grits in the atmosphere. Heavy metal surveys and blood lead levels are monitored. Foods submitted for analysis are examined and this includes milk and milk products and ice cream. Ground water tests and the solvency of water and sewage systems are also covered.

Specific Solutions

Each city in the developing world will have to look at its own specific problems. Urban renewal and housing may present different problems to that in Birmingham but other services and issues may be more appropriate and these can be introduced into the basic systems of control defined here.
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   Arnold Pacey (editor)
   John Wiley & Sons Ltd

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   World Bank - Comtrean S. J.

   S. E. Asia Region New Delhi India

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   World Health Organisation Regional Publications S. E. Asia Series No.1 New Delhi India
PUBLIC HEALTH & WASTE CONTROL
SINGAPORE ORGANISATION & FUNCTION CHART
OF THE MINISTRY OF THE ENVIRONMENT

SOURCE
Environmental Public Health Division
Ministry of the Environment
Government of Singapore.
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<td>5. The Behaviour of Refuse in Compaction</td>
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THE NATURE OF DOMESTIC SOLID WASTES

Refuse Composition

The following tables illustrate the contrasts in constitution and rate of generation of solid waste in various parts of the world. Per capita quantities of waste are lower in developing countries, because of lower prosperity and consumption as well as extensive scavenging and salvage by beggars and the very poor. Densities of waste are much higher because of the absence of paper, plastic, glass and packaging materials and hence a much greater concentration of putrescible matter. The indications for a prosperous Middle East city clearly show the trend towards 'western' refuse as density falls and paper, packaging and containers increase. The high density of waste in developing countries often approaches its terminal point and hence calls into question the use of compaction-type refuse collection vehicles designed to deal with much larger quantities of lighter waste. Refuse is, and always has been, a keen pointer to the socio-economic conditions of those who create it.

FIGURE 2

SOME COMPARISONS IN REFUSE CHARACTERISTICS

<table>
<thead>
<tr>
<th>% by weight</th>
<th>United Kingdom</th>
<th>Asian City</th>
<th>Middle East City</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetable</td>
<td>28</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>Paper</td>
<td>37</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Metals</td>
<td>9</td>
<td>0.1</td>
<td>5</td>
</tr>
<tr>
<td>Glass</td>
<td>9</td>
<td>0.2</td>
<td>2</td>
</tr>
<tr>
<td>Textiles</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Plastic</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td>12.7</td>
<td>23</td>
</tr>
<tr>
<td>Weight/person/day</td>
<td>0.845 kg</td>
<td>0.415 kg</td>
<td>1.080 kg</td>
</tr>
<tr>
<td>Density kg/m³</td>
<td>132</td>
<td>570</td>
<td>211</td>
</tr>
</tbody>
</table>

Source: Managing Solid Wastes in Developing Countries by J. R. Holmes (editor) John Wiley & Sons Ltd Chapter 1.
The Accuracies and Relevance of Refuse Analyses

In Western Europe and the United States refuse analysis procedures are well established and several published booklets illustrate the principles of composite sampling and analysis. Among the better known is the work of Mr A E Higginson, a past President of The Institute of Wastes Management, of the United Kingdom.

In cities where high technology plants have been constructed it has been necessary to derive an accurate picture of the refuse to be treated. A case in point is that of a heat recovery refuse incinerator plant where the fuel capacity of the refuse, its calorific value in other words, must be known with tolerable accuracy. Several consultancy practices in the United Kingdom and other countries are well experienced in the derivation of refuse calorific values. In every case the method flows from a quantitative analysis of the components of the waste.

Another case would be where the municipal authority is to construct a composting or refuse recycling plant. In this case it clearly is evident that the constituents of waste, in particular those useful elements amenable to recovery techniques must be accurately determined. In the case of the two United Kingdom Government sponsored waste reclamation plants in Newcastle (Byker) and Doncaster, accurate analyses were performed by the Department of Industry’s Warren Spring Laboratory, in Stevenage. The services of this laboratory are available to external organisations. They have an unrivalled experience in the principles and applications of mechanical sorting of solid waste.

In developing countries the most common technological need to be aware of refuse composition is that of composting plant construction. Here organic and non-organic fractions require to be established for from this will flow the anticipated yield of compost, the likely level of discards and the necessity of additives such as sewage sludge.

The point in all this is that the relevance of accurate refuse analysis must be linked to some finite practical end use. It is of little value for its own sake particularly where a hard pressed municipal organisation has better things to do with limited management and technical skills. With the best will in the world accuracies of such forecasts will not be high and consultants and waste managers will require to steer a careful path through the profusion of published data on this or that part of the developing world. Anyone familiar with the dynamics of a crowded, bustling and polyglot African city will be well conditioned to the discounts that require to be put on such data.
Nonetheless some reasonable information is better than none and in the following tables the more reliable sources of data have been assembled. A judicious balancing of the factors given should give the waste manager and consultant a reasonable order of magnitude of the problem facing him.

**FIGURE 3**

**SOME TYPICAL REFUSE GENERATION RATES**

<table>
<thead>
<tr>
<th>PLACE</th>
<th>KG/PERSON/DAY</th>
<th>VOLUME/DAY IN LITRES</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>0.25</td>
<td>1.0</td>
</tr>
<tr>
<td>Ghana</td>
<td>0.25</td>
<td>1.0</td>
</tr>
<tr>
<td>Aden</td>
<td>0.25</td>
<td>1.0</td>
</tr>
<tr>
<td>Egypt</td>
<td>0.30</td>
<td>1.25</td>
</tr>
<tr>
<td>Syria</td>
<td>0.30</td>
<td>1.25</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>0.40</td>
<td>1.6</td>
</tr>
<tr>
<td>Philippines</td>
<td>0.50</td>
<td>2.0</td>
</tr>
<tr>
<td>Turkey</td>
<td>0.60</td>
<td>2.4</td>
</tr>
<tr>
<td>Malaysia</td>
<td>0.70</td>
<td>3.5</td>
</tr>
<tr>
<td>Singapore</td>
<td>0.85</td>
<td>4.25</td>
</tr>
<tr>
<td>Arabian Gulf State</td>
<td>1.0</td>
<td>5.00</td>
</tr>
<tr>
<td>Europe</td>
<td>1.0</td>
<td>8.00</td>
</tr>
<tr>
<td>United States</td>
<td>1.25</td>
<td>12.00</td>
</tr>
</tbody>
</table>

**NOTE:** Compiled from a number of W.H.O. Reports (1981) these figures give a general indication of the variations in generation rate and density. It is as well to note that even the poorest countries have pockets of prosperity and in these areas per capita rates may be as much as 1.5 times the mean figure. Numbers per dwelling will be much higher than in Europe and the United States.
<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetable Matter</td>
<td>10.7</td>
</tr>
<tr>
<td>Screenings</td>
<td>29.3</td>
</tr>
<tr>
<td>Paper</td>
<td>33.8</td>
</tr>
<tr>
<td>Glass</td>
<td>4.2</td>
</tr>
<tr>
<td>Metals</td>
<td>5.7</td>
</tr>
<tr>
<td>Rags</td>
<td>4.6</td>
</tr>
<tr>
<td>Wood</td>
<td>3.3</td>
</tr>
<tr>
<td>Plastics</td>
<td>4.6</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>3.8</td>
</tr>
</tbody>
</table>

**Total (by weight)** 100%

Source: Powell Duffryn Pollution Control Ltd. Kuwait Cleansing Project 1980 - Surveys by Author
# FIGURE 5

**AJODA NEW TOWN, NIGERIA**

Refuse Composition

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fines</td>
<td>10</td>
</tr>
<tr>
<td>Vegetable</td>
<td>42</td>
</tr>
<tr>
<td>Textiles</td>
<td>3</td>
</tr>
<tr>
<td>Paper</td>
<td>15</td>
</tr>
<tr>
<td>Wood and Board</td>
<td>8</td>
</tr>
<tr>
<td>Leather and Rubber</td>
<td>3</td>
</tr>
<tr>
<td>Plastics</td>
<td>4</td>
</tr>
<tr>
<td>Glass</td>
<td>7</td>
</tr>
<tr>
<td>Ceramics</td>
<td>2</td>
</tr>
<tr>
<td>Ferrous Metals</td>
<td>5</td>
</tr>
<tr>
<td>Non Ferrous Metals</td>
<td>1</td>
</tr>
</tbody>
</table>

Total (by weight) 100%

Source:—Ajoda New Town Nigeria Personal Correspondence from Municipal Council to Author.
### REFUSE ANALYSIS - CITY OF ACCRA

<table>
<thead>
<tr>
<th></th>
<th>Cantonment Areas</th>
<th>Market Refuse</th>
<th>Public Dumping Area</th>
<th>Accra Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>House to House Collection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetable &amp; putrescible</td>
<td>69.0</td>
<td>96.4</td>
<td>90.9</td>
<td>87.1</td>
</tr>
<tr>
<td>Paper</td>
<td>15.5</td>
<td>2.1</td>
<td>3.0</td>
<td>5.7</td>
</tr>
<tr>
<td>Metal</td>
<td>7.0</td>
<td>0.01</td>
<td>2.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Textiles</td>
<td>1.9</td>
<td>0.51</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Glass</td>
<td>1.5</td>
<td>0.01</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Plastics</td>
<td>3.7</td>
<td>0.04</td>
<td>0.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>1.4</td>
<td>0.93</td>
<td>1.6</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

**Source:**

Mr B L Ahinakawa, Cleansing Manager, Accra City Council (Private correspondence to Author).
Per Capita Generation Rates

Of great significance day to day management will be the per capita generation rates of refuse and this information will be of infinitely greater use than an excessively introspective contemplation of what makes up the refuse. The practical manager will want to know:

What is the population I serve.
Where is the population distributed.
How much refuse is there.
When and where is it generated.
How does it vary over the seasons.
How often should I collect it.
What must I provide to store it.
How can I dispose of it.

Some information on its density, moisture content and rule of thumb visual appreciation of its constituents will also be desirable. This will enable him to choose his vehicles and plant correctly. As the evidence shows, density appears to vary with prosperity and rate of generation. Refuse in Africa tends to be moist and dense, while that of a prosperous Middle East oil state tends to the Western European norm of high volumes and low densities. The vehicle to handle the one is not necessarily that required to handle the other. So some reasonable knowledge of quantities and densities have their part to play.

FIGURE 7

AJODA NEW TOWN, NIGERIA
General Characteristics of Refuse

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation Rate</td>
<td>.450 kg/person/day</td>
</tr>
<tr>
<td>Density</td>
<td>280 kg/m³</td>
</tr>
<tr>
<td>Volume person day</td>
<td>2.2 litres</td>
</tr>
<tr>
<td>Mean moisture content</td>
<td>39%</td>
</tr>
<tr>
<td>Gross calorific value</td>
<td>1079 kcal/kg</td>
</tr>
<tr>
<td>Compostible Fraction</td>
<td>80%</td>
</tr>
</tbody>
</table>
# FIGURE 8

**REFUSE GENERATION RATES - AFRICAN CITIES**

<table>
<thead>
<tr>
<th>Place</th>
<th>Per Capita Rate</th>
<th>Density</th>
<th>Volume per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algiers 1974</td>
<td>0.410 kg/day</td>
<td>330 kg/m³</td>
<td>1.212 litres/day</td>
</tr>
<tr>
<td>Libreville 1975</td>
<td>0.400 kg/day</td>
<td>210 kg/m³</td>
<td>1.094 litres/day</td>
</tr>
<tr>
<td>Ibadan</td>
<td>0.630 kg/day</td>
<td>230 kg/m³</td>
<td>2.739 litres/day</td>
</tr>
<tr>
<td>Ajoda</td>
<td>0.450 kg/day</td>
<td>210 kg/m³</td>
<td>2.143 litres/day</td>
</tr>
</tbody>
</table>

**SOURCE:**

Journal Mull & Abfall, West Germany

Ajoda New Town, Nigeria - Waste Disposal

Dr Ing Koo Cheul Shin
**FIGURE 9**

**REFUSE GENERATION RATES — MIDDLE EAST CITIES**

*WHO Figures*

Mr. John Marriott — March 1980 (W.H.O. Consultant)

<table>
<thead>
<tr>
<th>City/Region</th>
<th>Refuse Generation Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) European City - upper limit:</td>
<td>1 ton/1000 p/day, 1 kg/person/day</td>
</tr>
<tr>
<td>b) Damascus, Syria:</td>
<td>0.3 kg/person/day</td>
</tr>
<tr>
<td>c) Aden: Peoples Republic of Yemen</td>
<td>0.156 kg/person/day</td>
</tr>
<tr>
<td>d) Dubai, United Arab Emirates:</td>
<td>1.0 kg/person/day, 6.8 litres/person/day, 4.7 kg/residence/day, 32 litres/residence/day, 20% commercial, 80% domestic</td>
</tr>
<tr>
<td>Dubai (Sampling Rates)</td>
<td>10% sample over 4 weeks weighed, 100% sample over 3 days weighed</td>
</tr>
<tr>
<td>e) Egypt:</td>
<td>0.3 kg/person/day</td>
</tr>
<tr>
<td>f) Middle East prosperous cities:</td>
<td>0.4 tons/person/year, (domestic &amp; commercial) 400/365 = 1.095 kg</td>
</tr>
</tbody>
</table>

Source:— Private correspondence with the Author.
Typical refuse density

(Lagos West Africa)

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DENSITY kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose market refuse</td>
<td>247 kg</td>
</tr>
<tr>
<td>Loose household refuse</td>
<td>269 kg</td>
</tr>
<tr>
<td>Mixed refuse</td>
<td>259 kg</td>
</tr>
<tr>
<td>Compacted refuse (1 year old)</td>
<td>916 kg</td>
</tr>
</tbody>
</table>

* Samples taken during 'dry season'
* Samples taken during 'rainy season'

 Courtesy: Powell Duffryn
 Pollution Control Ltd. (1981)
As weight of refuse per day varies in direct proportion to prosperity with generation rates of say 0.2 kg/person/day in an African city to over 1.1 kg/person/day in a prosperous OPEC Middle East city the density of refuse varies in inverse proportion to these parameters. In general, the lower the prosperity level or more primitive the society, density tends to be higher. This combination of opposing qualities gives a volume generation per day of 1.0 litres/person/day in the least active economies to over 5.0 litres/person/day in say Kuwait. Some intermediate examples are as follows:

**FIGURE 11**

**AJODA NEW TOWN, NIGERIA**

Variations in Per Capita Volume Generation of Refuse

<table>
<thead>
<tr>
<th>Volume Generation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2 litres/person/day</td>
<td>Mean</td>
</tr>
<tr>
<td>2.3 litres/person/day</td>
<td>Maximum</td>
</tr>
<tr>
<td>2.1 litres/person/day</td>
<td>Minimum</td>
</tr>
</tbody>
</table>

**SOURCE:** World Health Organisation Study.

These figures will be subject to some corrections and seasonal variations as for example in the maize harvest in Africa or India when very great amounts of maize husks will distort the waste volumes and impose strains on the solid waste service.

In mixed communities the volume per person per day will be recognisably different for each element of that community. Some studies in Kuwait where prosperity levels slot neatly into bands that range from Kuwaiti Nationals (the richest) through the expatriate managers and middle classes down to the generality of the immigrant working population. Field studies gave the following figures. (See Figure 12)

The same will apply to other cities with very clearly defined socio-economic residential areas. Consultants and managers should be well aware of these variations and use composite generation rates with some caution.
### FIGURE 12

**KUWAIT CLEANING PROJECT 1980**

<table>
<thead>
<tr>
<th>Project Design Constants 1980</th>
<th>Composite</th>
<th>Kuwaiti</th>
<th>Non Kuwaiti</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean weight of refuse/person/day</td>
<td>0.65</td>
<td>1.08</td>
<td>0.49</td>
</tr>
<tr>
<td>Mean volume of refuse/person/day</td>
<td>5.00</td>
<td>7.5</td>
<td>3.40</td>
</tr>
<tr>
<td>Mean weight of refuse/family/day</td>
<td>3.73</td>
<td>8.59</td>
<td>2.53</td>
</tr>
<tr>
<td>Mean volume of refuse/family/day</td>
<td>28.74</td>
<td>61.05</td>
<td>17.68</td>
</tr>
</tbody>
</table>

Tested Refuse Density (1980) - 144 kg/m³

**Source:**

Powell Duffryn Pollution Control Limited
Private correspondence to Author
The Behaviour of Refuse in Compaction

The behaviour of refuse as it undergoes compaction has been studied in Europe and the United States, primarily to assist the design of refuse vehicles and mechanical compacting devices. In the refuse incineration plants of Europe, electro-hydraulic and rope operated grabbing cranes feed refuse from large storage bunkers into the furnace feed chutes. The behaviour and payload of these crane grabs has been observed and from this has been derived the compacted refuse densities. Also studied is the recovery of volume of refuse on release from compacting device and whether discharged refuse continues to possess any residual compaction. In other words, does it return to its original state.

Another source of information is the performance of the high density baling plants where very powerful hydraulic presses compact refuse to near its ultimate density. In one such type of plant, the refuse is pressed to a point where the bales retain size and density without restraining bands or wires after discharge from the press. From all these sources is emerging a fairly clear picture of how refuse behaves under compaction. This information is of more than passing interest to waste managers in developing countries. (see Figure 13)

By and large they will be buying refuse vehicles, compactors, capital plant or indeed studying plans that deal with refuse very different from their own. They will hear terms like compaction factor payload and 'in place' density. Unless they are careful, they may purchase vehicles and plant that will not behave as they expect. Refuse vehicles and plant in the United States and Europe are designed to deal with refuse with densities as low as 100-125 kg/m$^3$ and compact this to densities of 500-600 kg/m$^3$. The compaction factor achieved here will be between 5-6 and the following graph (Figure 13) illustrates the relationship between the initial density of refuse and the compaction factors that can be achieved with modern equipment. The important point is that refuse will have a very definite terminal density. In high density baling plants, it approaches 800 kg/m$^3$, but in modern compaction vehicles or static packers it will be of the order of 600kg/m$^3$. All refuse will tend to converge to this terminal density and the compaction factor that will be achieved will depend upon its initial or starting density.

*The Operational Characteristics of Refuse Handling Grabs
P J Scott and J R Holmes
Institute of Solid Wastes Management Journal April 1974.*
An automatic refuse vehicle working in San Francisco and accepting domestic refuse of 100 kg/m$^3$ density will compact it 6 times to a maximum density of 600 kg/m$^3$. The same vehicle operating in an African city accepting refuse of 300 kg/m$^3$ density will compact it 2 times to approximately the same terminal density of 600 kg/m$^3$. In every case the compaction factor will be inversely proportional to the initial density of the refuse. Some vehicle and equipment manufacturers designing and selling to the developed countries state compaction factors as finite and immutable properties of their machines. This is not so and waste managers in developing countries should be well aware of the nature of refuse and how it will behave in storage and transit to final disposal. Readers should also refer to later text on sanitary landfill operations and the text relating to the behaviour of waste in landfills.
THE COMPACTION OF REFUSE

THE CASE AGAINST
HIGH COMPACTION EQUIPMENT
IN DEVELOPING COUNTRIES

Practical Limit
in Compaction Vehicles

Approximate
Terminal Density

Range of Refuse Density t/m³

J. R. Holmes, Aug. 1980
B.1

REFUSE COLLECTION
<table>
<thead>
<tr>
<th>TOPICS B.1</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Work &amp; Method Study</td>
<td>33</td>
</tr>
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<td>2. Sectors of Activity</td>
<td>33</td>
</tr>
<tr>
<td>3. The Formal Sector</td>
<td>34</td>
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<td>4. The Formal Private Sector</td>
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</tr>
<tr>
<td>5. The Informal Sector</td>
<td>42</td>
</tr>
<tr>
<td>6. Household Storage Media</td>
<td>46</td>
</tr>
<tr>
<td>7. Communal Storage Media</td>
<td>51</td>
</tr>
<tr>
<td>8. Basic Collection Modes</td>
<td>59</td>
</tr>
<tr>
<td>9. Basic Transportation Modes</td>
<td>66</td>
</tr>
<tr>
<td>10. Safety Standards</td>
<td>76</td>
</tr>
<tr>
<td>11. Hospital &amp; Clinical Wastes</td>
<td>76</td>
</tr>
<tr>
<td>12. Industrial Wastes</td>
<td>78</td>
</tr>
<tr>
<td>13. Refuse Vehicles</td>
<td>82</td>
</tr>
<tr>
<td>14. Specimen Calculations of Resources</td>
<td>88</td>
</tr>
<tr>
<td>15. Codes of Practice &amp; Information Bulletins</td>
<td>93</td>
</tr>
</tbody>
</table>
Work and Method Study

In developed countries there is an extensive literature in the use of work study techniques in refuse collection. A number of text books make detailed reference to these systems but in the main they are applied only in very well ordered cities with well laid out roads, enforced parking rules and development control. The systems are designed to optimise size of refuse vehicle crews, manpower productivity and the most effective ways of deploying vehicles and men.

In developing countries they have a limited practical use. The author, while listing the principal variants, makes the point that basic commonsense deployment of vehicle, waste containers and manpower resources using the guidelines in this book will serve just as well. Reasonably qualified engineers, managers, public health inspectors and sanitarians using their local knowledge will be able to achieve most of the benefits of the more formal analytical tools. Where cities have reached an advanced stage of development these sophisticated tools may be used. In the United Kingdom, as an example, there are in existence a number of computer programmes designed to plan municipal cleansing services. The services of the Local Government Operational Research Unit (LGORU) and Local Authorities Management Services and Committee (LAMSAC) are examples of these. Other commercial computer programmes are also available and most of the bigger public health engineering consultants have solid waste specialists on their staff. Occasionally the British Government's Department of the Environment is called upon to offer advice on city cleansing problems.

For the purposes of this thesis the use of the practical performance constants given as well as the waste management plan guidelines stated in Section C should serve in most cases.

Sectors of Activity

In many developing countries or for that matter in developed ones the collection of municipal, commercial and industrial wastes falls into several sectors of activity. These may be defined as:-

The Formal Sector
The Informal Sector

The first category, the Formal Sector, can further be split into:-

Municipal Activity
Licensed and Structured Private Operators
Delegated Duties to Other Authorities

Each of these has a role to play. The contribution each makes
depends upon a number of factors that include custom, the efficiency of the municipal service and the extent of commercial and industrial activity. These notes define the scope of each participant.

The Formal Sector

This and best known activity is that municipal service operated legally by the public authorities under the power and sanction of legal statutes. It operates in a manner common to much of the developed and developing world. It may be carried out directly by resources and manpower employed by the municipal authority or occasionally by private contractors acting as its agents. The service is performed with varying degrees of efficiency related to public motivation, political will, the availability of resources and management skills. At one end of the scale are the highly effective and efficient city cleansing service of Singapore and Hong Kong and at the other the ramshackle and neglectful half efforts of many municipal organisations in the Middle East, Africa and South America. In the middle ground are the innumerable well-intentioned authorities with dedicated managers trying hard to operate an effective service with chronic shortages of vehicles, equipment, spare parts, finance and administrative support. If this thesis is dedicated to any group of people it is to these silent heroes.

The Formal Private Sector

In most cities of the developing world particularly those where progress has been made in commerce, industry and tourism a structured private sector in waste collection and disposal starts to operate. At the lower end of the scale these private sector companies consist of little more than one or two open lorries operating but a little higher than the Zabbalene Gypsy families of Cairo. At the other end of the scale they may be subsidiaries of international companies in joint venture partnerships with prominent local business houses. Here they are very well organised and offer a wide range of industrial and commercial waste services including industrial cleaning, chemical waste disposal and a variety of port and dock services. In cities like Hong Kong, Singapore and Kuala Lumpur, reputable private sector waste companies run to several sheets in the Yellow Pages of the local telephone directory. These companies are usually well organised, have access to all the skills and expertise of their European or United States parents and operate modern vehicles and equipment at least as good as their municipal counterparts. It is common to find that industry, commerce, as well as large hotels and offices are required to make independant arrangements to dispose of their wastes. In one Middle East city condominiums or groups of villas above 6 or 8 are required to make their own arrangements and here, of course, the private sector steps in. In some cases hotels and commercial enterprises prefer to opt out of the municipal service to protect themselves against its vagaries.
### Operational Comparisons in Solid Waste Management

**Asian Cities - 1982**

<table>
<thead>
<tr>
<th>CITY</th>
<th>Development</th>
<th>Population x10^3</th>
<th>Rate of Refuse kg/p/day</th>
<th>Total Municipal Wastes</th>
<th>Principal System</th>
<th>Refuse Vehicles in Use</th>
<th>Street Sweeping Vehicles in Use</th>
<th>Labour Force</th>
<th>Refuse Labour per Head of Population (1000s)</th>
<th>Refuse Vehicles per Head of Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>CITY A</td>
<td>Very High</td>
<td>2250</td>
<td>1.0</td>
<td>2250</td>
<td>Communal</td>
<td>260</td>
<td>60</td>
<td>2800</td>
<td>1.24</td>
<td>8654</td>
</tr>
<tr>
<td>CITY B</td>
<td>High</td>
<td>1200</td>
<td>0.8</td>
<td>1000</td>
<td>Communal</td>
<td>168</td>
<td>4</td>
<td>2500</td>
<td>2.17</td>
<td>7143</td>
</tr>
<tr>
<td>CITY C</td>
<td>Moderate</td>
<td>800</td>
<td>0.5</td>
<td>400</td>
<td>Communal</td>
<td>32</td>
<td>Nil</td>
<td>5000</td>
<td>6.25</td>
<td>25000</td>
</tr>
<tr>
<td>U.K. CITY</td>
<td>Very High</td>
<td>800</td>
<td>1.0</td>
<td>800</td>
<td>House to House</td>
<td>100</td>
<td>30</td>
<td>850</td>
<td>1.06</td>
<td>8000</td>
</tr>
</tbody>
</table>

**Note:** U.K. Cities now have an element of communal collection in that public access waste disposal sites are provided for use by car owning families.

**Source:** Authors research, South East Asia Manzoni Award Study Visit 1982.
### SOLID WASTE COLLECTION OVERVIEW
#### ASIAN CITIES

<table>
<thead>
<tr>
<th></th>
<th>LOW</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Production per head/day</td>
<td>0.25 kg</td>
<td>0.87 kg</td>
</tr>
<tr>
<td>Waste Collected per head/day</td>
<td>0.075 kg</td>
<td>0.87 kg</td>
</tr>
<tr>
<td>Density of Waste</td>
<td>250 kg/m³</td>
<td>600 kg/m³</td>
</tr>
<tr>
<td>Workers per 1000 population</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Workers wages per hour</td>
<td>5 US$</td>
<td>20 US$</td>
</tr>
<tr>
<td>Annual expenditure per head of population</td>
<td>25 US$</td>
<td>150 US$</td>
</tr>
</tbody>
</table>

**SOURCE:** B N Lohanu

Handling Storage Collection and Transportation of Solid Wastes in large cities in Asia.

**Recycling International Conference Berlin 1982**

**NOTE:** - Difference in waste collected to waste produced arise because of deficiencies in the efficiency of the collection service.
It is good practice to recognise that an efficient and responsible private sector is a valuable partner in keeping a city clean. Having said this, it is also good practice to introduce a licencing and registration system to bring the private operators under scrutiny and control. The responsible companies will welcome this regulation. In the United Kingdom the private sectors trade association, the National Association of Waste Disposal Contractors, works in the closest co-operation with government departments and the regulatory County and District Waste Disposal Authorities. In the United Kingdom private sector companies handle substantial tonnages of industrial and commercial wastes as well as 20% of municipal refuse disposal. In several towns in Britain the collection of household and commercial wastes is undertaken by them.

Insofar as the disposal of difficult toxic and hazardous wastes is concerned it is common to find that entire treatment resources are owned and operated by private sector companies. This is particularly so in the United Kingdom.

In some other Western Countries there are varying degrees of state intervention and regulation in the free play of market forces. In some EEC countries it is felt that the disposal of toxic industrial wastes is too sensitive to be left to the mercies of unrestrained market forces. When this philosophy prevails the state produces a national plan for the disposal of such wastes and may give exclusive or regional franchises to companies prepared to construct and operate facilities within the plan. The policies of the West German Government are a good example of this intervention.

Whichever path is taken managements in developing countries should recognise the important contribution that the private sector can make particularly in the collection and disposal of commercial and industrial wastes.
SOME IMPROVED SYSTEMS OF REFUSE COLLECTION

A
COMMUNAL 300 LITRE KERBSIDE WASTE CONTAINERS
TRANSFER LOAD TO
SATELLITE SMALL 0.5 TONN PAYLOAD
COLLECTION VEHICLE
TRANSFER TO AUTOMATIC REFUSE COLLECTION VEHICLE
WITH TRASH CONTAINERS
TRANSFER STATION

B
HOUSEHOLDERS KERBSIDE DEPOSIT OF WASTE CONTAINERS
INITIAL COLLECTION IN 300 LITRE TROLLEYS BY COLLECTION LABOURERS
LOCATED AT NEAREST ROAD ACCESS POINT
AUTOMATIC REFUSE COLLECTION VEHICLE
LOCATED AT NEAREST MAIN ROAD ACCESS POINT
LANDFILL

C
GROUND DUMPS & KERBSIDE DEPOSITS
HAND LOADED TO
SATELLITE SMALL PAYLOAD COLLECTION VEHICLES
AND/OR
DIRECT TRANSFER
COMMUNAL CONTAINERS TO SATELLITE COLLECTION VEHICLE & TRANSFER STATION
IN INITIAL DUMP TROLLEY COLLECTION AND HENCE TO AUTOMATIC COLLECTION VEHICLE
GROUND DUMP LOADING TO SATELLITE VEHICLE & HENCE TO AUTOMATIC COLLECTION VEHICLE
SATELLITE VEHICLE COMMUNAL CONTAINER
HENCE TO AUTOMATIC COLLECTION VEHICLE

SOURCE: POWELL DUFFRNY POLLUTION CONTROL LTD
MANAGEMENT TEAM - JEDDAH, SAUDI ARABIA 1980
SOME CURRENT SYSTEMS OF REFUSE COLLECTION

A
GROUND DUMP MECHANICAL LOADING
TO TIPPER VEHICLE

B
GROUND DUMP HAND LOADING
TO AUTOMATIC VEHICLE

IMPROVISED BARROW TRANSFER
TO GROUND DUMPS

LARGE GROUND DUMPS
ON OPEN GROUND SEMI
- CONTAINED BY EARTH BANKS AND
ADJACENT STRUCTURES

OR
LABORIOUSLY
HAND
LOADED
TO

GROUND DUMP CLEARED

MANUAL TRANSPORT
TO GROUND DUMPS

SMALL GROUND DUMPS
AND KERBSIDE DEPOSITS

OPEN SHEETED TIPPER TRANSPORT
REFUSE
TO

LANDFILL

SOME CURRENT SYSTEMS OF REFUSE COLLECTION

SOURCE:- POWELL DUFFRYN POLLUTION CONTROL
MANAGEMENT TEAM PROJECT - JEDDAH SAUDI ARABIA 1980
PRIVATE SECTOR WASTE OPPORTUNITIES IN THE UNITED KINGDOM

CONTRACT A
district

collect
domestic waste

CONTRACT B
county

bulk haul road, river and rail
remote disposal - landfill, or other system

CONTRACT B

county

bulk haul

ROW, RIVER AND RAIL

remote disposal
- landfill, or other system

private industry

industrial waste

collect

commercial waste
The Informal Sector

Side by side with the structured and legally sanctioned municipal and commercial operators is the work of the informal sector. Varying in scale from small 'one man band' entrepreneurs to substantial freelance operators these informal activists can play an important if somewhat undisciplined part in a city's cleansing efforts.

The Zabbalene in Cairo are a good example of substantive freelance operators. In this city, and the municipal authorities freely admit it to be so, the Zabbalene - groups of Gypsy families, could not be dispensed with in spite of several undesirable aspects to their activities. Not least of these is the de-humanising lifestyle of the families, more especially the children who work in the activity. The Cairo municipal authorities, through one of their spokesmen, gave the following summary of solid waste generation, collection and disposal in Cairo and pinpointed within these figures the contribution of the Zabbalene Gypsy families.

The Zabbalene's activities are well recorded within several main family tribes. Under patriarchal leadership several hundred individual family units operate a daily refuse collection service using 2m³ donkey carts. Each cart is capable of collecting about 1.0 tonne of Cairo's solid wastes each day and serving the needs of say 333 six person families with per capita generation rates of 0.5 kg/person/day. These wastes are hand sorted by children sitting on top of the rubbish en route to the city's waste dumps. Hessian sacks slung over the back of the donkey cart acts as a container for the hand sorted and useful recovered waste fractions.

At the dumps in disused quarries extensive hand sorting of waste continues with surprisingly effective separation of paper, metals, glass and organics. The organics fraction is fed to herds of swine also living on the waste dumps. In this crude unstructured way a considerable proportion of Cairo's solid waste is collected, hand sorted, recovered and disposed. Officials of the World Bank speaking at the 3rd International Recycling Congress in Berlin in February 1982 applauded the work of the Zabbalene. Albeit this with a realisation of the many disadvantageous elements of their life style particularly that of the children.

The municipal authorities in Cairo would think carefully before seeking to dispense with the efforts of the Zabbalene. Admitted deficiencies of the Cairo municipal service to the extent that several hundred metres of streets are blocked with refuse to a depth of one metre and this in February 1982 further guarantee the continuance of the Zabbalene. Equivalents to these family waste services can be found in cities in South America, Lima is an example.
The informal sector can and does operate at other levels indeed even when a tolerable municipal service exists and operates. In Lagos in Nigeria where a highly structured Lagos State Waste Disposal Board provides a good communal kerbside bulk bin collection, in many parts of the city nonetheless a thriving informal sector exists. Gangs of small boys and girls run an enterprising business in relieving individual householders of the need to carry their household wastes to the nearest communal collection bulk bin. This service is particularly active in downtown market areas and congested shanty towns where the Lagos State Waste Disposal Board’s 20m³ bulk demountable containers (of the Rolonoff type) 200-300m operating diameters are located. These boys and girls use the householders own 50 litre baskets and bins. The charge for this service in oil rich Nigeria is of the order of 1 Naira (p0.70) per house per day. A not inconsiderable sum.

Wherever there are deficiencies in the municipal service or where this service operates in a less than complete way informal and enterprising people will always step in to fill the gap. Apart from collecting refuse the services they offer include drain cleaning, litter picking and night soil removal. When consulting practices are looking at cleaning operations in third world cities an effective informal sector needs be left well alone at least until alternate upmarket solutions are well implemented and proved to be able to work. And this at least as well as the informal service they replace.

In some circumstances the informal sector still can have a role in an hygienic waste management plan. Not the least of the benefits is the provision of work and income to the otherwise unemployed urban poor. High technology, high productivity and carefully calculated solutions are a long way from the day to day realities of many cities. Figure 21 illustrates the figures given by Istanbul Municipal Council on waste generation rates and how these are split between domestic waste and street sweepings. These figures can be compared with the information given on Cairo in Figure 20.
WASTE MANAGEMENT - CAIRO

Population: 7,000,000
Cairo Municipality: 12 districts
Area: 220 km²
Roads: 4,000 km
Waste: 0.5 - 0.6 kg/person/day
Rubble & Industrials: 2,000 tonnes/day
Total Generation: 6,000 tonnes/day
Density Refuse: 0.250 tonnes/m³
Density Rubble & Industrials: 1 - 1.5 tonnes/m³
Zabbalene collect: 2,000 tonnes/day
Municipality collect (if): 2,000 tonnes/day

Zabbalene give house to house service

Donkey carts: 2 - 3 m³ capacity
Zabbalene families: 15,000
Zabbalene Donkey carriages: 2,300
Collection Cost Municipality: £25E/tonne
Collection Cost Zabbalene: £5E/tonne
Collection Charges to public: £1.0E/house/month
Family Size (typical): 5
Collection Cost to Public: £0.2E/person/month
Definitions:
Zabbalene pick over refuse
Pig manure sold as fertiliser

History (Given by Engineer J Coudsi - Cairo Governorate, Sept 1984)

In the 1930's and 1940's Cairo and Alexandria were very clean cities. Zabbalene handled almost 100% of service in both these cities. The size of Zabbalene families adequate to cope with 100% of waste arisings. Current population growth has now outstepped the Zabbalene manpower. The Zabbalene (in Cairo) now handle about 50% of solid waste arisings but the Zabbalene now pick and choose the areas in which they want to operate. The Municipality has had to step in for and provide a service for the remainder. The Municipality offers a communal collection system from the kerbside. This is a lower standard of service than that offered by the Zabbalene. The World Bank has a scheme to upgrade Zabbalene lifestyle, convert dumps to sanitary landfill and segregate waste deposit from sorting areas, provide water, electricity, access roads and other amenity services.

Courtesy: Cairo Governorate, Arab Republic of Egypt.
Authors visit 1984.
FIGURE 21

WASTE MANAGEMENT

FACTS & FIGURES - ISTANBUL

Population : Over 5,000,000
Solid Wastes : 1,288,000 tonnes
Per Capita rate (1979) : 0.72 kg/p/day
Domestic element (1979) : 0.60 kg/p/day
Street Sweeping & Litter (1979) : 0.12 kg/p.day
Per Capita rate (1981) : 0.80 kg/p/day
Per Capita rate (1985) : 1.00 kg/p/day

Refuse Composition:

Food Wastes : 42%
Paper : 15%
Plastics : 4%
Glass : 0.7%
Metals : 8.2%
Ashes : 10.0%
Textiles : 9.2%
Misc Wastes : 11.9%

100%

Courtesy:
Istanbul Municipal Council - Authors visit 1982
HOUSEHOLD STORAGE MEDIA

It has already been defined that storage at or near the point of generation is the first step towards an effective solid waste cleansing service. These following notes set out the principal variants used by individual householders or small groups of householders to store solid wastes while it waits collection or transfer to the nearest communal collection point.

Plastic Buckets with Lids

These usually have a capacity from 7 to 10 litres and are suitable for household solid waste storage where a daily communal collection service exists. This size of container will be suitable in lower middle and lower income areas where the per capita generation rate is low and the waste mainly organic in nature with a corresponding high density. With some compression a 10 litre bucket will contain 3 kg of waste and serve the needs of a 6 member family whose mean per capita generation rate is of the order of 0.5 kg/person/day. This empirical calculation assumes a refuse density of 300 kg/m³.

In more temperate climates where a twice a week collection is permissible, typically the hilly areas of India, a 20 to 30 litre capacity bin will serve the needs of a middle to low income family. Using the same criteria a 30 litre container with some compression will hold 9 kg of waste. This should, taking the 0.5 kg/person/day norm accommodate the household waste needs of a six person family unit for up to three days. In this rough calculation the refuse has been assumed to have a density of 300 kg/m³.

Plastic Bins with Lids

As income and prosperity levels increase refuse generation rates rise accordingly. Container capacities of 50 to 70 litres become more appropriate. Working on the basis of the earlier calculations a 70 litre container would serve the needs of these typical cases:

i) At 0.5 kg/p/day generation rate

<table>
<thead>
<tr>
<th>Maximum payload</th>
<th>21 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>42 man days of refuse contained</td>
<td></td>
</tr>
<tr>
<td>Family of 6</td>
<td>7 days</td>
</tr>
<tr>
<td>Family of 12</td>
<td>3–4 days</td>
</tr>
<tr>
<td>Communal group of 30–40</td>
<td>1 day</td>
</tr>
</tbody>
</table>
ii) At 0.75 kg/p/day generation rate

<table>
<thead>
<tr>
<th></th>
<th>Maximum payload</th>
<th>28 man days of refuse contained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family of 6</td>
<td>21 kg</td>
<td>4 days</td>
</tr>
<tr>
<td>Family of 12</td>
<td></td>
<td>2 days</td>
</tr>
<tr>
<td>Communal group of 20-30</td>
<td></td>
<td>1 day</td>
</tr>
</tbody>
</table>

The 50-70 litre plastic lidded bin is as well a common receptacle for commercial waste generated by shops and small business premises. These container sizes will be met in kerbside storage modes in Singapore, Kuala Lumpur and other cities throughout Asia. In the author’s experience it is very easy to find an itinerant food hawkers stall producing 50-70 litres of solid wastes for each days activity. Dealing with the waste generated by food hawkers and pavement eating stalls is a very worrisome problem for cleansing managements, especially in areas where communal streetside eating is a popular social affair.

**Reed and Woven Baskets**

By local custom and to economise on imports it is sometimes found that cities and villages make use of reed and coconut leaf woven baskets with capacities of 50-70 litres and occasionally smaller. These containers perform tolerably well especially where waste is high in organic matter and low in dust and small size debris. Surprisingly one finds these baskets used in quite prosperous cities in Asia. Occasionally the baskets are used by communal block dwellings whose owners are required to take household waste to neighbourhood waste depots. In addition they are often used by market traders to store food scraps and vegetable waste. Refuse vehicle crews collecting waste from back alleys will sometimes use woven baskets to economise on the number of return trips to the vehicle. On occasions similar baskets are used to form the containers for street sweeping orderley trolleys. In a four unit 50-60 litre configuration on a trolley they can form quite a useful waste conveying resource of 200-240 litres.
**Manpower Used**

1000-3000 labourers per 1,000,000 population (in 75% of cities)

**Refuse per Capita**

| Metropolitan high | 0.51 kg |
| Urban mean        | 0.33 kg |
| Urban low         | 0.21 kg |

**Paper Content**

3 - 7%

**Compostible Fraction**

40%

**Density**

330 - 560 kg/m³

**Calorific Value**

800 - 1100 k cals/kg (nett)

**Collection Barrows**

50 - 100 litres (nominal)

**Collection Barrows (improvised extensions)**

200 - 300 litres

**Hand Carts 4 Wheel**

500 - 750 litres

**Tricycle Barrows**

200 - 350 litres

**Tricycle Trailers**

300 - 400 litres

**Community Bins**

i) RC Pipe Rings 1m x 1m dia
   Capacity 785 litres

ii) Metal GI bins rectangular
    Capacity 1m³

iii) Masonry Housings:
    Plan Area 2m x 2m
    Walls Front 1m
    Walls Back 2m
    Capacity (max) 4-5m³

**Provision of Transport Volume (per 1,000,000 population)**

- 12.5% of cities - less than 100m³
- 30.0% of cities - 100-200m³
- 27.5% of cities - 200-300m³
- 17.5% of cities - 300-400m³
- 12.5% of cities - over 400m³
Vehicle Journeys 2 - 4 trips per day
Average Trip Distance 20 kms
Vehicle Types

i) Tipper trucks 5-7 tonnes
   Capacity 10-14m$^3$

ii) Mechanical Tractor Trailers
    Capacity 4-4.5m$^3$

iii) Bullock Carts
     Capacity 2-2.25m$^3$

iv) Compaction Vehicles (local manufacture)
    Capacity 10m$^3$ + (nominal)

Sources:
A D Bhide, Director, Solid Wastes, National Institute for Environmenta; Engineering Research, India
(ISWA Conference London 1980)
In the most prosperous locations, and Singapore is an example, the public authorities require that detached residential householders use 85 litre plastic lidded bins. Refuse densities here may fall below 200 kg/m$^3$ and the daily generation rate rise to 1.0 kg/person/day. Per capita volume generation is of the order of 5 litres/person/day and a 6 person family would require a storage capacity of 30 litres.

In practice space consumption may be higher and the 85 litre bin will give a safe two day carrying capacity even if a daily service operates. The specifications for western expatriate compounds in Saudi Arabia have been known to require a 110 litre plastic bin for an alternative day collection mode. This assumes a 50 litre/day generation rate for a family of 4. Even given the atypical social conditions of the country with packaged import of all food stuffs and a very high standard of living these circumstances will not be met outside very special diplomatic housing areas and similar extraordinary situations.

**Expendable Plastic Sacks**

In higher prosperity areas it is now not uncommon to find a leaning towards the use of plastic sacks. Cities like Kuwait and Singapore recommend, if not impose the use of sacks. They may take the form of purpose built refuse sacks conforming to plastic strengths and specifications found in Europe and the USA or less formally they may be discarded grocery bags from supermarkets. Packets of refuse sacks may be purchased at supermarkets in Saudi Arabia and the Gulf States and these have a capacity of up to 150 litres per sack. In other cases sacks may be purchased from municipal authorities.

The use of plastic sacks does impose certain disciplines on the collection service. Neat and hygienic they may be, but they are notoriously liable to damage by foraging dogs, cats and vermin. It is essential that to reap the full benefit of their hygienic properties, the collection service must be efficient and regular.

Likewise the public and shopkeepers in particular must be disciplined to place sacks out at approved times. Spilled refuse from kerbside plastic sacks is a direct function of the length of time the sack is left for collection.
Turning from the household storage media that can be used in a system we now look at the next storage step in many developing country operations - communal storage media. These are the fixed or mobile containers or structures at which the vehicle or transport system commonly takes over.

Depots

These consist of a storage area with walls and a roof about the size of a large motor garage. Commonly they may have a floor area of 20m² with a practical storage height of 1-2 metres. This gives a refuse storage capacity of 20-40m³ equivalent to 6-12 tonnes of refuse. These depots may be used for the storage of domestic, commercial and market wastes and for many years they have formed the focal point of intermediate waste storage in cities. In their physical location they may be associated with other communal facilities such as public toilets and wash houses. The depots system is falling out of favour with progressive cleansing managements. More often than not they are badly operated and controlled. Over-spilling and uncontrolled waste deposits are common and they are a ready magnet for scavengers, flies, dogs, cats and rodents.

Sites are difficult to acquire, public opposition is intense and where they are most needed, in inner city market and downtown areas, land and development costs are very high. The depot principle is sound but is coming to be replaced by the use of mechanical bulk lift containers up to 20m³ capacity. Placed in single or multiple units in temporary enclosures or on open lots, supervised by orderlies, these modern variations to the depot concept are infinitely preferable. The Lagos State Waste Disposal Board has used this principle with considerable success in Nigeria. The adjacent tables give some indication of the operating norms of these modern 'depots'. In the United Kingdom most county waste disposal authorities are obliged to provide sites - called Civic Amenity Sites where members of the public may bring waste in cars, vans or on foot. Designed primarily, at least in the U.K., to eliminate countryside dumping of surplus household waste, the design and operation of these Civic Amenity Sites have many features of the 'depot' concept in developing countries. Cleansing managements in developing country metropolitan areas would not do badly if they studied the mechanics of the use and management of these sites. Figure 23 illustrates a British Government Department of the Environment recommendation for the construction of such a Civic Amenity Site.
TYPICAL "CIVIC AMENITY" SITE
SHOWING SOME DESIRABLE FEATURES

Where site is at an existing enclosed and fenced local authority depot, additional fencing may not be necessary.
The Enclosure

Essentially a construction of timber, corrugated iron, brick or concrete, the enclosure is the most common ground storage facility in Africa and Asian countries. They have a wide range of capacities from 1 to 8m³ and possess many of the disadvantages of their bigger brother, the depot. In rural areas the smaller enclosures of say 1m³ can provide a useful storage facility for a farm or group of houses. A 1m³ enclosure may provide a day's storage of waste for 60 families, at 0.5kg/person/day. Opponents of the idea stress the easy access for animals, flies and scavengers. With heavy rainfall the open enclosure gives rise to sodden refuse and the generation of polluted liquors which may cause problems in the drainage system. The collection process is dirty and unhygienic and degrading for the cleansing labourers. As with the depots, wastes tend to be thrown at the entrance of the enclosure or indeed in the area around it. In the author's experience enclosures and depots often have more waste around than inside them. Occasionally they are used as informal toilet areas so adding to the many other health risks of refuse collection labourers. They can work, and the author has seen in the remote mountain areas of the Lebanon 1 - 2m³ capacity enclosures used as farm disposal and humus producing units. Occasional firing (not a serious matter in remote and scattered communities) is used to keep volumes of dumped waste under control.

The enclosure idea has been adapted by modern waste management practitioners. The mobile refuse bulk bin capable of hydraulic lift into a rear or front end loading compaction refuse vehicle is the result. With a capacity range of 0.75 to 1.5m³ made of galvanised steel, extremely robust and fitted with wheels, these are the natural successors to the fixed enclosure. Wherever economic resources permit, cleansing managements in many countries are eliminating the fixed enclosure with the mobile hydraulic lift bulk bin. The Colombo Municipal Council has started to institute such a policy. With an initial fleet of 10m³ capacity enclosed rear end loading refuse vehicles the authority had placed 450 1.0m³ bins in the central parts of the city in 1982. Located at about 100m intervals on main commercial roads and appropriate residential areas. Each 10m³ vehicle is capable of holding the contents of 20 - 25 1.0m³ bins of Colombo's wet and dense refuse. Public co-operation has been good. The bulk bin idea is used in many cities including, in the author's experience, Cairo, Singapore, Kuala Lumpur and Lagos. Bulk bin storage in association with modern refuse vehicle fleets must be the right solution for these cities whose economic circumstances and environmental priorities require solid waste management at higher than subsistence levels.
Fixed Storage Bins

A common feature in Asian Cities, this unit is built of masonry or concrete blocks with a storage capacity of up to 2.0m³. The walls are about 1 to 1.25m high. There is no side entrance to the bin except via a removable metal flap. Wastes are removed through this flap. The public deposit wastes over the walls. The common disadvantages are those of overspill by broken or removed doorflaps. More serious is the excessive contact that the cleansing labourer must have with the waste to empty the storage bin. Although inevitable in many areas, for the sake of the cleansing labourer's health and human respect, it is a system that should be replaced as soon as circumstances permit.

Concrete Pipe Sections

These have been used in some cities in India. The most common size is a pipe diameter of 1.0m with a height of 0.75m to 1.0m. This gives a capacity range of 0.6 to 1.0m³. With a filling factor of, say, 0.8 the pipe section may hold up to 200kg of solid wastes.

Some writers like B N Lohani, have commented that although they have enormous strength they are subject to all the disadvantages of the enclosure and the depot. These are of course their access to flies and scavengers and the necessity for intimate contact between the waste and the collection labourers.

The Oil Drum

The ubiquitous oil drum with a capacity of 150 to 300 litres is used at least in some parts of almost every Asian, African and South American city. Robust and more tolerably protected against excessive access by dogs it is the most common kerbside communal storage media. It has its disadvantages; it is heavy and difficult to move especially when full. It requires at least two labourers to lift and empty them into the feed hopper of a refuse vehicle but it is better than nothing. Drums of this capacity can carry 45 to 90 kg of domestic wastes and provide a communal storage for several families. Coming back to the familiar 0.5kg/person/day generation rate with a refuse density of say 300kg/m³, the 200 litre oil drum will serve the needs of say 120 people or 20 six person families with access to a daily collection service.
<table>
<thead>
<tr>
<th>Definition</th>
<th>Description</th>
<th>Typical Capacity</th>
<th>Typical Handling Systems</th>
<th>Operational Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Controlled open</td>
<td>Roadsides or vacant land with retaining bund.</td>
<td>20 - 30m³</td>
<td>Hand shovel into vehicle, cart or trailer. Occasional assistance by mechanical shovel</td>
<td>Unsightly, litter prone. Low productivity, cheap.</td>
</tr>
<tr>
<td>2. Enclosures</td>
<td>Masonary or stone construction or pre-fabricated pipe sections</td>
<td>1 - 8m³</td>
<td>Hand shovel into vehicle cart or tractor trailer.</td>
<td>Laborious, dirty work, low productivity.</td>
</tr>
<tr>
<td>3. Concrete Pipes</td>
<td>Concrete pipe sections 1m diameter</td>
<td>1.5 - 2.0 m³</td>
<td>Hand shovel into vehicle cart or tractor trailer. Sometimes via baskets.</td>
<td>Laborious, dirty work, low productivity.</td>
</tr>
<tr>
<td>4. Depots</td>
<td>Masonary or Block construction occasionally with roof</td>
<td>20 - 40 m³</td>
<td>Hand shovel into vehicle, cart or trailer. Sometimes via baskets. Occasional assistance by mechanical shovel.</td>
<td>Good for bigger communal collections. Markets, commercial uses. Can work if regularly emptied and kept clean.</td>
</tr>
<tr>
<td>5. Open Metal Bins</td>
<td>Oil drums or Western type dustbins</td>
<td>0.15 - 0.3 m³</td>
<td>Hand carry and empty into vehicle or cart</td>
<td>Common use, difficult to handle when full.</td>
</tr>
<tr>
<td>6. Mechanically Emptied Bulk Bins</td>
<td>Purpose built Steel capable of hydraulic or mechanical lift into refuse vehicle</td>
<td>0.75 - 1.5 m³</td>
<td>Hand rolled and maneuvered to lift mechanism on automatic enclosed vehicle</td>
<td>Moveable and flexible system can be positioned on roadsides. Most common mechanised option. Expensive vehicles. Demands higher skill levels.</td>
</tr>
<tr>
<td>7. Interchangeable</td>
<td>Skip or bulk container permanently in position</td>
<td>6.0 - 20 m³</td>
<td>Automatic lift and unload onto load lugger skip and like vehicles</td>
<td>Good if emptied to schedule neat, hygienic. More expensive vehicles and higher skill levels.</td>
</tr>
</tbody>
</table>

Sources: i) WCDC Loughborough University
ii) Powell Duffryn Pollution Control Ltd

NOTE: This table is not exhaustive but most other variations fit into one or other of these categories.
In more prosperous areas where the generation rate is say 0.75kg/person/day, with refuse of say 200kg/m³ the 200 litre bin will serve the needs of 53 people or 9 six person families. Occasionally the drums can be punched out to provide hand-lift holds or, in some cases, have lifting handles welded to the bin. In one specific case an American waste disposal contractor in Saudi Arabia modified 300 litre bulk bins to enable them to be hydraulically lifted into the feed hoppers of refuse collection vehicles. When cut in half they can form street sweeping storage containers. The Colombo Municipal Council has used this idea to construct 2 x 75 litre twin bin orderley trollies on tubular steel frames. These are used for house-to-house collections as well as the movement of street sweepings and drain cleaning debris.

Although it has its disadvantages those municipal authorities unable to buy manufactured purpose built galvanised steel or heavy duty plastic bins will find the 300 litre drum a very useful tool in the realities of day to day refuse management.

Hydraulic Lift Bulk Bins

A wide variety of bulk bins capable of hydraulic lift in modern refuse collection vehicles is available worldwide. Often they are manufactured by companies in the refuse vehicle and waste handling business. Made usually of galvanised steel, fitted with wheels and, occasionally, lidded covers the bins come in sizes up to 1.6 to 2.0m³. They may be cylindrical or rectangular in shape and have the necessary adaptors to enable lifting and emptying into refuse collection vehicles. Several western countries with a standards organisation have gone to the trouble of issuing standard specifications for bulk refuse containers. The British Standards Institute BS.1136 is an example.

Cleansing managements must exercise special care to ensure that the refuse vehicle and bulk bins are compatible. Stringent conditions should be established to ensure that the cleansing authority retains flexibility and does not become tied to one particular type of bin or vehicle because of some excessively exclusive features. Most of the reputable bulk container manufacturers will, if required by specification, modify standard bin lift attachments to suit a particular set of vehicles.

It is usual for bins to be painted in the livery of the authority. A numbering system will ensure that the management can control bin locations and have them recorded. It should be said here that in some countries, particularly where highly spiced foods are eaten, it is common to find galvanised steel bulk bins subject to serious corrosive attack. This is worse where bins are fabricated in local factories where galvanising
or other protective treatments may be indifferently applied, if at all. If this situation is likely to arise it is as well to bring this to the notice of the manufacturer before an order is placed. If at all possible refuse analyses and chemical compositions and pH levels of refuse liquors should be established. Careful specification of steel quality and protective treatments can save an enormous amount of problematical maintenance work later in life.

**Plastic Containers**

To counter these problems and for other advantages such as lightness, several plastic manufacturers offer similar containers up to about 1.5m³ capacity. The use of plastic waste containers is popular in Europe and there are several reputable manufacturers there and in Japan. There is now good evidence of satisfactory performance in very arduous high temperature conditions. Thousands of plastic waste containers have been used in Saudi Arabia and the Gulf States and after some early hiccups the problems of prolonged high temperature use have been solved. Colour fading was another problem but this too has been solved for most colours.

**Skip Containers**

Used throughout Europe and the United States the refuse skip can give storage capacities of 4 to 8m³. Extensively used for dry commercial and industrial wastes and building debris, the refuse skips with their bigger volumes are a useful alternative to the depot and enclosures.

Handled by the hydraulic arms of vehicles of the 'load lugger' type, this type of unit is manufactured by a very large number of Western and Japanese manufacturers. One prime mover can service the placing and collection of 10-20 skip units depending upon distance to the disposal point, traffic conditions and like factors. Skip containers are particularly useful in markets, souks, commercial and industrial areas.

In establishing the logistics of the use of skip containers it is as well to allow a derating 'fill' factor when establishing payloads of based on skip volumes and assumed refuse or commercial waste densities. A factor of 0.8 is prudent and 0.85 the best that may be achieved except when handling particularly dense materials. Then a 6m³ skip container collecting by public deposit refuse of say 250kg/m³ should be deemed to have a practical payload of:

\[ 6 \times 0.80 \times 0.25 = 1.2 \text{ tonnes} \]

With lighter refuse of say 150kg/m³ this payload will fall to:

\[ 6 \times 0.80 \times 0.15 = 0.72 \text{ tonnes} \]
These figures are borne out by practical experience. In this way a prime mover may be able to make, say, 10 trips per working day and carry 7 - 12 tonnes of waste depending on density, distance of travel and other physical factors.

In market areas or larger communal collection points it is common to find skip units placed in groups of 2, 3 or 4 units. This gives, with 6m$^3$ containers, a gross receiving capacity of 12 - 24m$^3$.

A wide variety of types and sizes of these containers and some smaller varieties up to say 4m$^3$ are designed to be handled by front loading vehicles, illustrations of which appear in this thesis. A very well known example of this is the Dumpmaster type vehicle from the United States.

**Demountable Bulk Storage Containers**

Moving up in capacity are the ranges of demountable bulk storage containers with capacities up to 24m$^3$. These are manufactured in the United States and Europe and their prime movers are heavy duty 3 axle 18-24 tonnes gross vehicle weight vehicles. Designed for a wide variety of industrial uses they can be used in European refuse transfer stations where they are filled by hydraulic refuse compactors. Similar containers are used by the Greater London Council in its major bulk haulage of refuse by road and rail to remote landfill sites up to 50km from the city. In their open non-compacted form they can be used as refuse containers at communal collection points. In the United Kingdom most Waste Disposal Authorities provide 'Civic Amenity' sites or 'Dumpit' sites for use by the public. Demountable bulk containers in the 20m$^3$ range are commonly used in these locations.

In developing countries the Lagos State Waste Disposal Board has been one of the first to make use of these containers to replace unhygienic and outmoded depots and enclosures. Located principally in downtown market areas and congested shanty towns these containers have been very successful.

Set down on specific sites often in place of old ground dumps the Rolonoff 20m$^3$ bulk container (and sometimes 2 or 3 together) supervised by a uniformed attendant, is a powerful waste containing and removal resource. A 20m$^3$ bulk container with a filling factor of say 0.8 handling refuse and general waste with a composite density of 250kg/m$^3$ will handle about 4 tonnes of domestic and similar waste.

In Lagos a prime mover is able in practical conditions to make 4 to 5 trips each day and thus handle 16-20 tonnes of waste each day. The number of bulk 20m$^3$ containers serviced by a prime mover will depend upon rate of filling as well as the number of containers, it is prudent to keep in place at any one time. It is usual to provide at least 6 bulk containers of
or other protective treatments may be indifferently applied, if at all. If this situation is likely to arise it is as well to bring this to the notice of the manufacturer before an order is placed. If at all possible refuse analyses and chemical compositions and pH levels of refuse liquors should be established. Careful specification of steel quality and protective treatments can save an enormous amount of problematical maintenance work later in life.

Plastic Containers

To counter these problems and for other advantages such as lightness, several plastic manufacturers offer similar containers up to about 1.5m$^3$ capacity. The use of plastic waste containers is popular in Europe and there are several reputable manufacturers there and in Japan. There is now good evidence of satisfactory performance in very arduous high temperature conditions. Thousands of plastic waste containers have been used in Saudi Arabia and the Gulf States and after some early hiccups the problems of prolonged high temperature use have been solved. Colour fading was another problem but this too has been solved for most colours.

Skip Containers

Used throughout Europe and the United States the refuse skip can give storage capacities of 4 to 8m$^3$. Extensively used for dry commercial and industrial wastes and building debris, the refuse skips with their bigger volumes are a useful alternative to the depot and enclosures.

Handled by the hydraulic arms of vehicles of the 'load lugger' type, this type of unit is manufactured by a very large number of Western and Japanese manufacturers. One prime mover can service the placing and collection of 10-20 skip units depending upon distance to the disposal point, traffic conditions and like factors. Skip containers are particularly useful in markets, souks, commercial and industrial areas.

In establishing the logistics of the use of skip containers it is as well to allow a derating 'fill' factor when establishing payloads of based on skip volumes and assumed refuse or commercial waste densities. A factor of 0.8 is prudent and 0.85 the best that may be achieved except when handling particularly dense materials. Then a 6m$^3$ skip container collecting by public deposit refuse of say 250kg/m$^3$ should be deemed to have a practical payload of:

$$6 \times 0.80 \times 0.25 = 1.2 \text{ tonnes}$$

With lighter refuse of say 150kg/m$^3$ this payload will fall to:

$$6 \times 0.80 \times 0.15 = 0.72 \text{ tonnes}$$
this size for each prime mover. These vehicle and containers systems are expensive and should not be contemplated unless the Municipal organisation has well developed workshops as the maintenance of hydraulic systems requires a high degree of skill.

**FOUR BASIC COLLECTION MODES**

Four basic collection systems are employed in developing country metropolis although in practice a complete city service will consist of all the basic systems with occasional combinations. In addition to this, one or more intermediate transfer mechanisms will be employed before the waste reaches its final point of deposit. In cases of extreme congestion it may require 5 or 6 separate actions to make up this chain of events. The illustrations in this thesis show the mechanics and likely productivity of the principal variants.

**Collection from Communal Sites**

In this system the Municipal Authority's work starts at the communal site which may take the form of an enclosure, a depot or a bulk container. Householders, shopkeepers and others are required to deliver their wastes to the communal site. Occasionally, considerable distances are involved. When these distances are excessive, dumping and illicit deposits tend to increase and a heavier burden falls on the city's street sweeping services.

This collection system is used in most parts of Lagos, Bangkok, Bangalore, Delhi, Madras, Manila, Rangoon and recently introduced to Kathmandu. Municipal authorities must cope with the problem of solid wastes as best they may but where a reasonable level of resources are available the communal collection site is still a sound principle and is capable of several upmarket variations using mechanically handled steel containers or mechanical front end loading shovels and tipper vehicle teams. Whatever form is appropriate to a particular city it is important to study the practical siting of the communal sites and take note of the public tolerance of distances they are prepared to travel to reach the site.

**Block Collections**

In this system a collection vehicle or animal cart travels a regular route at pre-determined intervals. Householders and shopkeepers deliver their wastes to the vehicle at the appropriate time. The service can operate daily but more usually two or three times a week. Residents are made aware of the arrival of the vehicle by ringing a bell or the use of 'ice cream' vehicle chimes well known in the West. A readily perceived disadvantage of the service is the absence of a
storage buffer to give some flexibility to the service. It will not take more than one or two failures of vehicle arrival to have the waste from congested and over-crowded houses spilling onto the streets. Nonetheless it can be a viable service.

**Kerbside Collections**

In this basic system residents place their bins and containers on the footway in advance of the collection time and remove them after the containers are emptied.

There are an infinite number of variations to this theme, some of the most appropriate are defined in this text. Plastic sacks can replace metal bins or plastic buckets. Instead of direct delivery to a refuse vehicle, refuse collection labourers with hand carts may act as the transfer medium to a communal site or transfer station.

More sophisticated variations of the kerbside collection may make use of a satellite collection vehicle. This may be a small tipping trailer or purpose built refuse vehicle of the 'Ant' type. In this case the larger Rear End Loaders take up positions at fixed main road locations. The secondary vehicles perform the kerbside collections and tip directly into the feed hoppers of the bigger vehicles. This requires a very good control of vehicle movement and routings. In more usual circumstances satellite collection vehicles would deposit at some fixed point.

Some practical waste managers, particularly in Asia castigate the kerbside collection system for these reasons:

i) the bins are sorted through by scavengers.

ii) bins can cause traffic and footway obstructions.

iii) bins and better quality containers may be stolen.

iv) bins attract roaming dogs and pests.

While one must respect these opinions, and they are given force by observations where front door plastic bags remain uncollected for some time, as in some parts of London. If an authority has come so far as to be able to operate a regular kerbside collection service then it has made considerable progress. Here then it would be better to turn its attention to management and tangible improvements to the concept rather than discard it. Some practical yields from kerbside collections are given in Table 32.
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>LABOUR</th>
<th>VOLUME OF CONTAINER</th>
<th>TRIPS/DAY</th>
<th>ASSUMED DENSITY kg/m³</th>
<th>TONNES/DAY OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Manual Labourer</td>
<td>Orderly Barrow</td>
<td>0.20 m³</td>
<td>5</td>
<td>200</td>
<td>0.20</td>
</tr>
<tr>
<td>B. Trycycle Tractor</td>
<td>1 Driver plus</td>
<td>1 m³</td>
<td>6</td>
<td>200</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>1 Labourer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Bullock Cart</td>
<td>1 Driver plus</td>
<td>4 m³</td>
<td>4</td>
<td>200</td>
<td>3.20</td>
</tr>
<tr>
<td></td>
<td>2 Loaders</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Tractor-Trailer Unit</td>
<td>1 Driver plus</td>
<td>4 m³</td>
<td>6</td>
<td>200</td>
<td>4.80</td>
</tr>
<tr>
<td></td>
<td>2 Loaders</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Side Loader Vehicle</td>
<td>1 Driver plus</td>
<td>8 m³</td>
<td>3</td>
<td>200</td>
<td>4.80</td>
</tr>
<tr>
<td></td>
<td>3 Loaders</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F. Tipper Truck &amp; Mech. Shovel</td>
<td>1 Driver plus</td>
<td>10 m³</td>
<td>5</td>
<td>200</td>
<td>10.00</td>
</tr>
<tr>
<td></td>
<td>1 Loader</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. Skip Vehicle</td>
<td>1 Driver plus</td>
<td>8 m³</td>
<td>5</td>
<td>200</td>
<td>8.00</td>
</tr>
<tr>
<td></td>
<td>1 Loader</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H. Rear End Loader Vehicle</td>
<td>1 Driver plus</td>
<td>12 m³</td>
<td>2</td>
<td>500</td>
<td>12.00</td>
</tr>
<tr>
<td></td>
<td>4 Loaders</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J. Bulk Rolonoff Vehicle</td>
<td>1 Driver plus</td>
<td>27 m³</td>
<td>4</td>
<td>200</td>
<td>21.60</td>
</tr>
<tr>
<td></td>
<td>1 Loader</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTES:
1. The populations served by these systems may be gauged by a typical 0.55 kg/person/day.
2. In many cities the collection to disposal chain may contain a number of the handling systems mentioned above.
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>TYPE OF SITE</th>
<th>PRIMARY COLLECTION</th>
<th>INITIAL ACTION AT TRANSFER POINT</th>
<th>SUBSEQUENT ACTION</th>
<th>OPERATIONAL REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ground Transfer</td>
<td>Level</td>
<td>Hand Trolley from premises</td>
<td>Collection Labourers tip to ground dump</td>
<td>Refuse double handled to tipper vehicle by mechanical shovel</td>
<td>Unsightly laborious should be replaced if resources permit</td>
</tr>
<tr>
<td>2. Ground Transfer</td>
<td>Level</td>
<td>Hand Trolley from premises</td>
<td>Collection Labourers tip to ground dump</td>
<td>Refuse double handled to compactor vehicle by hand</td>
<td>Unsightly laborious should be replaced if resources permit</td>
</tr>
<tr>
<td>3. Ground Transfer</td>
<td>Level</td>
<td>Hand Trolley from premises</td>
<td>Collection Labourers tip to ground dump</td>
<td>Refuse double handled to tipper vehicle by mechanical shovel</td>
<td>Better productivity Transfer points can be bigger &amp; kept cleaner Can be satisfactory interim solutions Much higher productivity Can be successful interim solutions Demands regular emptying schedule</td>
</tr>
<tr>
<td>4. Container Transfer</td>
<td>Split Level</td>
<td>Hand Trolley from premises</td>
<td>Collection Labourers tip to container</td>
<td>Direct container despatch from site</td>
<td>Higher mechanisation but gives good service in better structured areas Demands good organization</td>
</tr>
<tr>
<td>5. Container Transfer</td>
<td>Split Level</td>
<td>Mechanised small capacity trailer or tipper collects from premises</td>
<td>Direct transfer to bulk container</td>
<td>Direct container despatch from site</td>
<td>Based on transfer station operation Higher investment but appropriate for some high density city areas</td>
</tr>
<tr>
<td>6. Static Packer Transfer</td>
<td>Split Level</td>
<td>Mechanised small capacity trailer or tipper collects from premises</td>
<td>Direct transfer to static packer at transfer station</td>
<td>Direct container despatch from site</td>
<td>Useful system to give daily collection service vehicle acts as static packer</td>
</tr>
<tr>
<td>7. Compaction Vehicle Transfer</td>
<td>Roadside</td>
<td>Mechanised small capacity trailer or tipper collects from premises</td>
<td>Direct transfer to compactor vehicle</td>
<td>Direct vehicle despatch from site</td>
<td></td>
</tr>
</tbody>
</table>

Sources:  i) WCDC Loughborough University  ii) Powell Duffryn Pollution Control Ltd

NOTE: This table is not exhaustive but most other variation fit into one or other of these categories
**AN OUTLINE OF SOME MECHANICAL SYSTEMS FOR A MIDDLE EAST CITY**

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>OUTLINE</th>
<th>PUBLIC PARTICIPATION</th>
<th>RELATIVE COSTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communal</td>
<td>Central Bulk collection by refuse vehicles</td>
<td>Place refuse in nearest neighbourhood bulk container</td>
<td>100%</td>
</tr>
<tr>
<td>Kerbside</td>
<td>Full access by refuse vehicle to all areas</td>
<td>Place refuse in adjacent kerbside container</td>
<td>110%</td>
</tr>
<tr>
<td>Kerbside</td>
<td>70% direct access by refuse vehicles with 30% secondary transfer necessity</td>
<td>Place refuse in adjacent kerbside container</td>
<td>128%</td>
</tr>
<tr>
<td>Kerbside</td>
<td>30% direct access by refuse vehicles with 70% secondary transfer necessity</td>
<td>Place refuse in adjacent kerbside container</td>
<td>162%</td>
</tr>
<tr>
<td>House to house</td>
<td>100% House to house service</td>
<td>Place refuse in individual household container at dwelling entrance</td>
<td>277%</td>
</tr>
</tbody>
</table>

**NOTE:** The % of direct access by refuse vehicles relate to the level of development of good road systems in the city. Secondary transfer becomes necessary when congestion is such that refuse vehicles cannot reach the origins of the waste.
Door to Door Collections

This, the most familiar collection mode practised in the West, involves the lowest level of householder co-operation. The refuse collector enters the garden or courtyard of the house, carries the bin to the vehicle, empties it and returns it to its original position. The daily collection of small volumes (relatively) of solid wastes and the time, manpower, and vehicle resources required make this an expensive and somewhat low productivity variant. It has its attractions, is liked by the upper socio-economic groups in the city and is usually confined to these areas. Some cost and productivity norms are illustrated by Table 27. It is also worth noting that in some Muslim countries custom and the privacy of the home preclude refuse collectors. This type of service cannot be worked here and at best it reverts to a kerbside form of collection.

A Definition of the Principal United Kingdom Refuse Collection Modes

BIN

Backdoor : Full bin is collected by loader, contents tipped to vehicle and empty bin return to site.

Kerbside : Householder placed bin at kerbside/premise boundary, loader tips contents to vehicle and replaces empty bin at kerbside/premise boundary for householder to return to site.

Short Return : Full bin is collected by loader, contents tipped to vehicle and empty bin replaced to kerbside/premise boundary for collection by householder.

Pullout in Advance : As for backdoor other than the collection team split so that some men pull out in advance of vehicle, some tip to vehicle and others return empty bin to site.

Skep : Loader carried an empty skep into which he tips the bin contents at bin site thereby eliminating the return of bin to site walks.
<table>
<thead>
<tr>
<th>SACK</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Loose</strong></td>
<td>Sacks only supplied to householders with no provision for cages, clamps, etc. or holders or alternatively the householder releases the sack from its holder so that the loader has only to collect a loose sack.</td>
</tr>
<tr>
<td><strong>Loose Pullout in Advance</strong></td>
<td>As for loose sack but combined with a pull out in advance system of collection.</td>
</tr>
<tr>
<td><strong>Cage</strong></td>
<td>Sacks are retained in a cage sack holder, normally supplied by the authority, from which they are released by the loader, carried to vehicle and loaded.</td>
</tr>
<tr>
<td><strong>Cage - Pullout in Advance</strong></td>
<td>As for cage but combined with a pullout in advance system of collection.</td>
</tr>
<tr>
<td><strong>Clamp</strong></td>
<td>Sacks are retained in a ring clamp normally supplied by the authority, from which they are released by the loader, carried to vehicle and loaded.</td>
</tr>
<tr>
<td><strong>Clamp - Pullout in Advance</strong></td>
<td>As for clamp but combined with a pullout in advance system of collection.</td>
</tr>
<tr>
<td><strong>Bin Liner</strong></td>
<td>Sacks are used as a bin liner, i.e. placed inside normal dustbins as a liner, and extracted by the loaders.</td>
</tr>
<tr>
<td><strong>Bin Liner - Pullout in Advance</strong></td>
<td>As for the bin liner but combined with a pullout in advance system of collection.</td>
</tr>
<tr>
<td><strong>Kerbside</strong></td>
<td>As for bin kerbside but using sack. The method of which the sack is retained is immaterial as the householder would undertake the releasing of the sack.</td>
</tr>
</tbody>
</table>

**NOTE:**

Taken from the publications of the Local Authorities Management Services and Computer Committee (LAMSAC) Ross Audit System.
BASIC TRANSPORTATION MODES

In setting out transportation modes for solid wastes it is advisable to sub-divide the heading into three basic prime mover groups:

- Manual
- Animal
- Mechanical

The mechanical prime movers are further considered in two headings of:

- Improvised Machines
- Purpose Built Vehicles

Each of these have very different costs, productivity and required operating skills. The use of hand carts instead of tractor trailers is not to be taken as a criticism of the city. It may well be the only choice it has and other more pressing environmental priorities dictate that limited financial resources are spent elsewhere.

In every form of container and vehicle defined in these notes there is an improvised or purpose built variant. The humbler handcart may be knocked up from tubular steel and wicker work baskets or it may be imported from developed countries with elegant plastic containers, ergonomically designed for maximum operator comfort with an array of brushes and even a lunch box. In Colombo the city authorities make good use of empty tar barrels and these serve just as well. The choices are conditioned by economics and environmental priorities and sophistication is not necessarily better than simplicity.
Handcarts are used in Asia and the Middle East for daily house to house collections as well as street sweepings. They are especially effective for use in narrow streets and alleys and can be modified to carry pails of night soil. Most handcarts are open wooden boxes with handles and single axle wheels but they are sometimes expanded to twin axle units. Capacities are in the range of 200 to 300 litres.

More than one prosperous city in the Middle East makes use of garden wheelbarrows of nominal capacity laboriously wheeled about the town by armies of labourers. The labour force displaying more common sense than their masters extend the carrying capacity of the barrows by fitting cardboard packing cases above the sides thus tripling the carrying capacity from 100 to 300 litres.

In other cases locally made tubular steel frames can be fitted with twin or quadruple purpose built metal bins or coir baskets which give a carrying capacity of 70 to 90 litres each. The Colombo Municipal Council use such prefabricated tubular steel frames fitted with twin 75 litre half tar barrels cut to size. The 75 litre half barrels also double for duty as kerbside litter bins. A simple and effective innovation requiring a minimum of imported materials.

The Singapore Authorities for all their sophistication in other fields still (in 1982) equip their 2000 street cleaning labour force with similar tubular steel single axle handcarts with a carrying capacity of 2 x 60 litres. Where one can afford it there are available a number of excellent purpose built steel frame, heavy duty plastic bin orderly trolleys. These can be fitted with 2 x 75 litre bins or very occasionally 4 x 75 litre bins. The handcart and orderly trolley is the first line implement of innumerable cleansing operations throughout the world. It should be treated with respect.

The Bullock Cart

Throughout Asia the universal bullock cart is used for refuse collection in rural communities. The single bullock cart has a carrying capacity of about 2m³ while the twin bullock variety will handle a about 4m³. Its open sides can be enclosed with coconut thatch and the author has seen the humble bullock cart working in this way in rural communities in Sri Lanka. In this case a driver and a crew of 2 loaders were carrying out a kerbside collection from 75 litre half tar barrels and ground dumps. With a somewhat slow average speed less than that of a brisk walking pace, the bullock cart can be
used only to deposit waste at a very local village dump. Another factor is that once used for waste the local populace will be reluctant to use the cart for food stuffs or passengers. It may be necessary to reserve it specially for waste and similar materials.

If a single bullock cart is capable of making 2 to 3 trips per day to the local village ground dump this gives it a waste carrying volume of 4 to 6m³. With waste of say 300kg/m³ this will be a payload of 1.2 to 1.8 tonnes per day. Given that a rural community of this type will not be generating more than 0.5kg/person/day this simple arrangement might serve the needs of a village of 2400 to 3600 people or 400 to 600 six person families.

As a prime mover the bullock can in an emergency be used to tow an agricultural tractor trailer if the tractor unit is unserviceable or otherwise engaged. Even when the trailer has been adapted for flexible drive, worm and screw tipping a mechanical crank can be used instead. All this reinforces the great usefulness of the agricultural tractor and trailer for communities who have not reached the point where more expensive purpose built vehicles and equipment are required.

Pedal Tricycles

This becomes apparent in cities where there is a tradition of bicycle movement of goods or tricycle-rickshaws for passengers. In a variety of uses they can be found in the Far East and some Asian cities. In use as refuse or goods containers the box can be located in front of or behind the rider and a common range of carrying capacities is 300 to 400 litres. Unsuitable for hilly locations it can render some limited use but it is not as popular as the hand cart or the bigger motor tricycle and trailer.

Motor Tricycles

The lightweight motor tricycle is a more effective vehicle and can have an enclosed cab with a tipping, carrying box. The box capacities are of the order of 2.0 to 2.5m³ and its relatively high speed gives it an operating radius of about 10km. The tricycle taxi common in cities of India and Sri Lanka and able to carry a driver and two grown men of say 60-70kg each gives an idea of the payload capable of being handled by the motor tricycle refuse cart. If Western imports are the order of the day there are several multi purpose units available that give carrying capacities up to 3m³. The motor tricycle can be used for direct journeys to landfill, to regional ground transfer points or directly into the feed hoppers of larger refuse vehicles.
**SOME EXAMPLES OF PRIMARY & SECONDARY ACTIONS ON REFUSE COLLECTION**

<table>
<thead>
<tr>
<th>PRIMARY ACTION</th>
<th>INTERMEDIATE DEPOSIT</th>
<th>SECONDARY ACTION</th>
<th>FINAL DEPOSIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection Labourer:</td>
<td>Ground Dump</td>
<td>Transfer Load</td>
<td>Refuse Vehicle</td>
</tr>
<tr>
<td></td>
<td>Enclosure</td>
<td>Transfer Load</td>
<td>Refuse Vehicle</td>
</tr>
<tr>
<td></td>
<td>Depot</td>
<td>Transfer Load</td>
<td>Refuse Vehicle</td>
</tr>
<tr>
<td></td>
<td>Communal Bulk Bin</td>
<td>Direct Load</td>
<td>Refuse Vehicle</td>
</tr>
<tr>
<td>Public Deposit:</td>
<td>Ground Dump</td>
<td>Transfer Load</td>
<td>Refuse Vehicle</td>
</tr>
<tr>
<td></td>
<td>Enclosure</td>
<td>Transfer Load</td>
<td>Refuse Vehicle</td>
</tr>
<tr>
<td></td>
<td>Depot</td>
<td>Transfer Load</td>
<td>Refuse Vehicle</td>
</tr>
<tr>
<td></td>
<td>Communal Bulk Bin</td>
<td>Direct Load</td>
<td>Refuse Vehicle</td>
</tr>
</tbody>
</table>
Agricultural Motorised Hand Tractor & Trailer

Sri Lanka as an example and there are many other places, makes use of a versatile and multi function hand steered motorised twin wheel tractor. They are fitted in front of trailers and can be used for carrying goods, food stuffs, tools and men in highways gangs as well as a multitude of other purposes. They can also be used for refuse collection. The driver can sit under a simple shelter and high sides can be fitted to the trailer to give a carrying capacity of about 2m³. Able to move at up to 16 to 20kph they can do a useful job. The trailers can be arranged for simple mechanical tipping. The beauty of this idea is that it is a modification to waste handling of a device that has so many other agricultural and urban uses.

Agricultural Tractor and Trailer

The agricultural tractor is universally available to developing countries and fitted with a trailer it can be adapted to act as a refuse collection vehicle. Carrying capacities of 3-4m³ can be achieved and with refuse densities of 300 kg/m³ this would give a payload of 0.9 to 1.2 tonnes. The appropriate deratings would have to be made for lighter refuse so that with refuse densities at the more usual western figure of say 150kg/m³ the corresponding payloads would be in the range of 0.45 to 0.6 tonnes. Trailers can be of the single or twin axle variety. With double axle trailers it would be possible to increase carrying capacities up to 5-6m³ and give corresponding payloads in the range:

- 300 kg/m³ refuse - 1.5 to 1.8 tonnes
- 150 kg/m³ refuse - 0.75 to 0.9 tonnes

Technical Adoptions

Using the versatility of the agricultural tractor with its variety of drive take off's it is possible to use tipping trailers giving easy discharge of the refuse payload. The tipping mechanism of the worm and nut type can easily operate from the tractor drive. Trailers may either be of the open top type or they can be purpose built with the semi tubular body of the western side loader. When trailers are used in this way, and Freetown, capital of Sierra Leone is an example, a fleet of side loader trailers are set down in various parts of the town and form communal collection points. A number of agricultural tractors carry out a regular sequential changing and emptying of trailers. With some limitations this can give a town a basic service and one that avoids the import of sophisticated equipment. Trailer modifications and body construction work must be well within the capability of almost all municipal workshops. In an emergency, tractor trailers can be towed by bullocks, horses or camels.
Kerbside Refuse Collection from Household, Markets & Souk in a Middle East City
Domestic, Commercial & Industrial Waste Collections based on Skip Vehicles & Orderley Trolleys

Middle East City
Communal Collection from Congested Markets & Living Areas

Nigeria
### Refuse Collection Performance Norms

<table>
<thead>
<tr>
<th>System Definition</th>
<th>System Container</th>
<th>Property performance collection times</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Terraces</td>
<td>Detached</td>
</tr>
<tr>
<td>A Front Door</td>
<td>Sack</td>
<td>0.85</td>
<td>1.15</td>
</tr>
<tr>
<td>B Back Door</td>
<td>Sack</td>
<td>1.02</td>
<td>1.30</td>
</tr>
<tr>
<td>C Front Door</td>
<td>Bin</td>
<td>1.11</td>
<td>1.50</td>
</tr>
<tr>
<td>D Back Door</td>
<td>Bin</td>
<td>1.20</td>
<td>1.73</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crew Composition</th>
<th>Assumed Time</th>
<th>Effective Collecting Properties</th>
<th>Mean Properties Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver</td>
<td>Veh Day</td>
<td>Vehicles/Day</td>
<td>Loader/Day</td>
</tr>
<tr>
<td></td>
<td>6.5hrs/day</td>
<td>1170</td>
<td>390</td>
</tr>
<tr>
<td>A 1 3</td>
<td>390mins</td>
<td>975</td>
<td>325</td>
</tr>
<tr>
<td>B 1 3</td>
<td>390mins</td>
<td>900</td>
<td>300</td>
</tr>
<tr>
<td>C 1 3</td>
<td>390mins</td>
<td>700</td>
<td>260</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mean Population Served/Vehicle</th>
<th>Mean Payload Per Vehicle</th>
<th>Mean Payload Per Trip (2 trips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2.25p/house)</td>
<td>(1.2 sacks/hse)</td>
<td></td>
</tr>
<tr>
<td>A 10,965</td>
<td>6.75t</td>
<td>13.5t</td>
</tr>
<tr>
<td>B 9,141</td>
<td>6.40t</td>
<td>12.8t</td>
</tr>
<tr>
<td>C 8,430</td>
<td>5.90t</td>
<td>11.8t</td>
</tr>
<tr>
<td>D 7,313</td>
<td>5.12t</td>
<td>10.24t</td>
</tr>
</tbody>
</table>
FIGURE 33

SOME EXAMPLES OF UNITED KINGDOM BULK BIN COLLECTION ROUNDS PERFORMANCE NORMS

<table>
<thead>
<tr>
<th>Area</th>
<th>Bulk Bins Handled Per Day</th>
<th>Average Bins Per Vehicle Load</th>
<th>Average Contents Per Bulk Bin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Med Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Metropolitan</td>
<td>110 100 90</td>
<td>50</td>
<td>125kg</td>
</tr>
<tr>
<td>B County Town</td>
<td>150 120 100</td>
<td>50</td>
<td>125kg</td>
</tr>
</tbody>
</table>

Average Payload Per Trip Specific Loading Time Per Bin
High Med Low

<table>
<thead>
<tr>
<th>Area</th>
<th>Payload</th>
<th>Time High</th>
<th>Time Med</th>
<th>Time Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6.25</td>
<td>3.5mins</td>
<td>3.9mins</td>
<td>4.33mins</td>
</tr>
<tr>
<td>B</td>
<td>6.25</td>
<td>2.6mins</td>
<td>3.25mins</td>
<td>3.9mins</td>
</tr>
</tbody>
</table>
Safety Standards

As a guide to cleansing managements the following safety rules taken from common United Kingdom practice illustrate the discipline that can be applied to refuse collection labour. Not all these provisions will be applicable, economic factors will see to that, but many will and at the very least they may set targets for the future.

1. No refuse collector shall climb walls, fences, or walk across private gardens to effect short cuts.

2. Refuse collectors will wear gloves to avoid personal injury.

3. No refuse collector shall place dustbins awaiting collection so as to obstruct pedestrians whether on public or private thoroughfares.

4. Refuse collectors shall not ride on any part of the vehicle except in crew cabs or approved platforms.

5. Refuse collectors shall take all reasonable steps to avoid lifting dustbins, refuse etc., in such a quantity as might impede their walk and cause personal injury.

6. No refuse collector shall compress refuse in the rear hopper of compression vehicle with his hands or feet.

7. Drivers of refuse collection vehicles in their journeys to disposal points should observe all speed limits, statutory requirements and rules of the road.

8. Drivers of refuse collection vehicles disposing of refuse at disposal points should keep to the speed limits laid down in traversing the sites.

9. Any other safety measures such as from time to time may be necessary depending on changing circumstances shall be observed by all members of the team.

Hospital & Clinical Wastes

While it is unreasonable to expect over-burdened public authorities in the poorer countries to take an over-sensitive interest in the disposal of hospital wastes by any other than the most rudimentary means, some order and care can still be introduced even in the most reduced circumstances.

The United Kingdom’s Health & Safety Executive has recently produced a code of practice on the Safe Disposal of Clinical Wastes* and while quite naturally it is aimed at a highly

* The Safe Disposal of Clinical Waste  HMSO United Kingdom
developed country many of its recommendations are of relevance to developing countries. In essence the Code of Practice says that special skill and care is required in handling these wastes. The Code deals with:-

Categories of Clinical Waste
Disposal Policy
Training in Handling & Disposal Procedures
Segregation of Waste
Colour Coding of Sacks & Bags
Bag & Container Specifications

A complimentary waste management paper has been prepared by the United Kingdom Department of the Environment.* It gives comprehensive guidance and advice on all aspects of collection and disposal of these wastes. Cleansing managers should try, so far as they are able, to follow these basic rules.

Basic Rules for Clinical Wastes

All wastes should be removed from the point of origin in suitable plastic bags of a specified thickness and colour coded relative to the type of waste discarded. The thorough segregation of non-hazardous waste from clinical or dangerous waste is essential and all staff should be adequately trained and disciplined to ensure that this vital principle is strictly observed. Satisfactory final disposal depends upon proper segregation of the different wastes at source, adequate storage at the point of origin and transfer to a central reservation for either on-site treatment and disposal or for loading into vehicles or containers for distant disposal including landfill.

Extra care is needed for "sharps" (disposable syringes, needles etc) which should be placed in special moisture resistant fibreboard barrels or recycled polyethylene containers to avoid injury or infection. Special sharps boxes are available and should be used.

There are wastes which can be discharged to the main sewer such as disposable bed-pan liners, urine containers, incontinence pads unless they are infected. These can be macerated by a grinder with ample running water and the waste flushed into the main drainage system. The operation is simple, extremely hygienic, fully automatic and safe.

*Waste Management Paper No. 26 H.M.S.O.
Unfortunately in practice macerators create considerable problems by being prone to breakdown. The system should never be used without a consent from the Regional Water Authority who will be concerned that the practice of maceration of these wastes does not overload the local sewage works.

Incineration is the usual route for clinical wastes at hospitals and similar establishments. This is regarded as the preferred method being safer, easier and more acceptable environmentally.

If properly managed, landfill offers an alternative form of disposal even for some types of clinical waste. It is at present an important route for large quantities of unwanted pharmaceutical waste but with clinical waste, owing to the offensive nature of some constituents, care must be exercised in considering landfill.

The DOE Waste Management Paper No. 26 recommends the types of waste to be incinerated, but in the event of a serious breakdown of facilities, landfill may have to be used. This means careful transportation of clinical waste in a totally enclosed vehicle that can be easily cleaned and disinfected to a high standard and is able to withstand impact damage without disintegration of the waste containers.

Only landfill sites licensed to handle clinical wastes should be used with strict adherence to the operating procedures laid down for placing, covering and integrating the clinical waste with sufficient quantities of domestic waste. Alternatively the clinical waste can be disposed in specially constructed cells and immediately covered with at least 0.25m of suitable cover materials.

To enhance municipal revenues the authority may expand its services to offer a paying collection service to industry and commerce. This can vary from a small scale incorporation of commercial and industrial premises into the domestic waste service to the establishment of a separate organisation. In Nigeria the Lagos State Waste Disposal Board operates such an activity and generates an annual revenue of over £6,000,000. The vehicles used can be those types already defined in this text but of course bulk lift containers and skip container vehicles will predominate. Where available a satisfactory service can be offered using the larger 20m³ Dinosaur type containers and at the other end of the scale the ubiquitous tipper vehicle and mechanical shovel are useful. Later text gives some guidance on the methods to be used in conducting industrial waste surveys and establishing arisings of waste by analysing types of industry and numbers of employers. One such survey in a West African city with a 4 million population and a buoyant industrial sector of 1500 companies gave the following guidelines:
Classification of Companies by Size (Employees)

Type A : 0 - 9
B : 10 - 24
C : 25 - 49
D : 50 - 99 + over

Number of Companies in Each Group

A : 550
B : 450
C : 400
D : 100
Total : 1500


FIGURE 34

TYPICAL DEMAND OF CONTAINERS & SERVICING

<table>
<thead>
<tr>
<th>Type</th>
<th>No's of Firms</th>
<th>Demand on Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>550</td>
<td>2 x 1.6m³</td>
</tr>
<tr>
<td>B</td>
<td>450</td>
<td>3 x 1.6m³</td>
</tr>
<tr>
<td>C</td>
<td>400</td>
<td>2 x 8m³</td>
</tr>
<tr>
<td>D</td>
<td>100</td>
<td>2 x 8m³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 x 27m³</td>
</tr>
</tbody>
</table>
TYPICAL PERFORMANCE NORMS

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Container &amp; Capacity</th>
<th>Cautious Performance Norms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear End Loader</td>
<td>1.6m³</td>
<td>250 lifts/week</td>
</tr>
<tr>
<td>Skip Lift</td>
<td>8m³</td>
<td>25 lifts/week</td>
</tr>
<tr>
<td>Bulk Container Vehicle</td>
<td>27m³</td>
<td>20 lifts/week</td>
</tr>
<tr>
<td>Tipper &amp; Shovel Vehicle</td>
<td>10m³</td>
<td>25 lifts/week</td>
</tr>
</tbody>
</table>

NOTE: These cautious performance norms take account of poor road conditions and other difficult local conditions. Performance would be much higher in developed countries.

A GUIDE TO PRINCIPAL VEHICLE RESOURCES

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Container Capacity</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear End Loading Vehicles</td>
<td>16m³</td>
<td>10</td>
</tr>
<tr>
<td>Skip Lift Vehicles</td>
<td>8m³</td>
<td>40</td>
</tr>
<tr>
<td>Bulk Lift Rolonoff Vehicles</td>
<td>27m³</td>
<td>5</td>
</tr>
<tr>
<td>Tipper Vehicles</td>
<td>10m³</td>
<td>15</td>
</tr>
<tr>
<td>Mechanical Shovels</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

PROBABLE CREW SIZES ON THE OPERATION

<table>
<thead>
<tr>
<th>Type</th>
<th>Driver</th>
<th>Loader</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear End Loader</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Skip Lift Vehicle</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Bulk Container Vehicle</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Tipper Vehicle</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Mechanical Shovel</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Waste Arisings

It is difficult to apply any per unit generation norms for industrial wastes. These are so critically linked to type of activity, economic conditions, size and similar factors that reliable correlations become almost impossible. For this reason on-site investigations are best coupled to a practical assessment of the required storage capacity on site and the required number of lifts (i.e. emptyings) that the industrial plant requires. This can vary from several lifts per day of a range of containers to one lift per week of a single container.

Resourcing

Calculating resources for industrial waste services usually rely on establishing the number of lifts per day or per week for each given type of container. From this and relying on realistic performance norms of waste vehicles bearing in mind local conditions, roads, congestion, disposal sites, skill levels the size of the vehicle handling resource is established. To these minimum figures the appropriate allowances are made to take account of breakdowns and routine maintenance. A factor of 1.25 to 1.30 is common.

The Service Industry Wants

Industrial companies will look for an efficient and regular service. They will be prepared to pay for this, usually on a basis related to a unit cost of lift per container or load. This rate will take account of all charges incurred by the collecting authority.

Before municipal authorities embark on industrial waste collections they must realise that the standard industry expects will be higher than a long suffering public has been wearedied into accepting. Revenues generated from this source can be beneficial but they should not be raised by depleting the resources of an already hardpressed municipal service. The industrial service should be resourced and costed to stand on its own two feet. Another route for raising municipal revenues from industrial waste services is to organise and administer a franchise system where licensed private waste collection contractors pay a royalty to the municipal authority.
Refuse Vehicles

This chapter has made mention of the range of purpose built and improvised vehicles used for the collection and transport of solid waste. Many cleansing authorities in developing countries must make do with what is locally available and in reality the service will operate with a combination of formal and informal equipments. These notes are intended to set out the guidelines to be used in specifying and selecting refuse collection vehicles of modern design. For the purposes of this exercise the fleet is assumed to operate with rear or side end loading enclosed collection vehicles.

Refuse vehicles are expensive, they are required to operate in very arduous conditions for several years. Their crews may be of low status and in a developing country workshops and spares back-up may be poor. In considering the purchasing decision the following factors as set out by J M Cotteridge writing in Chapter 18 of Practical Waste Management published by John Wiley & Sons Ltd are worthy of record.

Definition of Required Performances.

Assessment of Reliability in Operating Conditions.

Safety & Level of Local Labour Competence.

Driving and Crew Cabs.

Demonstration of Performance in the Operational Area.

Availability of Spare Parts and Service Organisation.

Price and Conditions of Purchase.
An illustration of the various methods of loading and containing waste in vehicles.

- **SIDE LOADER DERBY**
- **HORIZONTAL PLATE**
- **ROTATING DRUM**
- **TWO STAGE**
- **GRAVITY**
- **RADIAL PLATE**
- **SPIRAL SCREW IN BODY**
- **SINGLE STAGE**
- **NO MECHANICAL COMPRESSION**
- **INTERMITTENT COMPRESSION**
- **CONTINUOUS COMPRESSION**

*Courtesy: IHM Journal*
Definition of Required Performance

A thorough knowledge of how the vehicle is to perform is the basis of refuse vehicle selection. The cleansing manager must have a very good knowledge of the dynamics of his local operation. The population served, the waste generated per person per day, the size of family unit, the type of containers to be used, the nature of the wastes, their density and constituents, and the likely compaction factors are all part of the thinking process. Other chapters in this thesis define the ways in which refuse vehicle payloads and performances can be assessed.

The state of the roads, the condition of the disposal sites, overhead clearances, turning circles, rainfall, ambient temperature and humidity all have a bearing on key aspects of engine, chassis, hydraulics, paint specification and likely operating efficiency. Most reputable vehicle and plant manufacturers have special tropical specifications for their equipment exported to those countries. If local management does not have access to specialised plant inspection and specification writing skills, at the very least the invitation to manufacturers should set down as clearly as possible every known parameter of the local operating conditions.

In nearly every country there will exist an import and service infrastructure for vehicles, earth moving plant and general machinery. It will not be difficult to obtain examples of check lists that may be modified to suit a refuse vehicle fleet. Even the humble side loader so extensively used throughout the developing world requires considerable thought and this should not be under-estimated.

Assessment of Reliability

The ability to sustain reasonable standards of performance at reasonable cost throughout its working life is surely at the very heart of what is expected from a vehicle. This reasonable performance particularly in a developing country must occur in spite of indifferent or even brutal treatment by badly trained operatives and chronic shortages of spare parts.

Safety in Operation

Compaction refuse vehicles with their compaction mechanisms all incorporating a shearing or guillotine action can be very dangerous. The possibility of limb amputation if not decapitation is an ever present risk. This is accentuated in countries where labourers may be poorly trained and badly supervised. Children playing in an area are often attracted to a visiting refuse collection vehicle. For this reason the purchase specification must consider these hazards. Most reputable manufacturers now provide emergency stop pads, reversing bleepers and similar safety aids. These will need to be defined.
Driving and Crew Cabs

Some thought must be given to the driving and crew cab. It must be designed to accommodate the crew with space for protective clothing. In some tropical countries the refuse collectors sit in a semi enclosed area behind the driving cab. Air conditioning may be a factor (for those who can afford such refinements). As with safety, crew seating and comfort is now given a high priority by reputable manufacturers. In spite of this, cleansing managers may need to make special references to crew accommodation.

Manoeuvrability in Operation

The vehicle must be able to approach to within a reasonable distance of the refuse containers or storage points. Refuse collectors should not be expected to carry small bins more than say 50m or wheel or push bulk containers more than 10m. The purchase decision must take account of likely road widths, turning circles and road surfaces. Height is also a factor as in some areas low level electricity and telephone cables may festoon rooftops and roadways.

Loading Rates

It is important to check that the vehicle can be loaded at the rate required by the cleansing plan. This is particularly important if large crews are used or if roadside collection is the norm. Many manufacturers' specifications will define the volume of waste per minute cleared by the loading hopper and compaction mechanism.

Capacity

An obvious statement perhaps but decision makers must define the payload required. These can be established during demonstration trials and there is now quite an extensive published literature on refuse vehicle design. Chapter 2 - The Nature of Municipal Solid Wastes draws attention to the behaviour of wastes in compaction as well as their terminal densities. A knowledge of this is particularly important when dealing with moist, dense refuse in vehicles primarily designed for the lighter, dryer refuse of developed countries.

Discharge

Most modern compaction refuse vehicles discharge their load by means of inclined tipping and hydraulically operated ejector plates. Invariably these are suitable for discharging at landfill sites. In some rare cases the vehicles may be required to discharge at mechanical treatment plants and transfer stations. Some such plants have enclosed tipping bunkers and these may restrict headroom clearances.
All reputable manufacturers, particularly those experienced in export to hot climates have long come to terms with the special conditions their vehicles will encounter. Usually they are very helpful to cleansing managers and without prejudice will guide and assist in the appropriate selections of vehicle types and sizes as well as spare parts holdings and like matters.

Assistance from Manufacturers
APPENDIX

Specimen Calculations to Establish Probable Waste Collection and Disposal Resources in a Nigerian City
CITY BASE FACTS

Population - 1,000,000
Waste Generation - 0.5kg/p/day
Waste Tonnage - 182,500t/yr
Collection days per week - 6
Collection days per year - 312
Waste collected per day - 585tonnes

Assumed Waste Densities
Loose Market - 247kg/m³
Loose House - 269kg/m³
Mixed - 259kg/m³
Assumed Mean - 260kg/m³

Types of Waste Collection Performed

A - Kerbside Bulk - 30% - 175
B - Communal Skip - 40% - 234.0
C - Communal Bulk - 20% - 117.0
D - Tipper/Shovel Task Force - 10% - 59.0

585.0 t/day

Volumes Generated

Waste Density - say 260 kg/m³

Volume generated per day = 585.0/0.260 = 2250m³/day

Volume generated per person = 2250/1,000,000
= 2.25 litres/p/day

Taking a mean occupancy rate of 6 persons/house

Volume generated per house @ 6 person/house = 166,666 houses

Volume generated per family/day = 2.25 x 6 = 13.5 litres
RESOURCE CALCULATIONS

SYSTEM A - Kerbside Bulk - 175 t/day

Bins are Mammoth Type 1.6m³
Say the vehicles used are 16m³ Rear End Loading Compactor Vehicles
Refuse density in the vehicle = 500 kg/m³
Payload will be 16.0 x 0.5 = 8 t/trip
Say 2 trips/day/vehicle = 16 t/day payload
Therefore No. of vehicles required = 175/16 = 11 vehicles

Containers
Assume 1.6m³ size - Refuse density 260 kg/m³
Fill factor say 0.60
Mean payload = 1.6 x 260 x 0.80 = 332 kg
No. of bins required = 175/0.332 = 527 bins
No. bins per vehicle/day = 527/11 = 47.0
Allow a diversity factor of say 2.0
Practical bins on the street = 527 x 2 = 1054

SYSTEM B - Communal Bulk Skip - 234.0 t/day
Say 6m³ skips used. Fill factor = 0.80
Payload = 6 x 0.260 x 0.80 = 1.25 tonnes
Skip loads per day = 234/1.25 = 188 loads
Each skip vehicle handles 5 trips/day
Basic skip fleet = 188/5 = 38 vehicles
Containers
Base containers required = 188
Density factor of 1.5 = 282
Vehicle skips on = 38

508 skips

SYSTEM C - Communal Bulk Dinosaurs - 27.0m³
Tonnage handled = 177 tonnes
Containers payload = 27.0 x 0.260 x 0.80 fill
= 5.6 tonnes

1 Vehicle achieves 4 trips/day
Vehicle refuse handled per day = 22.4 tonnes
Vehicles required = 117/22.4 = 5

Containers
Base containers 117/5.6 = 21 containers
Density factor of 1.5 = 32 containers

SYSTEM D - Task Force - Tipper/Shovel
System D = 59 t/day
Tipper size = 10.0m³
Payload/trip = 10.0 x 0.260 x 0.8 (fill) = 2.08 tonnes
Tipper trips/day = 5
Tipper performance per day = 5 x 2.08 = 10.4 tonnes
No. of tippers required = 59/10.4 = 6 vehicles
No. of shovels (1 per 5) say 1 shovel
Task Force Module = (6 tippers
(1 shovel
Backlog Clearance

Task Force module handles 52 tonnes/day

Say 3 months backlog on the streets = 182,500/4 = 45,625 t.
1 module handles 52 t/day = 312 t/week = 16,224 t/year
So, 45,625/16,224 = 2.8 modules - say 3.

Say we provide 2 modules in total

| Tippers | 10 |
| Shovels | 2 |

Abandoned Cars

1 Abandoned car unit i.e. 1 Hiab Unit 7 - 10 cars/day

say 7 cars
42 cars/week
2000 cars/year

General Purpose Vehicles

3 - Flat-Bed Vehicles - Miscellaneous Wastes
2 - Enclosed Vehicles - Clinical Wastes

Landfill Disposal

Yearly arisings of waste = 182,500 tonnes
Daily arisings = 585 tonnes
Landfill space demand = 1.5 m³/tonne of waste (initial)
= 1.25 m³/tonne (1 year)
= 1.00 m³/tonne (3 years)

Volume Consumed per year = 182,500 x 1.5 = 273,750 m³

Minimum suitable site (Giving say 5 years life.) = 1,368,750 m³ say 1,500,000 m³
Say we are filling a 3m mean depth.

Area \(= \frac{273,750}{3.0} = 91,250 \text{m}^2\) area

**Per Year:** Site Space @ \(91,250 \text{m}^2\) = \(300 \times 300 \text{m/yr}\)

1 Big Machine i.e. Landfill Compactor i.e. Cat. 816

or Bulldozer Cat. D.8

will handle N 500 - 600 tonnes/day site

N \(80 \text{ t} - 100 \text{ t/hr}\)

N \(10 - 12\) refuse vehicles loads/hour

+ 1 Support Machine

Probably i) Wheeled Shovel

ii) Wheeled Digger/Excavator

iii) Tracked Shovel/Excavator

**Cover Material**

May require Tipper/Shovel part Module to import cover -

say 20% of waste input = \(100 \text{ t/day} = 10\) loads/day

**Other Issues:** Workshops & Depot

Garaging

Management

Manpower Assessments

Spare Parts

Replacement Programme

Training of Staff

Public Relations

**Note:** These are dealt with in other parts of the text.
Developments in refuse collection as well as all other aspects of solid waste management are extensively discussed in Wastes Management, the Journal of the Institute of Wastes Management in the United Kingdom. The Institute also publishes a number of technical monographs on subjects connected with waste collection and related matters. A study of these is recommended to waste managers and decision makers.

Also of considerable value is the (1982) Code of Practice published by the National Association of Waste Disposal Contractors (NAWDC) in the United Kingdom. This comprehensive work contains data on:

- Safe Loading and Unloading of Waste Materials
- Safe Transportation of Waste
- Collection from Household and Commercial Premises
- Collection and Safe Disposal of Clinical Waste

Copies of the Code may be obtained from the offices of NAWDC in the United Kingdom. These are at 26/29 Wheatsheaf House, 4 Carmelite Street, London, EC4Y OBN.
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   (Editor)
B.2

STREET_SWEEPING
<table>
<thead>
<tr>
<th>TOPICS</th>
<th>Page</th>
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<tbody>
<tr>
<td>1. Systems in Developed Countries</td>
<td>97</td>
</tr>
<tr>
<td>2. Mechanical Methods</td>
<td>97</td>
</tr>
<tr>
<td>3. Hand Sweeping</td>
<td>98</td>
</tr>
<tr>
<td>4. Operational Features of Various Systems</td>
<td>102</td>
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<tr>
<td>5. Sweeping Machines</td>
<td>106</td>
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<tr>
<td>6. The Experience with Litter</td>
<td>107</td>
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<tr>
<td>7. Sweeping in Developing Countries</td>
<td>108</td>
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<tr>
<td>8. Car Parks</td>
<td>112</td>
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<tr>
<td>9. Practical Management Assessments</td>
<td>113</td>
</tr>
<tr>
<td>10. Street Hawkers</td>
<td>113</td>
</tr>
<tr>
<td>11. Beach &amp; Foreshore Cleaning</td>
<td>114</td>
</tr>
</tbody>
</table>
In developed countries there are a variety of street sweeping and litter prevention systems – these cover a range of manual and mechanical methods including battery operated electric road vehicles as well as vacuum sweepers. While many of these systems are inappropriate to all but the more advanced developing metropolis the principles behind them can be used with good effect in countries that must adopt humbler and simpler alternatives.

A tractor trailer, tricycle tractor and trailer, a push hand cart or even a bullock cart can still be used, albeit with appropriate amendments to performance. The principles remain the same and for this reason it is appropriate that the text includes a review of developed street sweeping techniques. Government officials and public health officials will realise only too well the practical discounts they must apply to synchronise these notes to their local circumstances.

Mechanical Methods

In Britain, as an example, about 70% of street sweeping is mechanised. There are three broad classes of activity. These are the cleaning of:-

- Roadways
- Light roads and footpaths
- Footpaths

While most sweepings occur within 1m of the gutter occasionally it may be necessary to employ full road width sweeping methods particularly where traffic flow does not blow sweepings into the side channels. There are a wide range of suction sweepers on the market and in most countries the market leaders will be represented by local agents or vehicle and plant merchants. The sales information usually contains considerable operational data. Suction sweepers are available with dual sweep mechanisms so that they can be used on dual carriageways and one-way streets. In keeping with modern standards these vehicles are now equipped with a full array of warning lights, crew seating cabins and safety devices. Many vehicles will be equipped with wandering hoses so that adjacent gullies and footpaths can be cleaned. Similarly litter bins can be emptied and concentrations of heavy grit lifted. Dust suppression is standard and this is of particular importance in arid climates. Occasionally towed sweeper brooms may be used to clear slush and heavy grit or to clear approach roads to sanitary landfill and disposal sites.
Hand Sweeping

Most systems are based on individual beats or part of team efforts with pedestrian controlled electric vehicles or ride-on electric vehicles. The motorised variations are inherently more productive in that the waste recepticle follows the team and is capable of being emptied while the team continues to work. Figure 42 gives some indication of the team size and productivity of mechanically sided and manual sweeping techniques.

In whatever form, the backbone of the system is the individual beat performed by a single sweeper. In developing countries where improvised trolleys and buckets may replace more sophisticated purpose built equipments the basic operation still applies.

Figures 40 and 41 give some definitions of best performance based on experience in Singapore and Colombo while Figure 42 reflects the guides used by local authorities in the United Kingdom. Some commercial companies in the country (now undertaking these services on behalf of local authorities) operate with somewhat higher productivities than those stated in Figure 42.

The Municipal Engineering Data Sheets published by the Municipal Group of Companies say that daily beat lengths vary from 200 metres to 5000 metres. A figure of 1600m is the norm for residential areas. The frequencies of sweep vary widely. Oxford Street in the West End of London is swept up to 8 times/day. Many residential roads will be swept once per week or less. It is usual that the best duties include weed clearing, channel cleaning and emptying litter bins.

In a tropical country with high rainfall storm drain cleaning would also be part of these duties.

**FIGURE 39**

Recommended Table of Frequencies

<table>
<thead>
<tr>
<th>AREA</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Metropolitan City Centres</td>
<td>Twice or more</td>
</tr>
<tr>
<td>2 Central Business and Shopping Areas</td>
<td>Once a day</td>
</tr>
<tr>
<td>3 Principal Traffic Routes and Housing Estates</td>
<td>Twice a week</td>
</tr>
<tr>
<td>4 Residential Areas &amp; Secondary Areas</td>
<td>Once a week</td>
</tr>
</tbody>
</table>
### Typical Productivity Levels of Street Sweeping Labourers

**South East Asia**

<table>
<thead>
<tr>
<th>System</th>
<th>Source</th>
<th>Area Served</th>
<th>Kerb M/Day</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Orderly</td>
<td>Singapore</td>
<td>Congested</td>
<td>1980</td>
<td>Highly Developed</td>
</tr>
<tr>
<td>Manual Orderly</td>
<td>Singapore</td>
<td>Residential</td>
<td>4290</td>
<td>Highly Developed</td>
</tr>
<tr>
<td>Manual Orderly</td>
<td>Colombo</td>
<td>Congested</td>
<td>800</td>
<td>Undeveloped &amp; Poor</td>
</tr>
<tr>
<td>Manual Orderly</td>
<td>Colombo</td>
<td>Residential</td>
<td>1600</td>
<td>Undeveloped &amp; Poor</td>
</tr>
</tbody>
</table>

**NOTE:** Duties may include the litter picking of gullies, storm drains, verges and ditches which may reduce the expected kerb m/day performance.

**Source:** Author research visit to South East Asia Manzoni Award 1982.
## TYPICAL_SWEEPER_COLLECTOR_PERFORMANCES

### WEEKLY PERFORMANCE

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance Travelled</td>
<td>210km</td>
</tr>
<tr>
<td>Distance Swept</td>
<td>165km</td>
</tr>
<tr>
<td>Running Hours</td>
<td>4.1</td>
</tr>
<tr>
<td>Sweeping Hours</td>
<td>30</td>
</tr>
<tr>
<td>Max. Sweepings Collected</td>
<td>5.0m³/day</td>
</tr>
<tr>
<td>Min. Sweepings Collected</td>
<td>1.5m³/day</td>
</tr>
<tr>
<td>Average Sweepings Collected</td>
<td>2.5m³/day</td>
</tr>
</tbody>
</table>

**Reference:**
Municipal Engineering Data Sheet
Street Cleansing Operations. United Kingdom.

**Note:** The growth of privatisation of municipal cleansing services in the United Kingdom in the period 1981/1985 has resulted in substantial improvements in some performance norms.
Street Orderly Trolleys

On the market in most developed countries are a large number of orderly trolley designs. The patterns of one such, made by Glasdon Ltd of the United Kingdom are featured in this book. This Company has been particularly active in exports to third world countries. The one man orderly truck usually comprises a two wheel metal frame chassis. It carries an array of cleaning brushes, space for protective clothing. It is usual to mount two bins on the frame with individual capacities up to 150 litres. This gives a sweeping carrying capacity of 300 litres. Some improvised varieties used in Singapore and Colombo are also mentioned in the text.

OPERATIONAL FEATURES OF THE VARIOUS SYSTEMS

Single Orderly Beats

Although in many cities single orderly beats have been absorbed into team beats, the single orderly beat remains the most effective method of keeping busy shopping areas clear of litter, even if the same area is covered by a team earlier in the day.

Equipped with an orderly trolley fitted with one or two bins or sacks, plus channel broom, pavement or platform broom and a shovel the single orderly has the flexibility to work his beat in a most effective way engendering both pride in his work and job satisfaction.

A comparison of this type of beat with one in a busy shopping centre leads many cleansing managers to the inevitable conclusion that there cannot be a standard length of beat for a single orderly. For example, an orderly in the West End of London might be expected to cover less than a quarter of a mile daily, working backwards and forwards over the same area. An orderly in an outer London shopping centre could have a beat of up to one mile, covering the same area twice in a day. Contrasting further, a single orderly beat away from a town centre could sweep one and a half miles or more daily.

There are additional factors which govern the size of a single orderly beat: The type of area, distance from the depot, road and pavement surfaces, grass verges, trees and even the standard of housing all play their part in establishing the frequency of service required. Schools often provide as much of a problem as shopping areas. In a tropical country the clearing of storm drains and gutters may be additional duties.
Planned Street Sweeping & Litter Prevention Services for Middle East City
The normal method of working is to sweep material from a short length of footway into the channel, including the wall line, and then to sweep the channel itself and form heaps which can be picked up with a shovel and emptied into the orderly trolley.

In order to prevent unnecessary walking the single orderly should work in conjunction with a parent vehicle on which he can dispose of his sweepings, bagged or unbagged. The disposable bag method relieves the need of a rendezvous as the orderly can leave his sacks at pre-arranged locations 'en route'.

If there is no parent vehicle the orderly has to carry all material collected back to a depot which tends to restrict both his range and enthusiasm.

The volume of material an orderly will collect each day depends on the type of beat. An orderly working in a residential area might collect just three or four sacks comprising mostly silt. An orderly working in a town centre could fill ten or more sacks comprising mostly paper and other litter; a great deal of which will have been emptied from litter bins.

**Pedestrian Controlled Electric Vehicles**

The pedestrian controlled electric vehicle was popular for many years as it gave its team of street orderlies a good load capability and a considerably greater range than that of a single orderly with his trolley. Unfortunately the ability of a greater range was a psychological disadvantage to the orderlies having to walk the increased distance with the vehicle. Nevertheless the output per man on P.C.V. teams was frequently shown to be greater than that of single orderlies.

**The Ride-on Electric Vehicle**

To try to eliminate the several disadvantages of the single orderly beats some felt that the solution to the problem was simple. It was to replace the pedestrian controlled vehicle with a 'ride-on' electric vehicle designed to carry the driver, four men and their equipment, eliminating the fatigue aspect, increase the range further and provide additional load capacity. Table 41 gives an indication of the range and performance of the ride-on vehicle and its crew.

This vehicle is extensively used by cleansing departments today. Fitted with a crew cab to accommodate up to five people, most vehicles have a range of 12 to 25 miles and a top speed of about 15 mph. Bodies can be either tipping with sliding side loading covers or platform with removable containers.
The batteries require charging at the end of each day and sub-depots should be employed to ensure that maximum utilisation is made of the vehicle's range each day. Smiths Cabac and Harbilt are the best known manufacturers of electric vehicles in municipal authority use.

Material collected by the electric vehicle should ideally be disposed of in its own depot, unless there is a disposal point adjacent to its area of work.

Removable containers can be emptied into a skip, while tipping vehicles should be able to tip into a properly designed refuse bay or skip recessed into the ground. One manufacturer makes a unit that can tip at a higher level than normal, for instance for use with open skip containers.

The team size depends on the area of work: a team sweeping a busy town centre each day, by necessity working on one side of the road at once would usually comprise a driver and two orderlies, one of whom would sweep the pavement whilst the other sweeps the channel. By comparison, a team working in a residential area covering both sides of the road at once would comprise a driver and four orderlies, two covering one side and two the other.

In most cases it is usual for the driver to pick up the heaps of refuse formed in the channel by the orderlies. He is also responsible for emptying litter bins as he travels along the road. Manual sweeping in conjunction with ride-on electric vehicles will cause a slight delay to heavy traffic in a busy town centre, but careful planning of the sweeping schedules can keep any possible traffic delays to a minimum. Where traffic is both heavy and fast moving then the channels must be swept mechanically.

Small Sweeper Collectors

Some of these machines are promoted as pavement sweepers, and their main virtue was excellent manoeuvrability in confined areas.

Usually purpose built, these machines were normally able to demonstrate excellent sweeping qualities but were not able to maintain them consistently, probably due to over complexity and the inability of authorities to employ competent drivers.

The current machines available are few in number. Most machines employ hydraulically driven channel brushes and vacuum assisted mechanical removal of the sweepers. They demonstrate fine sweeping qualities and it is felt that they should become more popular. They have a particular value where there are access problems in city centres.
Footpath Sweepers

Not strictly sweepers but pure pedestrian controlled suction cleaners, these machines are used by many authorities in the clearance of litter from pedestrianised shopping areas. Normally petrol driven these machines are usually fitted with a detachable canvas bag which can be easily emptied when full. Although earlier machines were pushed along by the operator, current machines are driven.

Vacuum Sweep Teams

A further variation on the team system is for a team of four men to work in conjunction with a large vacuum sweeping machine. The four men work in two teams of two men, sweeping the pavements and forming heaps in the channel where there are no parked vehicles and heaps on the crown of the road where there are. The vacuum sweeper driver then sweeps the roads previously covered by the orderlies, alternating between teams, sweeping the channel where possible and the crown of the road where not.

The system is most effective in roads free of parked vehicles or heavy through traffic. The inevitable delay between the manual sweeping and mechanical picking up sometimes leads to the efforts of the orderlies being eliminated before the vacuum sweeper arrives. A particular problem with the system is that the orderlies are required to report for work 'on site'. Therefore if a team is short-handed there can be a considerable delay before a spare man can be taken out to the team.

Other advantages and disadvantages of the system are very similar to those of the 'Ride on' team. Whole teams and vehicles are less easy to conceal than single orderly trucks, therefore supervision is somewhat easier. Men working together tend to chat. The single orderly does not have the same opportunity. Traffic conditions have little effect on a street orderly truck, but can delay the vacuum sweeper or ride-on electric vehicle.

Sweeping Machines

It is probably significant that the only machines to find lasting favour with most cleansing officers are the heavy duty machines, based on commercial tipping chassis of about seven tonnes G.V.W. There are at least four manufacturers of large suction sweepers in Britain at present and they all incorporate the following principal features:

1. Hydraulically driven channel brush (nearside or offside) and optional wide sweep brush.
2. Vacuum removal of sweepings through a low level nozzle, to a large capacity body.

3. Exhauster fan driven by auxiliary diesel engine through 'V' belts, gearbox or direct coupling.

4. Water spray equipment for spraying channel and inside suction nozzle.

5. Tipping body with hydraulically opening rear door.

THE EXPERIENCE WITH LITTER

Litter is produced by the public in differing quantities although it is noticeable that people involved in pleasure activities tend to produce more litter than people involved with work. A simple assessment on litter and its sources will show that bus tickets are produced at bus stops, newspapers at railway stations, wrappers and cartons are dropped near ice cream stalls, confectionists, tobacconists and 'take-away' food shops. Locations can be further generalised as city centres, open public places (parks), shopping areas, adjoining places of entertainment (including sport), picnic areas, garage and service areas, large car parks, laybys on trunk and main roads.

Although bins should readily be seen and be available for the public they should not spoil the amenities of an area, or cause an obstruction.

The public will tend to be more responsible with their litter if there is a regular pattern of litter bins, therefore if a person is aware that a litter bin is available at every lamp column he is less likely to discard his food carton or bus ticket irresponsibly.

In busy areas it may be seen as advantageous to use the largest capacity litter bin available, however, this is not always the case. Large litter bins tend to attract trade refuse from nearby shops, while small litter bins can often be provided in larger numbers at less cost and therefore be organised in a more effective manner.

Free standing litter bins are not suitable on busy, narrow footways, whilst column bins can be utilised in large quantities without causing an obstruction.

Obviously an important criteria is the frequency of emptying. Column bins in a busy town centre will require emptying several times daily, but as street orderlies will probably be in attendance throughout the day anyway, this is no problem. Regardless of the location of a litter bin, its emptying service must match its capacity. Overflowing litter bins are unsightly, unhealthy and encourage litter on the ground.
Municipal managements will be able to apply the mechanical and manual sweeping systems so far described to their own circumstances. In almost all cases manual systems will predominate using the several prefabricated or purpose built orderly trolleys and brooms that are available. The planning of systems will vary from a totally unstructured distribution of labourers (who may also collect refuse) to more formally planned arrangements. The Singapore Government has developed a system for manual sweeper duties and this is a good guide to what may be used in other cities. Figure 44 illustrates the management structure used to control the service.

**The Singapore System**

The Singapore Government has classified the city (as far as sweeping is concerned) into 4 categories of area. These are:

- Congested areas
- Mixed developments
- Residential and housing estates
- Highways

The system uses the conventional notation of kerb km as a measure of work and because Singapore is located in a moist, heavy rainfall, tropical environment, the system is designed to accommodate tasks that are specific to tropical countries. Stormdrains are a case in point, while in desert locations sand clearance may be an equivalent special factor.
The Gross Work Norms

For each of these areas a gross work norm has been established by the authority. This is expressed in kerb metres in the usual way. These gross work norms are reduced by the introduction of cleansing factors that are designed to take account of the varying work load that the road sweeper will encounter in practical circumstances.

The gross work norms are as follows:-

<table>
<thead>
<tr>
<th>Area</th>
<th>Norm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congested Areas</td>
<td>1980 metres/day</td>
</tr>
<tr>
<td>Mixed Developments</td>
<td>3600 metres/day</td>
</tr>
<tr>
<td>Residential &amp; Housing Estates</td>
<td>4290 metres/day</td>
</tr>
<tr>
<td>Highways</td>
<td>5040 metres/day</td>
</tr>
</tbody>
</table>

The Cleansing Factors

The cleansing factors are set out in three headings. Each heading defines the scope of work to be performed starting with the basic task of road sweeping and then on to encompass other tasks such as cleaning grass verges, traffic islands, pavements and scupper holes and other features.

The factors are defined as:-

Factor 1 - Basic road sweeping activity.

Factor 2 - Drain cleansing, including sweeping of grass verges, traffic islands, pavements and scupper holes.

Factor 3 - Sweeping of back lanes, side lanes, related drains, cycle tracks, pedestrian malls.

The Nett Work Norm

The actual length of beat to be maintained by each labourer is established by the following formula:

\[
\text{Nett Work Norm} = \frac{\text{Gross Work Norm}}{\text{Number of Cleansing Factors Present}}
\]
**Urban Services Directorate**

**Divisional Organisation - Street Sweeping**

<table>
<thead>
<tr>
<th></th>
<th>Head Labourer</th>
<th>Head Labourer</th>
<th>Head Labourer</th>
<th>Head Labourer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 Labourers</td>
<td>20 Labourers</td>
<td>20 Labourers</td>
<td>20 Labourers</td>
</tr>
</tbody>
</table>

**Figure 44**
The following examples illustrate the point:-

Manual Street Sweeping Norms

The following factors and guidelines are adopted for street sweeping beats to determine the operational length of the beat:-

CLASSIFICATION

Street sweeping beats are classified into one of the following categories:-

A) Congested Areas - Busy business areas, Chinatown street hawker congregations.

B) Mixed Developments - Light industrial and residential areas, shopping complexes and commercial shopping roads.

C) Residential & Housing Estates - Residential areas.

D) Highways - Main highways and arterial roads.

Example One

A congested area in Classification A with Factors 1 and 2 cleansing factors present:-

\[
\begin{align*}
\text{Gross Work Norm} & = 1980 \text{ metres} \\
\text{Cleansing Factors present} & = 2 \\
\text{Nett Work Norm} & = \frac{1980}{2} = 990 \text{m of kerb length}
\end{align*}
\]

Example Two

A residential and housing estate area in Classification C with cleansing factors 1, 2 and 3 present.

\[
\begin{align*}
\text{Gross Work Norm} & = 4290 \text{ metres} \\
\text{Cleansing Factors present} & = 3 \\
\text{Nett Work Norm} & = \frac{4290}{3} = 1430 \text{m of kerb length}
\end{align*}
\]
Example Three

A major highway in Classification D with only Factor 1 cleansing factor present:

<table>
<thead>
<tr>
<th>Gross Work Norm</th>
<th>= 5040 metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleansing Factors present</td>
<td>= 1</td>
</tr>
<tr>
<td>Nett Work Norm</td>
<td>= 5040/1 = 5040m of kerb length</td>
</tr>
</tbody>
</table>

Kerb length and Multi-lane Highways

In normal practice the Nett Work Norm expressed in kerb metres will be dealt with in relation to the carriageways of the road concerned. Thus:–

<table>
<thead>
<tr>
<th>Single Carriageway</th>
<th>2 Road Edges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual Carriageway</td>
<td>4 Road Edges</td>
</tr>
</tbody>
</table>

These factors will be used on the Nett Work Norms to establish the actual linear measure of road controlled by each road sweeper.

Car Parks

Some special factors apply in the treatment of car parks where large open spaces and/or converted surfaces may carry a sweeping load out of proportion to that on normal highways. In these cases the following factors apply:–

Each 4m² of car park area = 1 metre of road length

Thus a car park of 100m x 100m = 10,000m²

Equivalent kerb length to be assessed = 2500 metres

Car park sweeping would equate to highway sweeping in Classification A and its Gross Work Norm would equal 5040 metres. Thus the cleansing of such a 100m x 100m car park would be taken to include only Cleansing Factor 1 and hence the Nett Work Norm would be identical at 5040 metres. This will be about 50% of the work of 1 street sweeper.
Practical Management Assessments

These calculations are not to be taken as inviolate commandments. They are testimony to the way in which one progressive and highly organised public authority - The Public Health Department of the Government of Singapore has tackled the problem.

In Singapore both male and female road sweepers are used and it must be said that these performance norms coupled to a highly motivated management go to produce a pristine network of public streets and pedestrian malls. In other countries the calculations may well be different and cleansing managements should carry out their own practical experiments to establish their own norms taking account of their particular circumstances. This text sets out the methods used in one of the cleanest cities in the world. Its example is worth following.

Street Hawkers

In some countries, Malaysia is a case in point, there is a tradition particularly among the Chinese and India population to eat meals and snacks in the open air. A wide variety of exotic and spicy food is sold, meat, pork and fish dishes abound together with sauces of every kind. Fresh vegetables, rice, fruit and vegetables add to the mix and the nett result in waste terms is a cocktail of highly organic and rapidly putrefying waste.

By tradition street hawkers are not the most caring members of the community. Open spaces, vacant lots, shady areas attract them and these places are very popular. They are however a bane to cleansing managements and few in the author's experience would not wish to see the hawking community mysteriously spirited away. Hawkers are careless and untidy and hawking food wastes often are deposited on adjacent open ground and storm ditches and drains. Their control is a serious problem.

The Singapore Government has tried to control the problem by providing set hawkers sites with bulk bins and containers emptied at least daily. In other countries traffic police and 'on the spot' fines may be used to control them. Whatever is attempted, until peoples habits change, cleansing managements in these countries face a very worrisome problem and special arrangements will always have to be made to cope with street hawkers and traders.
Beach and Foreshore Cleaning

In some cities beaches and foreshores are an important part of its recreational tourist resources. Tourism is such an important hard currency earner for many poor countries that they are forced to give a high priority to these somewhat decorative and cosmetic cleansing services.

Beach and foreshores can be cleaned by methods simple or increasingly sophisticated. In the former case a system of beat orderlies with regular rounds allocated to them can be used. The performance limits of each beat will to some extent depend on the extent of public use of a particular beach but in general beat orderly distribution can follow the rules laid down for inshore litter picking duties, a generous supply of litter containers and a publicity programme similar to that described in Section C.4. Pavement mechanical sweepers can be used on sea wall public walkways or other formal walking or congregating areas. It is also useful to provide a light enclosed refuse vehicle of the side loading type. This would be used to collect and dispose of the contents of litter baskets and other waste containers. A low loading trailer pulled by a tractor will help with heavier items of beach debris as well as towing beach pavement sweepers from location to location.

The regular beach beat orderly system, and in one such scheme 6 labourers were provided for a popular 2km of beach and foreshore, may be unable to cope with litter clearing after public holidays and festivals. Contrary to some Western ideas other nationalities including Arabs are very fond of using recreational beaches. After the Arab day of rest, Friday, in the author’s experience it is necessary to provide extraordinary resources to clean up. Some families like to visit beaches in the late of the evening when it is cool, laying carpet on the floor, smoking the hookah, talking and more likely watching a portable television set. Families stay up very late and it is common (at least in the Arab world) to find young children playing at 10 or 11 pm. It is very important to study and appreciate these social habits, they have a fundamental impact on municipal cleansing methods.

For these reasons the beach beat orderlies may need to be reinforced by a mobile cleaning team. This team would have a variety of duties. On off-peak days they would give a regular litter picking service to the less popular and remoter sectors of the public beaches. At other times they would back-up the beach and esplanade beat orderlies as well as supplementing roads and pavements in the immediate beach areas. This team may be called upon to work unusual hours. In one practical exercise a 14km stretch of less used beach and foreshore was capable of being kept clean by a mobile team of 12 labourers.
Analysis of a Major Beach & Foreshore Cleaning Operation

The area to be handled - Central beach area and esplanade - 2km
- Other public beach areas - 14km.

Plant Resources

1 - Specialist beach cleaning machine
1 - Side loading tipper vehicle
1 - Low loading trailer
1 - Pavement mechanical sweeper
6 - Orderly trolleys

Manpower Distribution

6 - Beach & esplanade beat labourers
12 - Mobile cleaning team labourers
19 - Total labourers
3 - Drivers
1 - Supervisor
23 - Overall Total

Where an exceptionally high standard of beach appearance is required there are available a number of specialist beach cleaning machines. The specification for one such is described below and these may be used in very special circumstances. It must however be said that much of this high polish still can be achieved by sweeping, and raking beach sand. The machines however have a much greater productivity and one such unit is probably capable of covering about 25 - 30km length of beach, upto 1.75m wide, in a day. The machines usually operate as mobile sand filters with bottles, cartons and other filtered debris being stored in a .5m³ hopper. It is then obviously necessary to arrange a system to transfer this waste to the city's regular collection system.
B.3

AUXILIARY CLEANSING SERVICES
<table>
<thead>
<tr>
<th>TOPICS - B.3</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Waste Backlog Clearance</td>
<td>118</td>
</tr>
<tr>
<td>2. Public Impact</td>
<td>121</td>
</tr>
<tr>
<td>3. The Regulated Ground Transfer Point</td>
<td>121</td>
</tr>
<tr>
<td>4. Emergency Cleaning Programmes</td>
<td>124</td>
</tr>
<tr>
<td>5. Undeveloped Land Clearance &amp; Levelling</td>
<td>128</td>
</tr>
<tr>
<td>6. Storm Drain Cleaning</td>
<td>130</td>
</tr>
<tr>
<td>7. Collection &amp; Disposal of Abandoned Cars</td>
<td>132</td>
</tr>
</tbody>
</table>
Waste Backlog Clearances

In some situations before regular containerised refuse collection and street sweeping services can be instituted it will be necessary to deal with accumulated backlogs of refuse, builders debris, vegetable waste, abandoned cars and mechanical goods. Apart from the obvious health hazards these wastes obstruct public squares, streets and alleyways. It is also common to find blocked drains and storm ditches. They must be cleared before a regular service can be instituted. Any waste management plan must take account of this need and understandably the equipment required for solid waste backlog clearance - usually tipper vehicles served by mechanical shovels are not those you would use for the collection of day to day arisings. In some desert locations hard packed wind-blown sand accumulates at kerb edges and can extend to one to two metres or so into the roadway. If it has been there for some time it acquires the mechanical strength of brickwork and cannot be swept. This is particularly noticeable in streets with teashops, cafes and general small businesses. Slops and waste water thrown on to the street bind the sand accumulations into a very obstructive mixture. The breaking out and removal of these wastes requires pick and shovel work by manual gangs or fairly intensive skimming of the road service by mechanical shovels.

In the city of Jeddah in 1981, my Company managed an intensive backlog clearance programme in some sectors of the city. It was possible to observe the performance of manual and mechanical plant gangs. These works were supervised by an experienced European expatriate manager and the following performance figures may be taken as a good guide. See Figure 45.

Manual Clearance of Kerbside Waste

A series of observed tests in this city showed that a labour gang equipped with hand shovels, brushes and wheelbarrows cleared both sides of a 100 metre length of road with a mean 2 metre band of accumulated sand and rubble in 7 hours. Allowing for rest, meal and travelling time this may be taken as evidence of good performance. The manpower resources were:

1 Foreman
10 Labourers

The waste accumulation was removed by mechanical shovel and tipper and deposited on adjacent desert. Up to 60m$^3$ of sand and rubble was moved in this exercise.
FIGURE 45

CITY OF JEDDAH BACKLOG CLEARANCE STREET SIDE WASTE

MANUAL AND MECHANICAL METHODS

<table>
<thead>
<tr>
<th>Method</th>
<th>Supervision</th>
<th>Labour</th>
<th>Drivers</th>
<th>Vehicles Tippers</th>
<th>Plant Shovel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>1</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>nil</td>
</tr>
<tr>
<td>Mechanical</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Length Cleared</th>
<th>Mean Width</th>
<th>Mean Area Cleared</th>
<th>Mean Volume Taken</th>
<th>Time</th>
<th>Productivity Volume/M. Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>100m</td>
<td>2m</td>
<td>200m²</td>
<td>60m³</td>
<td>7hrs</td>
<td>5m³</td>
</tr>
<tr>
<td>Mechanical</td>
<td>100m</td>
<td>2m</td>
<td>200m²</td>
<td>60m³</td>
<td>1.5hrs</td>
<td>30m³</td>
</tr>
</tbody>
</table>

Source: Jeddah Project Team - June 1981
Mechanical Clearance of Kerbside Waste

A similar 100 metre length of road with a 2 metre band of accumulated waste and debris against each kerb was cleared in 1.5 hours with a mechanical loading shovel. The mechanical shovel technique was to skim the kerb edge and road surface and pile the waste for loading on to tipper vehicles. There is of course a striking difference in performance, but practical experience showed that it was sometimes necessary to put a 'polish' on the work with a final hand broom sweep. Working on a density of 1200kg/m³ the estimated 60m³ of compacted sand and rubble weighed 72 tonnes and required 14 tipper vehicle loads.

Mechanical Clearance of Refuse Heaps

As part of the same programme, observations were made of the performance of mechanical shovel and tipper teams employed on specific clearance of accumulated refuse heaps as distinct from extended kerbside accumulations of waste and sand. A very common sight in many cities these heaps have a number of origins. They may have occurred by specific illicit deposit of waste or grown up from long history of use by local inhabitants and shops. Unsightly as they are, as long as the refuse accumulations are removed regularly they seem at least to restrict pollution to a smaller number of treatable locations. Waste managers must be careful that before such less than satisfactory practices are discarded they must be sure that their chosen alternative will really work. If this is a container system then its volume and rate of emptying must at least match the refuse input to the pile it replaces. In working on the clearance of such refuse heaps with 1 mechanical shovel fitted with a 3m³ or 6m³ bucket the following performances were noted:

Max tipper performance (12m³) - 5 trips @ 4 tonne/trip = 20 tonnes
Mean tipper performance (12m³) - 4 trips @ 4 tonne/trip = 16 tonnes

Loading times were found to be:

3m³ bucket = 10 - 12 minutes
6m³ bucket = 5 minutes

In this particular exercise the landfill site was a 20km round trip with a round trip time of at least 1 hour. In such an
operation 1 mechanical shovel with a reasonable intensity of refuse accumulations will service 8 - 10 tipper vehicles.

Public Impact

These seemingly primitive systems can do more to impress public opinion than many more sophisticated ideas. A tipper and shovel team so described will be able to remove 160 to 200 tonnes of refuse each day. This, at densities of say 250kg/m\(^3\) would equate to 640 to 800m\(^3\) of refuse. The following table taking a per capita waste-generation rate of 1kg/person/day (as an example) indicates the population that might feed such a dump over various periods of time.

<table>
<thead>
<tr>
<th>Accumulation Period</th>
<th>Population Served</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>160 - 200,000</td>
</tr>
<tr>
<td>1 week</td>
<td>23 - 29,000</td>
</tr>
<tr>
<td>1 month</td>
<td>5 - 7,000</td>
</tr>
<tr>
<td>6 months</td>
<td>900 - 1,000</td>
</tr>
</tbody>
</table>

This shows quite clearly the impact of such a first aid remedial service to the community. In some parts of Africa for instance the problem might not necessarily be that of refuse. Maize husks and coconut shells, for instance, can cause immense problems to the sanitary authorities at particular times.

The Regulated Ground Transfer Point

Making the best of a bad job, ground dumping and secondary transfer of refuse may be all that is possible. Shortage of money, a primitive organisation or occasionally a very rapid rate of urban growth may dictate this as the next improvement step. Short term population groups of tribesmen, pilgrims or refugees may require collection and disposal solutions based on collection labourers, wheelbarrows and a series of ground transfer points. See Table 46.

Even if these cannot be constructed as concrete housings or hard standing deposit areas a considerable degree of order and method can be instituted with simple earthworks and banks. In the author's experience one successful example of ground transfer point consisted of a shallow depression with a gentle slope and a 1 metre high wind break of piled sand or soil for
an arc of say 240°. The centre of the wind break facing into the general direction of the prevailing winds. Looked at in plan the transfer point would be roughly circular and up to 50m in diameter. Such a construction might be able to contain 1000m³ of refuse equivalent to say 250 tonnes at 250kg/m³ density. If emptied say 2 times per week it would handle the daily arisings of say 36,000 people or 7000 premises @ 5 person per premise. In these circumstances a mechanical shovel and tipper team could work several such ground transfer points on a rota basis. One team of mechanical shovel and 8 tipper vehicles would be able to give a 2 per week clearing service to two such ground transfer points each day or 12 on a 6 day week. Albeit in a somewhat rough and ready way a basic service of sorts would be provided and for many situations in developing countries this would be much better than nothing. A judicious selection of ground transfer site at reasonable distance from housing and the minimum of visual intrusion would complete the picture. This system could well be used as an interim solution while refuse vehicles, containers and transfer station investments are being developed.
SPECIMEN

COLLECTION LABOURER PERFORMANCE ANALYSIS
GROUND TRANSFER POINT & TIPPER VEHICLES TO LANDFILL

<table>
<thead>
<tr>
<th>1. Initial Collection</th>
<th>Transfer Point Visits</th>
<th>- 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean load per visit</td>
<td>- 90kg</td>
</tr>
<tr>
<td></td>
<td>Total load per day</td>
<td>- 360kg</td>
</tr>
<tr>
<td></td>
<td>Mean pick-ups labourer/day</td>
<td>- 100</td>
</tr>
<tr>
<td></td>
<td>Mean weight per pick-up</td>
<td>- 3.6kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Secondary Transfer to Vehicle</th>
<th>Vehicle capacity Hino tipper</th>
<th>- 7m³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean refuse density</td>
<td>- 250kg/m³</td>
</tr>
<tr>
<td></td>
<td>Mean payload</td>
<td>- 1.7t</td>
</tr>
<tr>
<td></td>
<td>Labourer loads per vehicle</td>
<td>- 20</td>
</tr>
<tr>
<td></td>
<td>Labourers serving vehicle/load</td>
<td>- 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Tipper Vehicle Performance</th>
<th>Vehicle trips per day</th>
<th>- 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vehicle payload per day</td>
<td>- 6.8t</td>
</tr>
<tr>
<td></td>
<td>Labourer loads per day</td>
<td>- 80</td>
</tr>
<tr>
<td></td>
<td>Labourers serving vehicles</td>
<td>- 20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Overall Operational Dynamics</th>
<th>Pick-ups served (total)</th>
<th>- 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pop. served @ 3 persons/house</td>
<td>- 6000</td>
</tr>
<tr>
<td></td>
<td>Pop. served @ 4.5 persons/hse</td>
<td>- 9000</td>
</tr>
</tbody>
</table>

Note: The same methods may be used to establish the overall operational dynamics of any of the other system variations detailed in this text.
Emergency Cleaning Programmes

An Emergency Cleaning Programme for a 1,000,000 population city might be devised as a prelude to the introduction of a more structured service or while a capital programme is under way. Its basic justification would be backlog clearance so that the start of permanent operations would deal only with daily arisings.

In the case in question the refuse generation rate of the city produced over 1000 tonnes of refuse each day which the Municipality's collection vehicle and transfer resources were capable of handling 650 tonnes per day. The balance of 350 tonnes less some refuse dealt with by individuals added to the accumulating backlog. Persistant low mechanical availability of vehicles (less than 80%) was the basic cause of the problem. Ineffective workshops, spare parts, holdings and administration was also part of the equation.

The backlog spilt over into the streets, squares, undeveloped land and the open countryside. To deal with this problem the following objectives were set:

1. Clearance of refuse stockpiles from open land.
2. Clearance of waste from all main road verges.
3. Clearance of waste from beaches and foreshores.
4. Clearance of waste in the vicinity of hospitals and schools.
5. Control of refuse debris stockpiles in development areas.
6. Clearance of waste from public buildings, squares and commercial areas.
7. Progressive emergency clearance of waste from residential areas.

It is essential that an emergency cleaning programme of this nature operates without placing further demands on the existing cleansing resources by withdrawing hard pressed vehicles and labour trying to cope with daily arisings. Because of this a special task force was provided. This consisted of mechanical loading shovels and tipper vehicles with the minimum use of labour. Mechanical shovels and tippers are commonly in use throughout the world, they are usually readily available and easily operated by local labour with a minimum of training. Shovel and tipper teams can be formed into task forces (on say a 1 shovel to 8 tipper basis) and allocated specific target areas.
It is useful to make up an emergency cleaning operating plan taking a large scale map of the city concerned. A 2 man survey team working for say 2 weeks would be able to identify the prime areas for attack and set out fairly balanced target areas. Areas requiring special attention might include large markets, beach and foreshore developments, pilgrim or refugee camps. It is important to keep one's client informed of the plan and submit weekly reports of areas cleared, tonnage moved and resources deployed. Before and after photographs are also a valuable record. If nothing else they can protect the cleansing management from unfair criticism. It is a fact that public expectations always step in front of whatever is achieved. While people might have walked happily passed a dead donkey or pile of stinking refuse before the emergency programme they will complain vociferously about a few pieces of wind blown litter after it. Cleaning waste near the Mayors house will always be more important than waste around the local hospital and sometimes it will be difficult to resist such disruptive pressures. So the programme requires sensitive management and it is wise to appoint a strong manager to co-ordinate the whole exercise.

Operational Factors

While mechanical shovel and tipper task forces from the main thrust of the operation it may be necessary to provide one or two bulldozers, and pick-up vehicles and the usual range of miscellaneous hand tools. What to do with the waste collected is another problem. Sanitary landfill sites will certainly not exist, what passes for them, the tip and burn open dumps may be inadequate, have poor road access or present other problems. All this leads to the point when it will be necessary to establish a new landfill or at the very best a controlled and visually discreet dumping area outside the city. If it is possible to segregate refuse from building debris the latter may be useful if a land reclamation scheme is under way. An active emergency cleaning programme will generate enormous tonnage of waste. A single shovel and tipper task force \((1 + 8)\) could clear \(800\, \text{m}^3\) of mixed refuse and debris, and it is easy to see that 4 or 8 of such teams would generate up to \(3200-6400\, \text{m}^3\) of waste. These waste quantities are sufficient to justify a fairly important landfill operation.

All the usual management guidelines for control of labour and plant still apply. The establishment of a proper marshalling area, clear instructions detailing where labour collect and dispose before and after each days work. To maintain productivity, first time line supervisors must be active and mobile. Simple administrative systems can be instituted to keep track of vehicle trips and loads collected, task force team performance, labour attendance and like matters. These are referred to in other parts of the text.
While all this work proceeds, these are but tactical measures and essentially a first aid operation. The institution of a structured collection and disposal service must follow together with substantially improved mechanical efficiency and statutory instruments designed to establish some basic public cleansing laws and restrictions on indiscriminate dumping of waste. Investment policies will vary. In some cases one's client may be able to buy the equipment needed, or it may be hired or diverted from other project work. The duration of the programme will depend on the extent of past neglect and the corresponding backlog tonnages. Cost and time scale of clearance are product variables of the same equation. An excessively rapid rate of clearance might distort capital and revenue programmes beyond acceptable limits. In two particular studies carried out on a 1,000,000 population city a distinction was made between backlog refuse and builders debris on undeveloped land. While the former was capable of substantial cure within a 1 year programme, the latter was estimated to take up to 5 years. Defining what is meant by waste is of cardinal importance.

Format of Emergency Cleaning Programme

<table>
<thead>
<tr>
<th>City Population</th>
<th>- 1,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Generation Rate</td>
<td>- 1,000 t/day</td>
</tr>
<tr>
<td>Municipal Resources Capability</td>
<td>- 650 t/day</td>
</tr>
<tr>
<td>Backlog Addition Daily</td>
<td>- 350 t/day</td>
</tr>
<tr>
<td>Assumed Period of Neglect</td>
<td>- 5 years</td>
</tr>
<tr>
<td>Backlog Accumulation/Year</td>
<td>- 127,750t</td>
</tr>
<tr>
<td>Backlog Accumulation/5 years</td>
<td>- 638,750t</td>
</tr>
<tr>
<td>Area Action Teams</td>
<td>- 10</td>
</tr>
</tbody>
</table>

Team Composition

| Mechanical Shovels | - 1 |
| Tipper Vehicles | - 8 |
| Labour Force | - 24 |
| Each Team Productivity per day | - 200t |
| Total Task Force Productivity per day | - 2000t |
| Task Force Productivity per week | - 12,000t |
| Task Force Productivity per year | - 600,000t |
| Backlog Clearance Time | - 1 year |
Equipment Schedule

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulldozers</td>
<td>2</td>
</tr>
<tr>
<td>Wheeled Loaders</td>
<td>10</td>
</tr>
<tr>
<td>Tipper Vehicles</td>
<td>56</td>
</tr>
<tr>
<td>Pick-up Vehicles</td>
<td>12</td>
</tr>
</tbody>
</table>

Labour Force

<table>
<thead>
<tr>
<th>Position</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Drivers</td>
<td>56</td>
</tr>
<tr>
<td>Plant Operators</td>
<td>16</td>
</tr>
<tr>
<td>Labourers</td>
<td>160</td>
</tr>
<tr>
<td>Operations Supervisors</td>
<td>10</td>
</tr>
<tr>
<td>Plant Fitters</td>
<td>5</td>
</tr>
<tr>
<td>Vehicle Fitters</td>
<td>6</td>
</tr>
</tbody>
</table>

Capital Investments

<table>
<thead>
<tr>
<th>Position</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant</td>
<td>750,000</td>
</tr>
<tr>
<td>Vehicles</td>
<td>1,600,000</td>
</tr>
<tr>
<td>Miscellaneous Stores</td>
<td>10,000</td>
</tr>
<tr>
<td>Spare Parts Provision</td>
<td>350,000</td>
</tr>
<tr>
<td></td>
<td>£2,710,000 *</td>
</tr>
</tbody>
</table>

Operating Costs

<table>
<thead>
<tr>
<th>Position</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle &amp; Plant Maintenance</td>
<td>47,000</td>
</tr>
<tr>
<td>Maintenance Staff Wages</td>
<td>38,000</td>
</tr>
<tr>
<td>Operations Staff Wages &amp; Salaries</td>
<td>640,000</td>
</tr>
<tr>
<td></td>
<td>£725,000 *</td>
</tr>
</tbody>
</table>

Note: 1982 Money Values
Undeveloped Land Clearance and Levelling

An optional cleansing service albeit one which can only be offered to the richest cities is that of clearing undeveloped land on the perimeters of a city. A distinction is made here between refuse and general construction debris and this latter is taken as the prime objective. The richer Middle East cities commonly present such problems and several have the immense problem of builders debris and discarded construction materials scattered over wide areas of undeveloped land.

Estimation of the size of the task can be very difficult. City boundaries are often undefined establishing cut off points and limits of responsibility are not easy and one should be extremely careful (particularly in commercial operations) in giving binding commitments against specific timescales. Some reasonable estimation techniques can be used and will include mapping of the worst areas and specimen 'head counts' of debris accumulations per hectare in several chosen types of land. Aerial photography is ideal but this may not always be affordable. A particular caution in ground based visual surveying is a known tendency to over estimate tonnages. Fly tippers and illicit dumpers tend to deposit waste close to roadways and this leads to give an erroneous view of the intensity of such deposits.

These task forces have a somewhat different construction from those employed on refuse backlog removal. In this type of operation the equipment would consist of bulldozers, wheeled or tracked loading shovels, vibrating rollers and, of course, the ubiquitous tipper vehicle. A task force for a serious debris clearance problem would consist of:–

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caterpillar Type D6 Bulldozer</td>
<td>1</td>
</tr>
<tr>
<td>Caterpillar Type 95 Crawler Loader</td>
<td>1</td>
</tr>
<tr>
<td>Towed Vibrating Roller</td>
<td>1</td>
</tr>
<tr>
<td>Tipper Vehicles 11m³</td>
<td>7</td>
</tr>
<tr>
<td>Tipper Vehicles 14m³</td>
<td>6</td>
</tr>
<tr>
<td>Driver/Plant Operators</td>
<td>14</td>
</tr>
<tr>
<td>Labourers</td>
<td>10</td>
</tr>
</tbody>
</table>

This team using a mixed technique of waste scraping, piling and loading would be able to remove over 300 tonnes of debris each day. In a very large city particularly in the circumstances of one of the prosperous Middle East OPEC countries 3 to 4 of such task forces may be necessary for at least 2 - 7 years.
Storm Drain Cleaning

In high rainfall tropical cities it will be necessary to institute a regular drain cleaning programme to remove accumulations of soil, silt, and refuse. As usual these may be badly neglected. In one or two bad instances in the author's experience the storm drains had not been cleared since initial construction and in drains 1 metre deep accumulated silt and debris rose to a height of 0.9m.

The institution of a drain cleaning programme requires some careful thought. An over enthusiastic programme may indeed increase the risk of flooding. This can happen where extensive up-stream clearances rapidly increase storm water flow to non-existent down-stream drainage points. On bigger jobs it would be wise for the solid waste sanitation team to seek professional guidance on the hydraulics of the system they propose to clean. Some form of plan should be constructed and a programme of work set out so as to avoid catastrophe. Timing is of course important and the work should be phased to be completed before the next rainy season.

Public relations are important and many of the principles set out in Section C.4 are relevant in this work. Public co-operation should be sought so that market stalls, parked cars and temporary dwellings can be removed from above the drains. The system of drain cleaning described here is one that may be used by a large city with limited access to sophisticated machinery and plant.

Preparatory Works

A labour gang should first enter the area to be cleared to prepare the ground for the main cleaning work. Their main tasks will be:

- Clear debris from around the drains.
- Remove abandoned and derelict cars.
- Clear other obstacles from the route of the drains.
- Sweep the streets and loosen the drain gratings.

Main Cleaning Tasks

The drain cleaning team will now enter the area. While local operational circumstances will dictate how the team will work, the following guidelines worked well in a similar operation in Lagos.
Remove drain gratings and covers for say 50m. Move parked cars, market stalls and other obstructions. Clear the drain section using the following methods:-

1. Mechanical wheeled shovel or back-excavator.
2. Using water jetting.
4. Some combination of the above methods.

The Plant Team

If the problem is of sufficient magnitude or if the Metropolitan authority has the resources and organisation to apply such equipment, a selection of mechanical plant may be used to polish and refine the earlier work. The various mobile gully emptying vehicles, or industrial suction tankers may be used to clear drains containing sludge or silt and water mixtures. Alternatively it may be possible to use tipper vehicles fed by portable water pumps.

Reinstatement Team

To keep the productivity of the cleaning teams to a high level it is sometimes desirable to delegate reinstatement work to a separate team. Their tasks will be:-

Replace drain gratings.
Sweep roads and adjoining areas.
Rod the drain holes from the roadside kerb to the drain.
Erect 'No Parking' signs, fencing or other barriers to prevent future illicit encroachments over the drains.

Remedial Works Team

The various cleaning operations will have revealed the need to repair, re-route and do various maintenance tasks on the system. This may be a considerable task and the following are the duties found to have been necessary in practical operations in Lagos:
1. Assess and measure the scale of works.
2. Repair drains and roads damaged by the cleaning teams.
3. Replace damaged drain gratings.
5. Construct mesh filters at strategic points.

**On-going Maintenance**

Once the main drainage channels and feeder drains have been cleared it will be necessary to devise a regular maintenance schedule. The timing and frequency of this will depend on local climate, rainfall and nature of the soil. Some areas of the system will be much more prone to blockage. These have been found to be:

- Walkways crossing main channels.
- Road junctions and crossroads.
- Changes in drainage direction.
- Entrances to underground channels.

From considerable experience in Lagos the following structures have been devised.

**Collection and Disposal of Abandoned Cars**

Abandoned cars are a symptom of affluence and cleansing managers must be aware of the problem. In the OPEC oil states in the Middle East abandoned cars arise from great prosperity and the low incentive this gives for repair and refurbishment. In Nigeria, as an example, the economy received a massive boost from the increase in oil prices in 1973. One result of this was a significant increase in the number of vehicles on the road.

In Lagos, as an example, records show that some 20,000 cars were scrapped in 1980 with estimates indicating increase to over 40,000 in the late 1980’s. The life of a car is relatively short as a result of climatic conditions, sub-standard driving, poor roads and vehicle maintenance. Individuals accept little responsibility for disposing of abandoned vehicles and so they are abandoned where they break down. Occasionally they are sold to roadside mechanics who strip them of all salvable elements and then dump the carcass that remains onto the highway or adjacent storm drains.
In October 1979 the Lagos State Waste Disposal Board instituted a system to collect and dispose of all the abandoned vehicles that littered Metropolitan Lagos. The following notes illustrate the system used. It is not exclusive. Readers are encouraged to refer to the book Work from Waste* by Jon Vogler, late of OXFAM. In this Vogler describes the ingenuity and enterprise that can be applied to collecting, stripping down and recovering valuable and usable materials from abandoned cars. Vogler goes on to show the variety of secondary fabrics and materials that may emerge from a sensitive use of old cars.

**Typical Car Crushing Team**

<table>
<thead>
<tr>
<th>Position</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreman</td>
<td>2</td>
</tr>
<tr>
<td>Crane Operator</td>
<td>1</td>
</tr>
<tr>
<td>Forklift Operator</td>
<td>1</td>
</tr>
<tr>
<td>Welder/Crusher Operator</td>
<td>2</td>
</tr>
<tr>
<td>Hiab Tipper Operators</td>
<td>4</td>
</tr>
<tr>
<td>Warden</td>
<td>1</td>
</tr>
<tr>
<td>Labourers</td>
<td>5</td>
</tr>
<tr>
<td>Night Watchman</td>
<td>1</td>
</tr>
<tr>
<td>Day Watchman</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td><strong>19</strong></td>
</tr>
</tbody>
</table>

**Resources**

To start the operation the Lagos State Waste Disposal Board employed a staff of 19 with a fleet that included:-

1 - Crane
1 - Forklift Truck
1 - 'Big Mac' Auto Crusher
4 - Long Wheel Base Tippers with Hiab Cranes

**Collection**

The area to be cleared is first visited by a warden who records details of all vehicles that appear to be abandoned. A notice is attached to the vehicle stating that unless it is removed within a period of seven days it will be removed by the Board. On the expiry of the notice the warden revisits the area with the collection team and clears any vehicles that have not been removed by their owners. Greatest impact is seen in an area when the Hiabs are concentrated in a 'blanket type' operation. The main roads surrounding a particular area are dealt with first and following this all side roads are cleared.
Storage & Treatment

The cars are then taken to the main storage yard where the petrol tanks are drained and wheels, doors, windscreen and any other useful parts are salvaged. The remains of the vehicle are then fed into the crusher where four cars can be compressed to the size of one. They are later removed and stacked using the forklift truck and the crane.

Performance

The crusher can handle over sixty wrecks per day if preparation work is efficiently set up, and each collection crew is expected to collect a minimum of eight vehicles per day although this figure can vary tremendously with local circumstances and traffic conditions.

Research

Several universities have researched the economics of abandoned car retrieval in developing countries. Among these is the work of the University of Nottingham’s Department of Metallurgy and Materials Science. Dr Michael Henstock has been actively concerned in this and wider recycling issues. Jon Vogler, mentioned earlier in this text, is another prominent consultant in this field. He is the author of Muck & Brass published by the Oxfam Public Affairs Unit and has contributed to Managing Solid Wastes in Developing Countries published by John Wiley & Sons Ltd.
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B. 4

WASTE DISPOSAL POLICIES

AND

WASTE RECLAMATION
<table>
<thead>
<tr>
<th>TOPICS</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A Review of Western Disposal Philosophies</td>
<td>137</td>
</tr>
<tr>
<td>2. The Broad Alternatives in Disposal</td>
<td>137</td>
</tr>
<tr>
<td>3. The Size of the Problem</td>
<td>138</td>
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A REVIEW OF WESTERN DISPOSAL PHILOSOPHIES AND THEIR RELEVANCE TO DEVELOPING COUNTRIES

The Environmental Pressures

With the current world interest in environmental matters, waste collection, disposal and reclamation, it is necessary for environmentalists and cleansing managements in the developing countries to understand how the public authorities in the West see their duties and to appreciate the economic and management realities that force them to one course or another. Too many committed people in the waste disposal industry in the West and, for that matter, the waste disposal authorities, appear to hold philistine and insensitive views towards recycling and other up-market disposal solutions. Before they are held to account for these real or imaginary failings, it is important to understand their point of view.

Faced with pressures from the general public and elected councillors, bombarded by the process industry with a plethora of schemes capable of separating and converting waste into various forms, yet constrained to operate a vital public service in an efficient and economic way, the operational decisions are not easily made and this chapter sets out to show the policies and attitudes held by the majority of public and private sector waste managers performing a vital public service against a background of limited financial resources.

While the solutions selected and the finances applied may be very different, the developing countries can learn much from an understanding of these decision-making processes however imperfect they may be. This chapter, as often in this thesis, focuses on the Western problem and shows how it applies to thinking in the developing world.

The Broad Alternatives in Disposal

All methods of waste disposal are, in the final analysis, landfill, and the choice rests in selecting the level of capital investment, operating costs and environmental impact of the various options available to waste disposal authorities and the private sector of the industry. These options cover a spectrum that ranges from simple sanitary landfill of untreated domestic and commercial wastes through various transfer station and bulk haul alternatives to remote landfill sites. Following these come the higher cost alternatives of composting and incineration. On the fringes of these main stream options are the bold and innovative processes of reclamation. Several plants are now operating in the United Kingdom, these include the DoE sponsored installations at Doncaster and Byker in the United Kingdom, and the private sector developments of Blue
Circle Industries at Westbury where pulverised refuse is used as a substitute fuel in the cement industry. Other private sector plants experiment with waste derived fuels in other forms.

Even the new generation of experimental waste reclamation processes still discharge significant tonnages of residue, and these are landfilled. As far as industrial liquids and sludges are concerned much the same range of alternatives exists with an overwhelming bias towards landfill. This, as we all know, occurs in mixtures with domestic and commercial wastes and occasionally in the deep mine shafts and mineral workings as well as some specialised sea disposal.

In the main most of these alternatives require land for their residues, and in general operational costs and capital investments are inversely proportional to the land or volume consumed by the system. These truths apply to the developing as well as the developed world.

The Size of the Problem

The United Kingdom as an example annually generates about 18 million tonnes of domestic and commercial wastes, and at least 20 million tonnes of industrial waste including about 3 million tonnes of building debris. Only a small proportion of industrial wastes are toxic and for these wastes chemical neutralisation, incineration or carefully controlled landfill are the only safe answers. The treated residues are inert and suitable for landfill. In addition, there are about 10 million tonnes of power station waste, 60 million tonnes of colliery spoil and about 20 million tonnes of quarrying waste. Most of these vast quantities of waste are inert and disposal by any means other than return to the land is impractical. Indeed, these wastes are often useful reclamation agents and, if sensitively and skilfully used, can serve a valuable purpose in the recovery of derelict and low-lying land.

While the ratios of municipal, commercial and industrial wastes will be different in say Nigeria or Saudi Arabia the philosophy still holds true. Where capital treatment plants are desired, waste managers have a duty to remind decision makers that refuse is only a part of the problem and like it or not the vaster quantities of other waste cannot escape landfill. In the author’s experience, developing countries have a good record in land reclamation and one has only to see the imaginative Corniche project in Jeddah in Saudi Arabia to appreciate what is possible with good management.
The United States Environmental Protection Agency in its comprehensive reports* to the United States Congress has attributed the limited response to the use of recycled materials to the following primary causes:-

1. Natural resources occur in concentrated form whereas recycled secondary materials from waste are dispersed and have attendant high collection cost.

2. Virgin materials, even unprocessed, tend to be more homogenous in composition than wastes, are of higher quality and are less contaminated. Product quality and specifications are thus easier to control.

3. The principal process technologies are designed to use virgin materials, while waste processing requires different attitudes and technology.

4. The use of synthetic material in combination with natural resources makes economic sorting difficult.

A later report went on to say:--*

5. The use of recycled materials appears to result in a reduction of energy consumption and pollution compared with the use of virgin materials.

6. The recovery of materials from wastes is very dependent on economic factors. Manufacturing costs from secondary materials are as high or often higher than those for the use of virgin materials. Consequently only high quality material can find a ready market and, often, artificial economic factors favour the use of virgin materials.

7. While technology exists to separate useful materials from municipal refuse, recovery costs are high and recovery is feasible only in areas where circumstances force a high costs disposal pattern combined with suitable local markets.

SOURCE:--


The Imperial Metal Industries project, City of Birmingham

Sketch illustrates injection of pulverised and screened refuse into coal fired chain grate stokers in the U.K.

(Courtesy: IMI Ltd.)
RECOVERY TECHNIQUES

Recovery of useful materials in refuse can occur at the
collection or at the disposal point of the wastes in question.

Collection point recovery, usually of paper but occasionally of
other materials, is, with the exception of occasional
operations by charitable groups, the responsibility of the
refuse collection authority in any country. Materials are
separated at source and collected separately by refuse vehicle
trailers or separate vehicles. Transport and collection costs
are significant factors in the economics of these schemes and
experience has shown that the long-term public response is no
higher than about 1:3.

Disposal point recovery can occur both on direct sanitary
landfill sites and at mechanical treatment plants such as
incinerators, pulverisers, transfer stations and composting
plants. In modern direct incineration plants, materials
recovery is usually confined to ferrous metals extraction from
the incinerated residues but in composting plants and other
treatment techniques this extraction takes place prior to
treatment. Many of the early generation of cell type
incinerators had extensive manual and mechanical 'front end'
separation of metals, glass and textiles.

METHODS OF RECOVERY

1. Collection Point Separation and Recovery:
   (a) Local authorities' refuse collection service;
   (b) Private charities and entrepreneurs.

2. Disposal Point Techniques:
   (a) Energy recovery;
   (b) Materials recovery;
   (c) Pyrolysis process;
   (d) Compost processes;
   (e) Chemical processes.
THE POTENTIAL IN REFUSE

A typical analysis of municipal waste in the United Kingdom shows a composition by weight of:

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust and cinder</td>
<td>22.9%</td>
</tr>
<tr>
<td>Large cinders</td>
<td>4.5%</td>
</tr>
<tr>
<td>Paper</td>
<td>32.5%</td>
</tr>
<tr>
<td>Vegetable matter</td>
<td>19.3%</td>
</tr>
<tr>
<td>Metals</td>
<td>7.1%</td>
</tr>
<tr>
<td>Glass</td>
<td>7.9%</td>
</tr>
<tr>
<td>Rags</td>
<td>2.2%</td>
</tr>
<tr>
<td>Plastics</td>
<td>1.0%</td>
</tr>
<tr>
<td>Unclassified debris</td>
<td>2.6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

The key issue here is that a waste reclamation project must be tailored to the waste in question. A plant designed for a town in the North of England may not work as well in the South. The same applies from country to country. It is not possible to transfer Western technology wholesale without regards to local wastes, markets and levels of operating skill.

This waste, in the United Kingdom, as an example, is generated at a rate of about 0.33 tonne/person per year or 12.6kg/household per week. Its density, currently at about 150kg/m³ (when tipped), is falling while volume is increasing. The combination of these two factors gives a gradual increase in weight generated per person of about 1% per year. Even a superficial study of the composition of the waste shows that it contains a number of things which can usefully be recycled or, through thermal processes, provide heat energy for industrial, commercial and domestic uses. Again, pioneering processes have been developed by which fuel oil, gas and combustible char can be produced by the pyrolysis of refuse and other wastes. Even more advanced fundamental research has been carried out to produce protein and ethyl alcohol by the hydrolysis of domestic refuse. Many of these research projects are the realities of the future but they point the way to an exciting new concept in conserving the raw materials we use. However, with some sources it must be said that these processes do not as yet present realistic options to the overwhelming majority of the developing world.
LIMITED PUBLIC RESPONSES

The limited long-term public response rate to separation and salvage at the collection point has caused a number of research and development authorities to reconsider separation and sorting of municipal waste at the point of disposal. This discarded idea, given new impetus of advances in materials handling technology, is again coming into favour. Pioneer research work at the Warren Spring Laboratory at Stevenage and in the U.S.A. has produced pilot plants designed to use the physical properties of the constituents in waste - density, size, mass, shape and colour to achieve separation by flotation, centrifugal and ballistic methods. These developments, operating together with collection point recovery of appropriate materials and the ultimate disposal of only the useless elements of waste, may be the way to effect practical and economic recovery by municipal authorities.

In considering these new techniques it should be remembered that, in most cases, a waste reclamation plant will not pay its own way in conventional income and expenditure terms. Such plants, as now operate, are designed to perform a waste disposal function and operate as reclamation units to economise on their operational costs. In every case a contribution towards the treatment cost is called for by the waste-producing or disposing authority.

In the United Kingdom these ideas have reached fruition in the two DoE aided projects in Tyne & Wear and South Yorkshire County Councils. The former aiming primarily at waste derived fuels and ferrous metals while the South Yorkshire plant develops more fully the separation techniques of the Warren Spring Laboratory.

Biogas Systems

Later text on Sanitary Landfill Operations (B5) makes mention of the hazards to be met and the benefits that may accrue from the phenomena of landfill gas generation on large landfill sites. In Malaysia, as an example, a West German company developed a proposal for the extraction and use of landfill gas from a large deep landfill site in the Kuala Lumpur Metropolitan area. Several successful operations now exist in the United Kingdom, the United States and West Germany. This idea, with its relatively low technology, may present a valid waste reclamation energy recovery option for large metropolitan areas in developing countries.

At the other end of the spectrum, ideas have been developed for small scale rural and semi-rural biogas reactors that combine a waste disposal facility with an energy source. As with so many good ideas of this type there is still considerable work to be done to bring well researched ideas to practical day-to-day
realities of real benefit to a community. Nonetheless research goes forward and the Technical University of Berlin hosted in 1981 a seminar dealing with Waste Reclamation in Developing Countries. Its proceedings have been published and are identified in the Bibliography for this chapter. Reports on biogas systems came from Sri Lanka and the Peoples Republic of China.

Transfer Stations

It has been established that sanitary landfill is, and must continue to be the predominant solution for waste disposal. The first economic option is the direct transfer to landfill of collected domestic and commercial solid wastes by whatever vehicle and container systems are in use. We have also shown that in many cities primary and secondary collection is a feature of the system. While the transfer points from primary to secondary modes may be occasioned by ordinary factors such as primitive roads, congested developments, laborious and time consuming manual collections and the like, it is also fact that most of such transfers will seek to compress and densify the waste so as to make its onward transmission more effective.

A reduction in the number of vehicles on the road is another important benefit to be sought. A three vehicle input to one bulk container output is feasible for many stations. In the main stream of current Western thinking on waste disposal remote haul to landfill sites is the next most realistic option to be considered when a metropolitan area exhausts its local landfill sites. The focal point of this system is the bulk transfer station, and this is the more formal suppression of the numerous improvised transfer points commonly found in developing countries. Bulk transfer stations with sizes that range from 100 to 1500 tonnes/day are a feature of many Western cities and the transfer medium may include the use of road, river or railways. There is available a substantial industry to manufacture the hydraulic compactors and containers necessary to move the transferred waste. The literature on transfer station economics is extensive and is available to those managers in the largest and better developed and resourced cities that are having to face remote haul to landfill for their solid wastes. Equally well researched are the civil engineering designs of such stations, the dynamics of traffic movement in and out of the station, operating costs and cost benefits of bulk transfer against other alternatives. All these will need careful study before metropolitan authorities come to a decision.

An important element in the cost benefit equation is the cost of bulk haul to remote landfill against the cost of a local incineration plant or composter. In this case the argument goes that the reduction in weight and volume of the waste and the onward transfer of the residues to landfill are a better
solution. The capital investments, technical sophistication and running costs of a transfer station will be lower but the point may be reached where the remoteness of the landfill and the attendant costs of the transport system may be greater than the costs of the other alternative. The argument runs in this way and there are several elegant mathematical tools to assist decision makers to determine the balance between the two. As with vehicles and plant the reputable manufacturers of transfer station plant can and do offer guidance to decision makers. A number of text books now published, and more appropriate to developed metropolitan problems, have looked at transfer station economics in great detail. The bibliography makes some reference to these. The Greater London Council (GLC) has an ambitious programme of road, river and rail transfer stations and their experiences may be of interest to the manager in the largest cities.

Typical Case

As a general guide to decision makers an operational scenario has been prepared based on a 500,000 population town with an exhausted local landfill site. Waste is being taken to a remote landfill site 24 km from the town. (See Fig. 49) A comparison is made in the operational dynamics of continuing this operation or

![FIGURE 49](image)

A - Direct Haul to Landfill by Refuse Vehicles

B - Refuse Vehicles to Transfer Station & Compacted Bulk Haul of Refuse to Landfill
installing a bulk transfer station rated to deal with the estimated daily arisings of 260 tonnes. The tabulations define the vehicle fleet, payloads, distances travelled and the economies in distance and work by the introduction of a bulk transfer station. (See Figure 50.)

The transfer station rated to handle 260 tonnes/day on a normal 8 hour shift would lead to a mean refuse transfer and compaction rate of 32.5 tonnes/hour. However, in practice, the cyclic nature of waste deliveries to the station may be such as to demand an instantaneous transfer rate up to 1.5 - 2.0 times the mean rate. This would lead to the need to specify the station to be able to deal with 50 - 60 tonnes/hour. The number of parallel compaction units installed to achieve this handling capacity will be determined by the vehicle arrival patterns to the station. These patterns will be dictated by local circumstances, but the station will probably have morning and afternoon peaks where at each peak it will be necessary to deal with perhaps 25% of the days total input. In our hypothetical exercise this could mean 13 vehicle discharges per hour as a maximum, delivering 65 tonnes to the station. The final design decision may come down to a 3 stream plant (1 stream standby) each operating stream rated at 30 tonnes/hour i.e. 2 full bulk container loads per hour per compactor.

The design may take the form of 4 streams (1 stream standby) each operating stream rated at 20 tonnes/hour but the final decision will be taken bearing in mind the equipment selected and the precise traffic flows to and from the station. The transfer station equipment and vehicle manufacturers can offer useful guidance on the best operating configuration.

In considering the case for and against the installation of a transfer station (or for that matter any other solid waste treatment plant) the location should be as close as possible to the 'centre of gravity' of the waste collection area it serves. In this context 'centre of gravity' is taken to mean the point at which the sum of the collection distances for each vehicle is a minimum. In other words whatever else a treatment plant may seek to achieve, it should optimise the performance of the waste collection service.

The transfer station installation including its associated bulk transfer vehicles will, in all probability, be the lowest capitally intensive solutions available to a decision maker. These capital costs will be a fraction of those for an incineration plant or similar installation. The following table (Figure 51) gives some indication of the capital investment required in the United Kingdom for various treatment systems. They are stated in monies per tonne/hour of installed capacity.
## Operational Scenario

<table>
<thead>
<tr>
<th></th>
<th>Direct Haul to Landfill</th>
<th>Transfer Station to Landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Served</td>
<td>500,000</td>
<td>500,000</td>
</tr>
<tr>
<td>Solid Waste Generation Rate</td>
<td>0.52 kg</td>
<td>0.52 kg</td>
</tr>
<tr>
<td>Waste Generated per day</td>
<td>260 t</td>
<td>260 t</td>
</tr>
<tr>
<td>Typical Refuse Vehicle Payload/trip</td>
<td>5.0 t</td>
<td>5.0 t</td>
</tr>
<tr>
<td>Performance equivalent trips/day</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Typical Tonnage Handled per day</td>
<td>10.0 t</td>
<td>12.5 t</td>
</tr>
<tr>
<td>Number of Vehicles Required</td>
<td>26</td>
<td>21</td>
</tr>
<tr>
<td>Distance to Landfill Site/Transfer Station</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>Round Distances per Vehicle Load</td>
<td>48</td>
<td>8</td>
</tr>
<tr>
<td>Work Measure Expressed as Tonne km (A)</td>
<td>648,960</td>
<td>108,160</td>
</tr>
</tbody>
</table>

### Transfer Station

- Payload of 24m³ Bulk Container: 15 t
- Number of Container Loads/Day: 18
- Number of Prime Moving Units: 4
- Distance Transfer Station/Landfill: 20
- Round Distance per Vehicle Load: 40
- Work Measure Expressed as Tonne km (B): 187,200

### Total Work Performed

- Total Work Measure of Work Performed (A + B) tonne km: 648,960, 295,360
- Work Reduction by Transfer Station: 0%, 54%
Informal Structures

While the foregoing text has concentrated on the purpose designed and structured transfer station, waste managers will appreciate that many of the benefits of the engineered variant can be obtained just as well from improvised arrangements. These will include the most basic enclosed ground transfer station where refuse vehicles will discharge onto a concrete apron with mechanical loading shovels, transferring waste to tipper vehicles or bulk containers. Other improvements may give an open but shielded split level site with refuse vehicles tipping from the higher level to a ground storage area. A further step may give weather proof static compactors placed in parallel on a split level site. There are numerous variations but the key point is that the operational benefits of the transfer station are available at several levels of sophistication and available resources.

THE FINANCIAL REALITIES

The substitution of waste reclamation processes in place of the established waste disposal techniques will be a formidable financial challenge. The inherent economy of sanitary landfill, even when this is coupled with the necessity to bulk transfer wastes to remote landfill sites, is such as to suggest that an authority must be faced with a disposal problem of moderate severity before such a substitution process becomes feasible. The Waste Disposal Authority must at least be faced with an inescapable decision to invest in some capital intensive solution to its problems. The most common of such decisions will be the construction of a bulk transfer station conveying wastes to remote landfill sites by road, rail or
river links. Both DoE sponsored waste reclamation plants now operating in Tyne & Wear and South Yorkshire County Councils will be seeking to establish not only the technical feasibility of the various separation processes they will employ, but that the ultimate cost of separation and reclamation of fibre, metals and other products and the discharge to landfill of only the untreated residues is more economic than the simple transfer of those wastes to landfill. If they can achieve this, they will have been a resounding success. The same applies to the other private sector/public sector collaborating schemes.

The established and proved treatment costs per tonne of these processes and the charges (if any) levied on the Waste Disposal Authorities will establish the band of disposal solutions against which they can compete. This, in turn, will define the rate at which reclamation processes can be substituted for other established disposal systems.

THE SPECIFIC CASE IN DEVELOPING COUNTRIES

It is a paradox that whilst we in Western Europe experiment and pontificate on the desirability of refuse recycling and reclamation, this is practised to a very high degree in the poorer parts of the developing world. While there is little scope for recycling as part of any national waste disposal plan, scavengers and beggars perform very efficiently. They are aided by the extensive use of communal storage of waste while it awaits collection. This, occurring in a variety of bins, oil drums, concrete drainage pipes and purpose-built ground drums, allows an excellent opportunity for hand sorting and recovery. Sometimes whole families of scavengers support themselves living on landfill sites and dumps and little of value is thrown away. Bottles, tins and other things have several life uses. Mr Jon Vogler, a former member of OXFAM, in his book Work From Waste, has set out an 'appropriate technology' philosophy for developing countries. In this he rejects the use of sophisticated western gadgetry (much of which is troublesome to operate even in our own countries) and urges developing countries to use their own intelligence and indigenous 'knowhow'. He continually hammers home the point that what is economic or not seen from Western eyes is not the case in most developing countries. We in the West, as we face the realities of diminishing reserves of metals and fossil fuels, could learn from our less prosperous brethren. His book is essential to those considering the implementation of those same principles. Recycling in developing countries is a speciality of the Technical University of Berlin and Professor Karl J. Thome Kozmiensky presented at the Berlin Conference in 1982 a collection of essays in this field. Readers may also wish to consult a contribution by this author - Refuse Recycling & Recovery published by John Wiley & Sons.
CONCLUSIONS

If operational economics are the main criteria, it is inescapable that the sanitary landfill of domestic, commercial and industrial wastes will continue to be the predominant method of waste disposal in the United Kingdom. Even in those European countries like West Germany and Switzerland, where there are massive investments in incineration and composting plants, the operational position is that over 60% of domestic and commercial waste is still landfilled. Evidence obtained by the Department of the Environment shows that in a fairly active year surface mineral extraction in the United Kingdom creates about $250 \times 10^6 \text{m}^3$ of space. All the refuse produced in the United Kingdom could, with compaction, be accommodated in less than one quarter of the depressions so created and still leave ample space for inert industrial wastes and construction industry debris. Leaving aside the accumulated reserves of despoiled land from earlier years of industrial activity, if only a fraction of this space is available for waste disposal, the reserves are such as to make one of the classic arguments for capitally intensive systems - shortage of space - difficult to support.

The landfilling of domestic refuse, now dignified by the title 'Sanitary Landfill' can be a very different operation from the usual paper-littered, rat-infested eyesores that normally come to mind. It is becoming a science of its own. Knowledge of the geology and hydro-geology of landfill sites, the civil engineering and drainage works that are necessary and the vastly improved mechanical engineering mobile plant are changing the face of this simple system. Plants are now under construction designed to press domestic refuse into high density bales and thus allow a neat 'building block' pattern of landfill disposal. These systems, together with the pulverisation of refuse prior to landfill, can perform useful land reclamation of derelict and despoiled land. Landfill solutions with their inherent economy have a powerful effect on the thinking of the waste disposal industry and materials and metal reclamation must fit into the realities of this situation.

There are many exciting innovations to be considered in the disposal of domestic and commercial wastes. Most, if not all, are still at embryonic stages of development and do not yet present viable and reliable day to day alternatives to sanitary landfill. As sensitive but realistic waste managers, let us be aware of them and in due course give them a fair chance but our responsible duty is to do that which is possible, safely and well and this chapter tries to illustrate the realistic options.
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SANITARY LANDFILL OPERATIONS
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<td>18. Final Restoration of Sites</td>
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SANITARY LANDFILL OPERATIONS

Science

K J Bratley writing in Chapter 6 of Practical Waste Management (John Wiley & Sons) summed up landfill science in this way. The process for the disposal of household or organic waste by controlled tipping has been accepted since the early 1900's. Scientific investigations carried out in Manchester from 1931-1934 still form one of the major works on the subject. Other more recent research work has shown little to disprove these early basic conclusions. It can be shown fairly easily that pathogens die when exposed to certain temperatures for certain times. However, the process of bacteriological decomposition, fermentation and breakdown of animal and vegetable sources is much more complex. The early researchers detailed many of the chemical formulae by which elements of the waste would break down. Since that time the constituents of waste have changed little, other than the amounts of each constituent has varied in relation to the whole. The major addition has been plastics. Plastics undergo little change in this process but remain very much in the same state as when deposited. Further information on the science of the process is given in 'Notes on the Science and Practice of the Controlled Tipping of Refuse by R E Bevan'. This book is obtainable from the Institute of Wastes Management in the United Kingdom.

Landfill Sites

Sites suitable for infill with waste are infinitely variable. They do not necessarily have to be holes in the ground although it is true to say that most sites are related to back-filling operations after mineral extraction. However, natural valleys, foreshores, river flats, railway cuttings and many other areas have been successfully infilled giving considerable community benefit by improving the environment and upgrading land for development or agricultural use.

The final use of the site should be determined before tipping commences. This will enable a satisfactory working plan to be drawn up that will ensure no unnecessary movement of material for final restoration works to be completed. All landfill sites should satisfy the criteria that there will be a resulting benefit to the community. Only in this way will this simple system secure public support and approval.
Topography of the Site

The design of the landfill site should include one or more topographic maps at a scale of 1:250 with 1 metre contour intervals. The map should show: the proposed fill area, any borrow area, access roads, grades for proper drainage of each lift required and a typical cross-section of a lift; special drainage devices if necessary, fencing, garaging, amenity facilities, and all other information which will clearly illustrate the planned development, operations and completion of the landfill.

Geology of the Site

The geological characteristics of the proposed site should be determined, preferably by on-site testing, or from earlier reliable survey data. Geological investigations are of the utmost importance in ensuring the site will not give rise to future pollution problems, particularly with regard to ground water sources. Such investigations will also show whether a suitable quality of cover material is available in the required quantity or whether material will have to be brought in specially for this purpose. In developing countries such specialist skills will usually be available in local universities or the Nation’s Environment Department or other appropriate Ministry. In more important cases expatriate consultancy skills can be used. As an example, in the United Kingdom there are now several specialist consultancy practices dealing with landfill geology and related pollution prevention measures.

Water Pollution

In most developed countries the water authorities have an important say in landfill site selection. The Water Authority must ensure no site is infilled which is likely to give rise to later water pollution problems. Indeed in almost every case it will be the task of the Waste Disposal Authority or private operator to convince the Water Authority that water pollution will not occur. There are many sites suitable for infill where the natural flows of water would give rise to pollution. However, if sufficient capital investment can be made to prevent this pollution then there would be no constraint on water pollution grounds in most areas. The matter then becomes an examination of the viability of the site compared with other available options for disposal.

In general landfills should not be located on sites where the surface or ground water will intercept the deposited waste. Waste often contains infectious material and other harmful substances that can cause health hazards or nuisance if permitted to enter surface or more important ground water supplies. Diversion of clean surface water by drainage
provision, diking or de-watering will often be sufficient to prevent water contamination. In particularly suitable geological areas pollution can be prevented by the slow dispersal and resulting dilution using the natural biological processes.

**Site Preparatory Works**

Assuming that topography, geology and water pollution prevention conditions have all been satisfied and planning approval and a site licence awarded, it is vital that site preparatory works are carried out before landfilling operations commence.

**Site Entrance**

A properly constructed roadway, preferably to normal highway standards is desirable having adequate visibility splays and extending as far as possible into the site.

An adequate lockable gate together with total perimeter fencing or total fencing of the working area of the site is essential.

An identification board showing name of site, name, address and telephone number of operator, waste disposal authority responsible for issuing licence. Also incorporated could be trade refuse charges and attention drawn to codes of practice displayed on notices within the site.

On more important sites a weighbridge facility should be provided or an adequate documentation system to maintain a record of the types and quantities of waste deposited.

Adequate amenity facilities for site operatives; including preparation of documentation; display of working plan and telephone facilities.

Garage facilities, particularly for plant which cannot be moved from site which should also incorporate security and first line servicing provision.

Storage facilities for site equipment including fuel.

Road lighting aiding security and improving safety.

Landscaping to provide pleasing appearance and screening.

Landfill sites are often in remote areas. Security of plant and equipment can often be a difficult and costly operation. It is advisable that facilities are placed as close to the main entrance as possible. Full-time security provision may be necessary particularly for sites handling hazardous wastes.
Access Roads

The successful operation of any landfill site is largely dependant upon the provision of adequate access roads.

Main Access Road

This road leading from the site entrance should be a properly constructed road permitting two-way vehicular traffic. The site control office must be located on this road. The extent of the roadway into the site will depend on the life of the site and the expected usage. Its route should be planned to ensure it can be used to the end of the landfill project (and possibly beyond). Incorporated along its length should be a wheel cleaning device.

Secondary Access Roads

These roads will lead off from the main access road and be constructed in such a way as to ensure the easy passage of vehicles in all weather conditions. It should only be necessary to construct one secondary access road for each lift. There are a number of materials available to facilitate the construction of semi-permanent roads to satisfactory standards.

Drainage

In addition to site drainage ensuring no water pollution risk, drainage of access roads is also necessary. It is not always possible for access roads to be above the level of the surrounding area. Consequently water will run towards them and with vehicle movements will produce unacceptable conditions. This can be avoided by suitable access road drainage.

Wheel Cleaning

Running vehicles on unmade roads must inevitably produce a problem of depositing mud on subsequent made-up roads. This problem is considerably reduced by the construction and maintenance of good secondary access roads. There are a number of mechanical wheel-cleaning arrangements available. In most developing countries a more simple arrangement of a 'cattle grid', a long drive through water trough, or a trough of pebbles are among a number of simple solutions all of which are acceptable.
Signs

Regular visitors to the landfill sites should be given a copy of the code of practice for tipping vehicles and any other relevant safety information. This code of practice will be displayed at the site control office for other visitors. Adequate directional signs (preferably standard highway signs) will ensure vehicles using the correct route from control to tipping face. A one-way system is ideal. Dangerous areas must be adequately signed e.g. lagoons, sumps.

Fencing

The extent of the fencing and security measures required will depend on the size, nature of operation, type of waste being deposited and location of the site. It is necessary to fence the total working area of the site as a minimal requirement. Natural barriers that may exist should be taken into account. Dangerous areas must be taped-off or fenced.

Equipment

The preparation of a landfill site for the receipt of waste is normally a straightforward civil engineering exercise. The equipment required is that necessary for earth-moving, road making, drainage provision and building. It is unlikely that a Waste Disposal Authority or Private Waste Disposal Contractor could find sufficient use in this context to justify the purchase of machinery to carry out this work. Motorised scrapers, drag lines, road laying machinery, would probably be better hired-in or borrowed from other activities.

Assuming that site preparation works are completed in the way I have outlined then the equipment and machinery necessary to operate the landfill site would depend in the main on the following four conditions:

1. Input quantity
2. Types of waste
3. Cover material available
4. Location of site

There is a very wide choice of machines available and later text in this chapter illustrate their principle operating features.
Other Necessary Equipment

i) Movable screens for quick assembly

ii) Insecticide spraying equipment

iii) Portable lighting equipment

iv) Machine fire fighting equipment

v) Machine cleaning equipment

Tipping Area

The tipping area should consist of a number of constructed bays. These bays should have banks on three sides approximately 2m high. The open end should be as close to the secondary access road as possible. The shape of the bays will depend on conditions prevailing at any particular site. The width of the bay will be governed by the number of incoming vehicles. Four vehicle width face, say 16m would be suitable for handling an input of 300 - 400 tonnes/day. The length of the bay will depend on the overall shape and size of the site. A single bay could handle a number of weeks input.

LANDFILL OPERATIONS

Examples of Instructions to Users & Operators

All vehicles carrying waste will be tipped in the operational bay at the lower level.

Traffic will be controlled by one site operative in clearly marked protective clothing. No other pedestrians allowed in this area.

Vehicles carrying cover material will be tipped at the higher level of the operational bay, preferably using the secondary access road for the next lift.

The tipped loads of waste will be run over by the steel-wheel compactor immediately after the tipping vehicle has left the area.

The number of passes the compactor makes over the waste at this time depends on the size and nature of the waste.
The compacted waste is then pushed forward in 'onion skin layers' up a 1 in 7 incline.

Each load of waste is treated in this way with the compactor making many passes up and down the incline compacting, chopping and breaking-up the waste with each pass. See Figure 52.

If this is done then there should be no large voids within the compacted waste and in-situ densities of over 1 tonne/m$^3$ can be achieved..

All bulky waste must be compacted before spreading up the inclined face.

At the end of each working day the cover material deposited at the higher level is spread over the inclined face. For large input sites, cover material will need to be spread over the finished level of the working layer (i.e. top of incline) during the day as the working face progresses.

During most weather conditions, using this method of operation, there will be no deposited waste leave the working area. However, in conditions of high wind, screen fences must be erected. As tipping is taking place 2m below the surrounding area then a 2m fence on top gives 4m screen fence for wind blown material catchment. Correct positioning of tipping bays will prevent the open end of the bay facing downwind of the tipping operation.

Waste compacted to high densities become less attractive to vermin. Seagulls lose interest if an adequate layer of cover material is used. During hot weather the waste may contain flies etc before arriving at the site. In these conditions the working face should be sprayed with an insecticide at intervals throughout the day.

Further Examples of Suggested Operating Procedures

These guidelines used by most United Kingdom waste disposal authorities set down a simple set of rules to alleviate most of the adverse effects of landfill disposal. They must of course be modified to meet local circumstances.

1. The deposit to be made in layers.
2. No layer to exceed 1.5m in depth.
3. Each layer to be covered, on all surfaces exposed to the air, with at least nine inches of earth or other suitable substance; provided that during the formation of any layer not more than 1.5 to 2.0 square metres will be left uncovered for every 3 cubic metres of waste deposited each day to a depth of 1.5 metres.
METHODS OF LANDFILL OPERATION

INERT BANK

12M

INERT BANK

COVER MATERIAL

4th. DAYS REFUSE

3rd. DAYS REFUSE

2nd. DAYS REFUSE

1st. DAYS REFUSE

12M

6M

TIPPING FACE

AREA FOR DEPOSIT OF LOADS

COLLECTION VEHICLES

Courtesy: K. Bratley
Chapter 6
Practical Waste Management
John Wiley & Sons Ltd
4. No refuse to be left uncovered for more than 24 hours from the time of deposit. Normally in good practice waste is covered at the end of each day's operations.

5. Sufficient screens or other suitable apparatus to be provided, where necessary, to prevent paper or other debris from being blown by the wind away from the place of deposit.

6. No refuse to be deposited in water.

7. All reasonable precautions to be taken to prevent the outbreak of fires and the breeding of flies and vermin in the deposit. Hollow receptacles likely to provide breeding places for vermin to be flattened or filled before being covered by refuse.

8. Deposits consisting entirely or mainly of fish, animal or other organic refuse must be covered forthwith with earth or other equally suitable substance to a depth of at least two feet.

9. Deposits must be maintained in a tidy condition; tins, hollow vessels and other loose debris must not be left lying on or about the place of deposit.

10. Sufficient and competent labour must be provided in connection with the deposit to enable the necessary measures to be taken for the prevention of nuisance.

11. So far as is practicable each layer of refuse which has been laid and covered with soil must be allowed to settle before the next layer is added.

12. Whenever practicable the person making the deposit must avoid raising the surface of the tip above the general level of the adjoining ground.

13. All refuse must be disposed of with such despatch and be so protected during transit as to avoid risk of nuisance.

Codes of Practice

Readers are recommended to consult the Codes of Practice issued by the National Association of Waste Disposal Contractors (NAWDC) in the United Kingdom. The Code contains substantial guidance of waste disposal procedures. These include safety guidelines.
Examples of Control of Incoming Vehicles

All vehicles must be received at site entrance control office. Documentation must be checked and quantity and type of waste recorded.

Attention should be drawn to relevant site notices and safety procedures on the site.

All drivers should be instructed to follow the signed route to the tipping face.

Only the driver and mate should be allowed to stay with the vehicle in the tipping area.

The vehicle should proceed to the tipping position only when instructed to do so by landfill operative.

The vehicle must tip in the position indicated (this should be at least a vehicle length from the tipping face).

The vehicle must leave the site via the signed route (this should pass the site control office).

Special loads must be tipped under supervision at all times.

Examples of Safety Rules for Refuse Collection Crews Visiting Landfill Sites

1. On arrival at site all crew members with the exception of the driver and one mate will disembark at the assembly point and remain at the point only until the vehicle returns.

2. All loose tools and equipment must be unloaded at the assembly point and collected on return.

3. Vehicles must travel to and from the tipping face on the prepared site roads. Drivers must obey all directional and instruction signs. At no time must the speed of a vehicle exceed 7 mph.

4. The driver must report to a responsible person as soon as possible on entering the site and must comply with all instructions given by him. The vehicle will be manoeuvred into a tipping position about 1 vehicle length from the tip face, if the driver has any doubts as to the stability of the site he must satisfy himself that it is safe to proceed.
On completion of the tipping operation the vehicle should be moved into a position away from the tip face where it is safe to clean dust trays, body seals etc without obstructing other vehicles using the site.

No tipping may proceed unless there is a responsible employee on site to direct the operation.

MECHANICAL PLANT ON LANDFILL SITES

The Tasks to be Performed

B McCartney, writing in Chapter 11 of Practical Waste Management has said that the efficient handling of waste materials and inert cover is at the heart of good landfill operations and it is worth looking at the principal tasks involved. These tasks start at the point at which the site is first prepared to receive refuse and end with its final restoration to agriculture or some other beneficial use. At every point earth moving or refuse handling machinery will be required. No one machine can perform every task, although some can perform several roles. These tasks include the following principal duties:

1. Levelling and preparation of the site.
2. Access roads and manoeuvring areas.
3. Digging and moving covering material.
4. Initial handling and segregation of incoming waste.
5. Spreading and placing waste in the landfill.
6. Covering the waste.
7. Final levelling and top soil placement.

At the beginning if we assume that our landfill is a relatively large void it will be clear that in present day conditions its market value will be high. So too will be the attendant development costs. Site preparation will be a substantial part of these costs and the work must be executed in such a way as to enable the site to operate efficiently and yet conserve as much of the gross void volume for commercial use.
The Need to Know About Mechanical Plant

While many cleansing managements chronically short of spare parts and capital funds may consider a treatise on the use of fairly expensive landfill machinery defining a set of ideal circumstances they may never aspire to, the author makes no apology for its inclusion in this thesis. Tips and dumps can be managed sensitively even in the worst of circumstances, but they will never become sanitary landfill sites without landfill machinery. Given that sanitary landfill by the very force of the economic arguments must be the inevitable solution in a great many cities, its mechanics must be understood.

The Concept

At this point it is essential that the site developer accepts the concept that the void is not just a place to tip waste indiscriminately, but that it must be treated as a 'factory' for waste disposal, because a properly constructed landfill site will, in the long term, fulfil almost the same function as a specialised multi-million pound pre-treatment plant. Moreover, it will have a greater capacity and flexibility, and will be far more useful in the future for the purposes of land reclamation. In creating agricultural development of recreational land, it may be possible that substantial financial gains can be achieved to set against the cost of the initial landfill operations.

In order to make the best use of this void it is necessary to have the right equipment available. It will be essential to make access roads down to the part of the site where the landfill operations are to commence. The covering material may have to be brought into the site or it may be possible to dig this out on site, so it is advantageous if the road making machine could be bought having in mind the possible continual heavy digging, stock-piling and placing of the covering material on the freshly tipped waste.

a) Controlled waste disposal
b) Sanitary landfill

The Nature of the Site

The nature of the site may require that excavations have to take place either prior to or during the course of the landfill operation and it may be that some form of impermeable sealing membrane will be required at the base of the site. This all calls for suitable heavy duty equipment. Therefore, basically, the main tasks to be carried out are of a heavy duty earthmoving nature where dense materials may have to be dug
out. Certainly, regular road maintenance must be catered for and this will involve handling variable quantities of stone, brick, rubble and clay.

Added to this, of course, is the actual covering operation itself. Managers connected closely with waste disposal and sanitary landfill know that if you have good and readily available sources of covering material, you should have a good sanitary landfill site.

Most experienced practitioners would say that in choosing one or another type of machine, there are no rigid rules which can be laid down. Every waste disposal site has its own individual characteristics and it is, in effect, 'alive' as its needs vary from day to day, dependent on the wind, rain and general variance of climatic conditions in addition to the nature of refuse being fed into it. In order that all these variances can be taken into account, what follows is a general set of rules which can be used as a guide towards the selection of the right equipment for the particular job in hand. The finance available also affects the decision particularly in developing countries.

Firstly, the machine bought today must not just be capable of coping with existing requirements but must, as near as it is possible to calculate, be well on top of the job at the end of its economic life. The emphasis is on a five year replacement period, but many feel that it is more advantageous commercially and more economic if machines are replaced after four years. During the fourth year, equipment begins to require unit replacements and part overhauls so that at the end of five years the machine has a deal of life left in it, but its commercial value has dropped in relation to its intrinsic value. In a developing country this philosophy may require to be adapted to local economic circumstances and it may well be that machinery may be operated for considerably longer periods.

THE CHOICE OF PLANT

Bearing in mind the inescapable necessity to compromise in one way or another, these are the principal machines that are available:

**Tracked Machines**

These are of two basic types, the bulldozer, which is unable to dig, lift and carry material but is ideal for site levelling and final grading, and the loader, which can dig, load and carry but has limitations on levelling, back-blading and grading. A very common machine in the early days of waste disposal, it is now less popular in dealing with the lighter and less dense nature of modern refuse. Nonetheless it still has numerous applications in materials handling.
Scrapers

These are normally used in conjunction with a tracked bulldozer in the preparation of large sites and stripping out and stockpiling material which can be used for cover at a later date. They can also be used to help construct access roads to difficult sites but generally, because of the special nature of their work, they are better hired and the work given to a reputable contractor.

Dragline Excavators

On the larger sites where there is already a usable void, the dragline can be utilised in site preparation and also winning covering material from the site. It comes into its own in places inaccessible to mobile equipment such as tracked machines, i.e. swampland. The dragline, if put on a sound base, can be very useful in excavating 'fingers' of top and subsoil to a suitable depth and stockpiling at one site for use as intermediate and final cover when the landfill operation is completed. Previously this type of equipment had only marginal use, but now certainly it seems its permanent presence is essential to the completion of the job. It can also be used satisfactorily for grading the steep sides of an existing hole and assist in the application of impermeable materials to the sides of the tip prior to tipping.

Four Wheel Drive Rubber-Tyred Loaders

A great deal of research has been carried out by manufacturers into the application of this type of machine in many waste disposal duties. This one piece of equipment covers a wide range of work and is extremely versatile in back-up applications, particularly on the larger site, i.e. digging out cover and placing cover into its final position. Its speed and flexibility of operation in this role is a most useful attribute. It is possible on the small site up to, say, 200-250 tonnes per day that this machine would be capable of handling all aspects of waste disposal on its own, but in the present context of larger 500-1,000 tonnes/day sites its role is that of a back-up machine. It is essential that it be fitted with under-body protection and special puncture-resistant tyres. In the past, this machine had its critics because of punctures, but used properly and taking advantage of puncture-resistant tyres, a great deal of advantage can be gained from its use.
Figure 8  Cross-section illustrations of a modern landfill compactor. (Courtesy of The Caterpillar Company, USA)
Steel-Wheeled Mobile Compactors

The steel-wheeled pulveriser/compactor is basically a converted articulated four-wheel drive loader and is an extremely popular machine on many larger sites. The extent of conversion is dependent on the manufacturer. In some cases, the manufacturer simply replaces the rubber tyres with steel wheels, fits under-body protection, fire extinguishers, battery isolator switches, redirects air flows, etc., and the machine is basically capable of being quite quickly converted back to a rubber tyred vehicle at any time during its life or with its secondary owner. Some have gone further than this and replaced the whole front end from the pivot forward. Some have restricted themselves to bulldozer blades only, some to a scoop but more recently a dual scoop and bulldozer blade has been introduced. Its steel wheels eliminate the risk of punctures and several papers have been published to illustrate its compaction and space-conserving properties on landfills.

Purchase or Lease

Today the purchase of equipment is made far easier than it was in the past by the diverse financial schemes that are available through banks and finance houses. In many cases, these schemes have been developed in conjunction with the manufacturers of the plant. These schemes include various forms of hire purchase with graduated payments, simple leasing and leasing with guaranteed buy-back at the end of three, four and five years. It is also possible from some reputable manufacturers to obtain contract hire terms which, although expensive at first glance, do reduce downtime considerably and really make the manufacturer responsible for the efficient operation of the equipment on the site. When one considers the position, equipment is not bought for its intrinsic value but rather for its use. In many cases, ownership of equipment can be a financial hazard and contract hire schemes may be a better proposition. In the private sector particularly, the purchase of equipment enables tax relief and other allowances which, in addition to the guaranteed buy-back schemes, do tend towards the common sense of buying the best for the job, irrespective of price. While these commercial routes may not be available in all developing countries they certainly are possible in the better developed.

SPACE CONSUMPTION ON SITES

The behaviour of wastes, particularly domestic and commercial wastes in landfills, is not static but changes over a considerable period of time as organic decomposition and natural compression increases density and vary other physical parameters. Aiming to determine the evidence on the in-situ
density in landfills of domestic and commercial wastes gave the following range of figures that may be a useful guide to waste management decision makers. In the United Kingdom the use of steel wheel compactors combined with modern systems of waste deposit is giving in-place densities considerably greater than the figures taken for granted in earlier years. These figures are a guide to current thinking but it is desirable to keep abreast of developments in plant used on site operating techniques. It is also important to appreciate the different nature of refuse in developing countries. Its higher organic content and moisture level, lower paper and plastics content give it a higher density and lower demand on space consumed.

FIGURE 54

<table>
<thead>
<tr>
<th>Type of Waste</th>
<th>Typical In-Place Densities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High t/m³</td>
</tr>
<tr>
<td>Refuse &amp; Similar Wastes</td>
<td>0.5</td>
</tr>
<tr>
<td>Light Industrial Wastes</td>
<td>0.4</td>
</tr>
<tr>
<td>Heavy Industrial Wastes</td>
<td>1.25</td>
</tr>
</tbody>
</table>

The Volume Consumed by Refuse

This factor is understandably the most important as a practical tool of waste management. It is the most common and obvious question to be asked by waste managers - how much land will I require for my operation.

The space consumed by landfill disposal can be obtained by the reciprocal of the in-situ density and the earlier table gives a guiding range of figures. In practice, however, waste going into a landfill will not be homogenous in composition. While domestic and commercial waste may be the principal component there will also be quantities of industrial and other waste including construction debris. These will all have different densities and different rates of compaction and bio-degradation.

The figures on the performance of landfill compactors and other modern plant are increasing in situ densities to 1 t/m³ or 1 m³/t expressing it as space consumption. There is also evidence to show a significant reduction in space demand in the course of the 1st and 2nd years after deposit in the landfill.
On one large landfill site in the South of England there was a reduction in space demand from 1.5 to 0.82 m$^3$/t at the end of the 1st year after deposit.

There are very encouraging results and they indicate the benefits from the use of better plant and methods coupled to a finer understanding of the nature of waste. In developing countries waste will have a higher initial density. It will be more organic and this coupled to climate and temperature will give a high degree of compaction and reducing space demand. These factors will tend to compensate for the absence of expensive landfill plant like steel wheel compactors.

As a general practical guide therefore waste managers would be prudent to plan space requirements using a composite space demand figure of 1.5 m$^3$/t and accepting further economies as a welcome bonus.

Leachate Production from Landfill

Alan Parker, writing in Chapter 7 of Practical Waste Management (John Wiley & Sons Ltd) makes the basic point that when rain falls on freshly deposited refuse, the latter will gradually become saturated (at least in the UK) until the field capacity is attained. When this is exceeded then leachate will be formed. Leachate production can be shown diagramatically:

Once field capacity is reached then it is estimated, in the South East of the UK, that 10-20% of the annual rainfall can appear as leachate. However, this can be minimised by good management techniques e.g. by capping the site after refuse has been quickly built to its final level thus preventing water ingress and by preventing surface water from entering the landfill. Landfill leachate, especially from industrial sites, is a nuisance since it may pollute surface or underground water sources. The composition of the liquid is often complex and can vary with the age of the landfill with the organic content decreasing with age. For example:
TABLE 55

<table>
<thead>
<tr>
<th>Elements</th>
<th>Fresh Leachate (0-2 years)</th>
<th>Old Leachate (5 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Organic Carbon</td>
<td>13800</td>
<td>70</td>
</tr>
<tr>
<td>Fatty Acids (C₂)</td>
<td>1340</td>
<td>not detected</td>
</tr>
<tr>
<td>(C₃)</td>
<td>660</td>
<td>&quot;</td>
</tr>
<tr>
<td>(C₄)</td>
<td>2000</td>
<td>&quot;</td>
</tr>
<tr>
<td>(C₅)</td>
<td>980</td>
<td>&quot;</td>
</tr>
<tr>
<td>(C₆)</td>
<td>1090</td>
<td>&quot;</td>
</tr>
<tr>
<td>Protein</td>
<td>1750</td>
<td>16</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>3245</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Note: (all results in mg/l)

Table 58

\[ L = P - (E + R + T) \]
When industrial waste is co-deposited with domestic waste then the complex mixture resulting from domestic refuse will contain an even greater variety of chemicals. For example, from a site in the United States at least 42 organics have been identified including camphor, di-ethyl phthalate, tri-n-butyl phosphate from plasticisers, p-creosol from creosote and o-xylene used in phthalic anhydride manufacture.

Leachate treatment methods can be divided into several categories:

<table>
<thead>
<tr>
<th>Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Spray over nearby land</td>
<td>Spray rate up to about 5000 gallons/acre/day in the UK. Is suitable land available? Will smell cause problems? Process likely to be more effective during dry weather. Liquid from industrial landfill may contain objectionable chemicals.</td>
</tr>
<tr>
<td>2. Spray over landfill surface</td>
<td>Elevated temperature in landfill will help evaporation. Decomposition of waste assisted by increased moisture content. Smaller volume of more polluted leachate obtained.</td>
</tr>
<tr>
<td>3. Treat at sewage works</td>
<td>Cost of tankering? Is a foul sewer nearby? Has the works sufficient capacity? Steady hydraulic and BOD loading must be maintained.</td>
</tr>
<tr>
<td>4. Aerobic treatment</td>
<td>Store in lagoons and oxidise with air or oxygen. Use of trickling filters - problem with blockages due to precipitation.</td>
</tr>
<tr>
<td>5. Anaerobic biological treatment</td>
<td>Conversion to methane and carbon dioxide - only on pilot plant scale so far.</td>
</tr>
</tbody>
</table>
6. Chemical treatment
   Oxidation with hydrogen peroxide or ozone. Use of precipitants and coagulants, e.g. lime, alum. More suitable for removal of colour and suspended solids rather than dissolved organics.

7. Physical treatment
   Reverse osmosis. Polishing of effluent with activated carbon.

**Landfill Leachate Attenuation**

The mechanisms of attenuation in the landfill itself are of particular interest since these will tend to reduce the pollution load of any leachate escaping from the site. This will mean that attenuation underneath the site need not be so effective e.g. the thickness of the unsaturated zone may be reduced. During this experimental programme and associated investigations valuable information was obtained on the behaviour of many potentially hazardous materials within the landfill. For many of these e.g. mercury, oil and PCBs, co-deposition with domestic waste has significant advantages since this waste has significant retention capacity for these materials.

- Halogenated Organics
- Cyanide
- Heavy Metals
- Mercury
- Acids
- Oils
- PCBs
- Phenols and Solvents

*’Containment’ versus ‘Disperse and Attenuate’*

Containment sites will not allow leachate to escape unless the site fills with water thus causing leachate to flow over the rim of the site. Containment sites initially appear attractive especially for the disposal of hazardous wastes but good management of possible water inflow is essential.
The converse of the 'containment' philosophy is that of 'disperse and attenuate'. In this, leachate is allowed to escape from the landfill with the pollutants contained therein being attenuated by the surrounding strata. Such attenuation mechanisms have been studied both in the laboratory and in lysimeters during the current DoE programme. Of particular relevance is the behaviours of heavy metals such as lead, cadmium and nickel in strata such as the Lower Greensand which contains a substantial proportion of clays, such as montmorillonite. For instance, lead is strongly absorbed while nickel is much more mobile. Such research enables predictions of the behaviour of hazardous materials to be made, and, together with a knowledge of interactions between wastes within the landfill itself, can prevent overloading of the site. It should be emphasised that in addition to chemical effects, a knowledge of the hydrogeology of the landfill site is essential. Thus close consultation between interested parties e.g. Water Authorities and Waste Disposal Authorities is of paramount importance before any deposition of hazardous materials is permitted. Finally, the problem should be kept in perspective since a review carried out in England and Wales by the Institute of Geological Sciences in 1973 identified about 2500 landfill sites of which only 51 presented a serious pollution risk to aquifers. Similarly in the United States a 1977 survey identified only 180 pollution incidents involving landfills, surface dumps or lagoons.

Gases in Landfills

The main gases to be evolved will be methane, carbon dioxide and hydrogen resulting from the decomposition of organic material. Traces of many other organic compounds have been identified in landfill gas. Some of these, particularly mercaptans and esters, are responsible for the typical smell associated with landfill sites. Hydrogen sulphide is often present, particularly if significant quantities of sulphate-containing waste e.g. plaster board impregnated with gypsum are present. Smell problems can be minimised by use of adequate cover or by installation of gas interceptor systems followed by burning the methane collected together with combustible impurities.

The relative quantities of the major gases will depend on the age of the landfill. This variation in composition has been investigated by a number of scientific workers. It is found that up to about 20% of hydrogen is present in landfill gas soon after refuse is deposited. This gas, together with any oxygen, quickly disappears and is replaced by nitrogen and carbon dioxide. After some months have elapsed, methanogenic bacteria in the refuse start to multiply so that methane concentrations build up slowly to about 65%. The residual gas is carbon dioxide together with a little nitrogen and traces of impurities. This gas mixture is of interest:
(i) As a hazard e.g. by lateral diffusion from site with methane possibly causing explosions in nearby buildings plus polluting agricultural land.

(ii) As an energy source. Collection and utilisation of methane from large sites. This is now being done in some sites in the United States and the United Kingdom.

The rate of gas production will depend on the moisture content of the waste as well as on its age but the presence of some hazardous materials may inhibit the decomposition processes thus minimising gas release. Vapours from deposited solvents may cause a potentially hazardous situation due to their possible flammability and toxicity.

The beneficial use of landfill gas as a source of energy could be of interest to environmental managers in developing countries. Obviously it will only be of significant interest in major cities with large and deep landfills and dumps (perhaps from past times) close to the urban and industrial areas of the city. The work now going on in the United Kingdom, West Germany and the United States (California in particular) will be of interest. With research and development into landfill gas as with so many other areas of advanced research into landfill techniques the Harwell Laboratory of the United Kingdom's Atomic Energy Authority is in the forefront of the business. Those interested should seek their advice.
Although there are many types of waste and sites for their disposal, it may be beneficial to attempt some simplification of the choices open for disposal and select groups that can be dealt with in similar ways. Two approaches are possible; one which categorises the hydrogeological conditions and specifies the types of waste that are suitable in each category; the second categorises the types of waste being deposited and states the hydrogeological conditions that are necessary to prevent pollution occurring. Mr R Aspinwall of the British consulting practice, Aspinwall & Partners, suggested the following route:— (See Bibliography Reference 5.)

First Approach — Hydrogeological Criteria

a) Those capable of providing a significant element of containment for wastes and leachates through the presence of an underlying impermeable layer. These sites should be selected to prevent any leachate reaching the aquifer for a considerable period of time, and because of problems with overflow into surface streams they should be preserved for the most offensive waste material.

b) Those sites allowing some migration, attenuation and dilution of leachate. Suitable sites might comprise dry pits in sand or silt where the aerobic conditions will assist with degradation of domestic and some industrial wastes.

c) Sites on highly permeable or fissured strata where the migration of leachate would be so speedy as to prohibit the tipping of other than inert waste material.

Second Approach — Waste Categories

a) Those wastes likely to cause groundwater pollution, from substances hazardous to health. Such toxic substances include industrial liquids, sludges, dissolved solids and oily wastes. The author suggests that such wastes should be contained by at least 15 metres of impermeable deposit with any source of groundwater abstraction being 2km distant.

b) Non-toxic organic and inorganic substances likely to render groundwaters non-potable. These include household and trade refuse, cesspool contents and sewage sludges. These materials should not be deposited on fissured aquifers. The water table in the aquifer should like at a depth of at least 15 metres and water supply sources be at least 0.8km away from the landfill site.
c) Non-polluting wastes, comprising solid and inert wastes such as construction and demolition wastes. No specific hydrogeological requirements are specified.

It is necessary to be careful in that the above methods assume that the hydrogeological properties of the prospective site or the nature of the waste material fit tidily within the categories described. More often than not this does not occur in practice where nature of fill material, inadequacies in the hydrogeological conditions, proximity of sources of water abstraction all blur the lines of decision and require special measures to be taken. Nonetheless, these guidelines are valuable in defining the limits of landfill operations from a hydrogeological point of view.

Preparation and Operation of Landfill Sites

Mr Aspinwall, in his work, went on to describe the measures to be taken in the preparation and operation of landfill sites. These lay particular stress on the hydrogeological factors involved. I include this text to redress the balance. Mr Aspinwall developed the following points:

Choice of Sites

"In choosing new sites every effort should be made to avoid areas where there are existing springs or small streams. Diversion of springs can be carried out but this is expensive and difficult to achieve in most cases. Culverting is another solution but this must be very carefully engineered. The hazard is that the culvert may be fractured by tipping and the use of heavy equipment above it or the differential settlement of the refuse itself. Once there is a culvert fracture, it is exceedingly difficult to repair. The fractured culvert then acts as a collector and conduit for the leachate to gain access to a stream and cause pollution."

Protective Measures

"With toxic wastes, it may be necessary to seal the site artificially to prevent leachate escaping to an aquifer. This may be achieved by using an impermeable lining such as butyl rubber or some form of tarmac. Natural materials can be laid down and puddled to achieve a low permeability. Successive layers of such clays laid to a depth of 1 or 2 metres can mean that percolation through the full depth of the layers can be prevented for periods
as long as 200 years. It is important that the clay seal should not be allowed to crack and fissure before waste is placed over it. The clay seals should cover the sides as well as the base of the tip to prevent lateral movement of groundwater through the refuse."

**Escape of Leachate**

"With domestic refuse sites, the need to prevent total escape of leachate is not so important. In fact, there may be advantages in allowing a slow seepage from the site in order that there is no accumulation of highly organic water within the tip and gradual decomposition and stabilisation can occur. The rate at which seepage can be allowed must depend on the purification that takes place as the leachate flows away from the tip into the surrounding strata. Important too is the dilution and attenuation that is achieved by normal groundwater flows within the strata itself. The proximity of nearby water supply boreholes must also be taken into account."

**Saturated & Unsaturated Layers**

"Where controlled seepage into the surrounding strata is possible, care must still be taken that the rate of seepage is not too great as to cause unacceptable pollution. There is a need to err on the site of caution. There are many benefits to be derived from the presence of an unsaturated layer of sand under a landfill which will act not only as a filter but also as a medium of oxidising leachates and minimising risks from them being anaerobic. Leachates from domestic refuse can have a highly organic content and the depth of the unsaturated layer and its access to fresh oxygen is important. No shallow layer of sand 1 or 2 metres deep will be sufficient to oxygenate a tip leachate even though it might act as a reasonably effective filter to prevent some chemicals and bacteria getting far."

**Separate Collection of Leachate**

"One possible method of eliminating pollution of water arising from landfills is to collect any leachate and remove it from the site for treatment and disposal. This can be done by under-draining by piping or ground drains but there are difficulties in treating the leachate itself. It is variable in terms of quantity and quality and its organic content is normally such that purification is impossible without considerable dilution or recirculation in some form of filter system. The best treatment is in conjunction with domestic sewage where the proportion of waste liquor should be no greater than 10%."
Care must obviously be taken to avoid the overloading of the works”.

Use of Sewage Treatment Facilities

"Provision for transporting leachates to a foul sewer or sewage works needs to be considered at the initial stages of considering a new disposal site. Adequately designed pumps and sumps together with storage bunks must be available. These must be sized such as to prevent overflow to a nearby stream or aquifer even under the heaviest rainfall conditions. Areas where there is no ready access to sewer discharging to large rivers and where there is no need for the most stringent standards of effluent quality are likely to produce the best results from this type of leachate disposal. Sites where there are long sea outfalls, or settled sewage discharges to estuaries could be satisfactory if the distance from tip to sewer is not prohibitive”.

Site Monitoring

"Site monitoring by the construction of boreholes could be a necessary feature of landfills handling difficult wastes. The boreholes will provide information of the permeability of the strata below the sites, the position of the water table and hydraulic gradients and the direction in which this groundwater will flow”.

Research Guidance

In the face of considerable controversy and ignorance the British Government set up a project to give guidance to Waste Disposal Authorities on site selection and control. This resulted in the setting up of a three year research programme ending in March 1977. This was carried out by the Harwell Laboratory, the Water Research Centre and the Institute of Geological Sciences all in the United Kingdom. Twenty landfills were selected for investigation to give information on the behaviour of many industrial wastes when deposited in sites situated in a wide variety of geological strata. This work has subsequently been extended for a further two years but the emphasis has changed to study also the behaviour of domestic waste. In particular, investigations are being carried out on the effect on gas and leachate production of various refuse deposition techniques. Co-disposal of hazardous and domestic waste is also being studied since reactions within the landfill may minimise the environmental impact of many hazardous wastes by immobilising such materials or by converting them into less hazardous compounds. This information is available to decision makers in developing countries and they should seek the guidance of the British Government’s Department of the Environment.
As a continuation of earlier pioneering programmes on the behaviour of wastes, two large scale experiments have been commissioned. At Edmonton in London, the Water Research Centre have constructed a series of large concrete cells lined with plastic in which toxics may be admixed with domestic waste. Amongst the materials being studied are solid wastes and residues from old gasworks, i.e. spent oxides. The behaviour of phenolic lime sludges and highly putrescible vegetable waste is also being investigated. The cells, which contain about 250 tonnes of waste, have facilities for the collection of gas and leachate samples, and the monitoring of temperatures.

At Stewartby, Bedfordshire, the Department of the Environment have funded an experimental programme which is being operated by the Harwell Laboratory in conjunction with London Brick Landfill Limited. In a worked-out clay pit eight large cells have been constructed each capable of containing about 1200t of refuse. Some of the cells have been filled using the same type of waste but with different machinery or deposition techniques. Useful data is being obtained on density, gas and leachate composition.

Other experiments are being carried out to study the effect of varying the percentage of moisture in refuse in an attempt to optimise methane production. Such information is of value if large landfill sites are to be run in order to obtain methane in an economic fashion. In other cells the co-deposition of acid wastes and oils from different sources is being studied. In addition, work is being continued at various selected landfill sites in order to gain a greater understanding of processes which occur within a landfill site - a subject, which until a few years ago, lacked much basic information.

The Planning Discipline on Landfill Sites

Most developed countries now recognise that the planning authorities have a prime role in deciding whether or not a site should be allowed to exist. The planning authority will take into account all the land use, aesthetic and socialised aspects of the decision. These notes illustrate the matters the planners should take legitimately into account in their deliberations.

Under the Control of Pollution Act in the United Kingdom controlled waste must not be deposited on any new site unless a planning permission has been granted and a site licence issued. Any application for planning permission will be concerned primarily with the principles involved, whilst a site licence will seek to control the day to day operation.
The following headings are intended to serve as an indication as to the type of conditions that might be included in any planning consent. These have been divided into primary and secondary issues. It is likely that conditions relating to primary matters will be included in every consent whereas those relating to secondary matters should only be included where it is felt necessary because of special local conditions.

**Primary Matters**

1. Type of permissible filling materials, in consultation with the Waste Disposal Authority.
2. Locations and design of any buildings or fixed plant to be installed on the site.
3. Location and design of access to the site.
4. Landscaping of the site.
5. Final treatment of site - including nature of final layers, contours and drainage.
6. Duration of planning permission and the ideal timescale of operations on the site.

**Secondary Matters**

1. Method of compaction and physical placement of the wastes.
2. Phasing of operations, including details of a phased restoration scheme.
3. Direction of working - this may depend on the prevailing winds.
4. Hours of operation - social factors might affect this issue.

**Licensing Conditions**

In the United Kingdom and other European countries the licensing of the deposit of controlled wastes in landfill situations has had the desired effect of centring attention on the problems of the past and the reasons for them. In the evaluations of the physical parameters and problems of existing sites, it has been possible to readily identify the individual elements which are desirable, even essential, or otherwise and to formulate an operational policy for each site. This has
resulted in the building up of a clearer picture for the development of new sites, based upon objective assessments of the nature of the wastes and the physical conditions likely to result within the geological situations found. In this respect recent research programmes on the behaviour of wastes in landfill and the passage and attenuation of leachates through strata beneath them, have been of considerable value to Waste Disposal Authorities.

The specific conditions applied through the licensing procedures have been aimed at achieving acceptable operational standards, to safeguard the public and the environment, whilst being compatible with disposal needs and commercial viability. Licences have specified the necessary physical site development requirements, such as access needs, void preparation, site security and general facilities like amenities, buildings and services. In addition the operational requirements in respect of manning and provision of proper plant have also been covered, along with measures for the identification, litter prevention, visual improvement and restoration or after-use of sites.

POSSIBLE FACTORS TO BE COVERED BY A SITE LICENCE

1. Type and quantity of waste to be deposited.

2. Site preparation work including matters relating to drainage.

3. Location and design of access road.

4. Provision of wheel washing facilities.

5. Phasing of filling operations and site restoration.

6. Compaction techniques.

7. Provision of site control office.

8. Provision of site fencing and gates.

9. Nature of final layers, final cover, contours, drainage of any on-going or past tipping operations.

10. Hours of operation.

11. Manning and supervision of the site.

12. Other operational matters like the control of vermin and flies as well as precaution against wind blown paper and other wastes.
But perhaps the most significant conditions imposed by licenses are those aimed at securing the management of a planned programme of operations and the following of nationally accepted procedures, together with the monitoring and recording of materials deposited. The real strength of these controls is in the power which the new legislation affords the authorities to ensure compliance. Sensibly and uniformly applied by the County Councils, the licensing of landfill sites has resulted in a considerable improvement in the management and operational standards of waste deposits.

Co-Disposal of Hazardous Wastes

In most developing countries industrial wastes however toxic will still have to be landfilled. Section B4 has defined the whole range of disposal options available in a developed country. Below, we list a set of decision and guidance rules once the landfill decision has been taken. The principles set out here are based on the work of Harwell Laboratory in the United Kingdom. There is now extensive literature on the landfilling of hazardous and toxic industrial wastes. Those specifically interested are encouraged to study the proceedings of the Institute of Waste Management. Expert professional help is available from the AERE Harwell and several private consulting practices are specialists in this subject. The United Kingdom Department of the Environment will always assist Governments or other public agencies who seek help.

EXAMPLES OF DISPOSAL DECISIONS FOR HAZARDOUS WASTES ON LANDFILL SITES

The Decision Chain

Obviously when faced with disposal of any wastes including hazardous materials, questions such as the following should be asked:

1. Is landfill the optimum disposal route?
2. Can a suitable landfill be found within an economic distance of the source of the waste?
3. If landfill is to be used what should be done to prevent problems due to gas and leachate production?
4. Can the use of liners make an originally unsuitable site acceptable?
5. Should a containment site be used or will a 'dilute and attenuate' philosophy be more appropriate?
6. Is the deposited material likely to react with other wastes on the site or can it affect the health of site workers, e.g. acid wastes, asbestos?

7. Should the waste be specially treated before landfilling; e.g. chemical fixation or sealing in concrete?

Health and Safety on Sites

In several countries, and the United Kingdom is one, legislation (The Health & Safety at Work Act) places onerous responsibilities on line managers at all levels. It also places responsibilities on the operatives. A landfill site can be, and often is, a very dangerous place. By its very nature it produces a daily changing workplace. Attention to planning, safe systems or work and above all trained supervision is of paramount importance if accidents and health risks are to be avoided. Following the simple modus operandi as outlined in this chapter will assist in the prevention of incident but attention must also be given to adequate training of operatives in all work they are asked to carry out. A trained first-aider is a requisite on every site. Limiting access to any working area will prevent personal accident.

Final Restoration of Sites

Final restoration work of any site is a comparatively easy civil engineering project. The possible public pressures applied when the site is operational quickly recede now the community benefit becomes apparent. This happy situation can be reached much earlier on many sites if the initial planning of the operation is geared to progressive restoration. Large areas of many sites can be completed to final profiles long before the whole site is complete. With suitable screening recreational, agricultural or industrial use can be made of completed areas whilst the remainder of the site continues to function as a disposal facility. Cosmetic treatment can be achieved by completing boundary areas of a site first and continuing landfilling screened by an attractive area.
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B.6

COMPOSTING OF WASTE
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<td>2. Refuse composting in developing countries</td>
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<td>3. Compost application</td>
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<td>4. Suitability of refuse for composting</td>
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</tbody>
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A BOOST FOR REFUSE COMPOSTING

While composting has taken a beating in the U.K. with a collapse of markets and a general disenchantment with the process, this is not the case in some other countries. British and foreign companies are doing very substantial business in third world countries, where composting appears to present a responsible solution in high population third world cities where refuse is wet and highly organic. Much of this business is in the Gulf States and Libya and U.K. companies like Peabody Holmes and British Jeffrey Diamond Limited are among the leaders in the field. The Swiss company, Buhler-Miag, has also performed well and Hazlemag AG of Dusseldorf have marketed composting plants as far away as Buenos Aires. The Buenos Aires plant, opened in 1972 and serving 300,000 people, and rated at 500 tonnes per day, embodies rapid fermentation processes. As a general guide the windrow system, following pulverisation and screening, is adopted in third world countries where engineering and waste management skills are lower. In more advanced countries, and where space is a problem, systems using primary and secondary shredding, fermentation towers, sewage sludge addition, and incineration of non-compostable elements are practised.

The choice is not always only between windrow and fermentation. The German company, Hazlemag AG, has developed a variation on the windrow system. This involves speeding up the natural maturing process by high pressure vacuum impulses to ventilate and agitate the composting material.

The City of Rotterdam in Holland has commissioned a major composting plant that involves fermentation and windrow. This is interesting because it shows that composting can be chosen side by side with the incineration and heat recovery processes used in the city, Rotterdam being the home of one of the biggest incineration plants in Europe at Botlec/5 x 20 tonnes/h).

REFUSE COMPOSTING IN DEVELOPING COUNTRIES

Peabody Holmes Limited of the U.K., one of the leading companies in municipal waste processing, recently presented, through its Technical Director, a paper on composting processes. Given at the 1979 Dubai Seminar it summed up the art in the following way.

Compost Properties

The aim of composting is to convert a major proportion of solid wastes into a marketable product. It is necessary to begin, therefore, with some understanding of the properties, and the limitations, of compost. Compost is a brown, peaty material
the main constituent of which is humus. It has the following physical properties when applied to the soil:–

- the lightening of heavy soil
- improvement of the texture of light sandy soil
- increases water retention
- enlarging root systems of plants

Composting also makes available additional plant nutrients in three ways:–

- it contains N, P and K, typical percentages being N, 1.2%; P, 0.7%; K, 1.2%; but with fairly wide variations.
- when used in conjunction with artificial fertilisers it makes the phosphorus more readily available and prolongs the period over which the nitrogen is available, thus improving nutrient take-up by plants.
- all trace elements (micro-nutrients) required by plants are available in compost.

**FIGURE 57**

**Table of Composting Trends**

<table>
<thead>
<tr>
<th>Europe</th>
<th>Third World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fermentation</td>
<td>Windrow</td>
</tr>
<tr>
<td>High technology</td>
<td>Lower technology</td>
</tr>
<tr>
<td>Low space requirement</td>
<td>More space required</td>
</tr>
<tr>
<td>Rapid throughout</td>
<td>Slower process</td>
</tr>
</tbody>
</table>
State of Qatar, Municipality of Doha, Composting Plant Flowsheet:

1. Feeding hopper
2. Slat conveyor
3. Bi-rotor hammer mill
4. Chain conveyor
5. Magnetic separation
6. Sludge tank
7. Drum digester
8. Drum screen
9. Chain conveyor
10. Double rotor hammer mill
11. Chain conveyor
12. Belt conveyor with travelling tripper
13. Compost windrow turning machine
14. Chain conveyor for rejects
15. Scrap iron press
16. Fan
17. Earth filter

Courtesy of State of Qatar - Ministry of Municipal Affairs.
COMPOST APPLICATION

Compost is applied to land at a rate of between 20 and 100kg per hectare per year. It is applied between harvesting of one crop and sowing of the next, and it is ploughed in; it can also be used as a mulch to assist moisture retention and inhibit weed in which case it is not ploughed in until the harvest. Because the time of applying compost is determined by the cropping cycle, demand is usually seasonal, thus a compost plant may require storage capacity for its product for several months. There are two situations in which the production and use of compost may be of great importance to the agriculture of an area:

- for bringing into cultivation marginal land suffering from organic deficiency; such areas are most common in tropical climates where hot sunshine tends to destroy organic matter;
- in areas where artificial fertilizers are in short supply or are very expensive.

SUITABILITY OF REFUSE FOR COMPOSTING

The character of the constituents of solid wastes have to be analysed to determine how suitable they are for composting.

Before considering a composting project it is necessary to carry out a physical analysis of the wastes, using reliable sampling methods. Although similar constituents occur in solid wastes throughout the world, there are wide variations in relative proportions, not only between countries, but even between regions within a country. Table 59 which compares Middle Eastern wastes with those of Europe and India illustrates the importance of adapting composting systems to match waste characteristics.

CARBON–NITROGEN RATIO

Bacteria use carbon as an energy source and nitrogen for cell building. The process of decomposition involves the reduction of the relative proportion of these elements, known as the C/N ratio, from an original level which may range from 20:1 to 70:1 to a point where the available carbon has been consumed and activity ceases. The final C/N ratio usually lies between 15:1 and 20:1 but may be higher.

The initial C/N ratio is a deciding factor in the speed at which decomposition takes place. The ideal initial ratio is between 30:1 and 35:1, if it exceeds 40 the time required
increases considerably. Ratios below 30:1 are undesirable for a different reason: there may be excessive nitrogen losses.

In the solid wastes analyses above, the main source of nitrogen is the vegetable/putrescible matter which has a C/N ratio of about 24:1, and paper is the main source of carbon. Thus the higher the ratio of paper to vegetable/putrescible matter the higher the C/N ratio.

### FIGURE 59

**Composition of Waste from Various Countries**

<table>
<thead>
<tr>
<th>Constituents</th>
<th>India % by weight</th>
<th>Middle East % by weight</th>
<th>UK % by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential to compost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetable putrescible</td>
<td>75</td>
<td>50</td>
<td>28</td>
</tr>
<tr>
<td>Acceptable for composting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper</td>
<td>2</td>
<td>20</td>
<td>37</td>
</tr>
<tr>
<td>Inert below 10mm</td>
<td>12</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Compostable total</td>
<td>89</td>
<td>70</td>
<td>74</td>
</tr>
<tr>
<td>Salvageable constituents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper (also incl above)</td>
<td>2</td>
<td>20</td>
<td>37</td>
</tr>
<tr>
<td>Metals</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Glass</td>
<td>0</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Textiles</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Plasctics</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Total of Potential Salvage</td>
<td>6</td>
<td>40</td>
<td>61</td>
</tr>
</tbody>
</table>

**PRINCIPLES OF COMPOSTING**

A composting process seeks to harness the natural forces of decomposition to secure the conversion of organic wastes into useful organic matter. The purposes of controlling the process are:

- to make it aesthetically acceptable;
- to minimise the production of offensive odours;
- to avoid the propagation of insects or odours;
- to destroy pathogenic organisms present in the original waste;
to destroy seeds;
- to retain the maximum nutrient content, N, P and K;
- to minimise the time required to complete the process;
- to minimise the land area required for the process.

There are two main groups of organisms which decompose organic matter:

- anaerobic bacteria which perform their work in the absence of oxygen;
- aerobic bacteria which require oxygen.

**Anaerobic Composting**

The main use of anaerobic composting has been in India where for many years it has provided, usually on a small scale, a cheap solution to the combined disposal of solid wastes and nightsoil. These materials are placed in alternate layers in small trenches which are sealed and left undisturbed for many months, the contents are then dug out and used as compost. This, the Bangalore system, is now being abandoned in favour of aerobic methods because of the very large land area required owing to the long retention period. In other respects, however, it is a low cost system as the amount of materials handling required is much less than for aerobic methods.

**Aerobic Composting**

Aerobic composting is characterised by:

- rapid decomposition, normally completed within one to ten weeks;
- high temperatures during composting, which destroy pathogens, insect eggs and seeds;
- no offensive odours are produced so long as the aerobic conditions are maintained.

All current composting systems aim to maintain aerobic conditions throughout the process. Many types of organism assist: bacteria, which predominate all stages, fungi which often appears after the first week, and actinomycetes, which assist during the final stages. The process begins at ambient temperature by the activity of mesophilic bacteria which oxidise some compounds of carbon to CO₂ thus liberating large amounts of heat. Usually the temperature of the wastes reaches 45°C within two days, and this represents the limit tolerance of the mesophilic organisms. At this point the process is taken over by the thermophilic phase, which lasts about two weeks, in the temperature range 55 to 70°C. If the
temperature increases beyond 70°C activity temporarily declines. The process is dependent, of course, on the provision of a suitable environment for the bacteria. In addition to the nutrient provided by the wastes, the main requirements are adequate supplies of air and moisture. It is important to stress that urban solid wastes, of the character described above, already contain at the time of collection all the organisms required for every phase of aerobic composting.

**Moisture Content**

Moisture content is a critical factor in aerobic composting. For the type of wastes now being considered the following are important:

- if moisture content falls below about 20 percent decomposition ceases;
- if it exceeds 55 percent water begins to fill the interstices between the particles of waste, reducing interstitial oxygen and causing anaerobic conditions; this results in a rapid fall in temperature and the production of offensive odours.

Middle Eastern wastes, of the analysis given earlier, probably fall within the optimum range of initial moisture content and are unlikely to require the addition of moisture during the first few days. During the thermophilic stage, however, the high temperature causes rapid loss of water and this must be replaced from time to time until the final fall in temperature.

**pH Control**

A final parameter which is important in evaluating the microbial environment is the pH of the refuse. As in the case of temperature, the pH of the compost varies with time during the composting process and is a good indicator of the extent of decomposition within the compost mass. The initial pH of solid waste is between 5.0 and 7.0 for refuse which is about three days old. In the first two to three days of composting the pH drops to 5.0 or less and then begins to rise to about 8.5 for the remainder of the aerobic process. If the digestion is allowed to become anaerobic, the pH will drop to about 4.5.
Completion and Testing

An important facet of the composting process is the determination of the point at which digestion of the solid waste has been completed. Generally satisfactory stabilisation is attained when the compost has the characteristics of humus, has no unpleasant odour, high temperatures are not maintained even though aerobic conditions and desirable moisture content exists, and the carbon to nitrogen ratio is such that the humus can be applied to the soil (if the C to N ratio is too high, the compost will remove nitrogen from the soil). To date, most methods used determine chemically when the digestion period had been completed by measuring the reduction in total carbon, cellulose, and lipids, and the increase in percent ash. These methods are adequate for determining the completeness of composting assuming that a representative sample has been taken. All, however, have obvious disadvantages such as complicated sample preparation, considerable time, and expensive equipment. Holmes accelerated windrow and digester systems compare very favourably with their main competitors in this way.
Peabody Holmes composting accelerated digestion system
AN ACCELERATION DIGESTION SYSTEM

The heart of the Peabody system is the digester, each digester typically 7m diameter x 17m high is a vertical tower divided into six stages. Shredded refuse enters the top stage with a load of up to 50 tonnes, and resides there for one day. It is then transferred downward to the second stage, where it is held for a further day, and so on, until it emerges from the base of the digester after six days as fully composted humus. Each stage of the digester is fitted with slowly rotating arms which both aerate the compost and provide periodic agitation and spreading.

The arm controls can be operated independently to a pre-programmed requirement for air flow and turning. Water, or sewage sludge, can be added to the upper stages of the digester and there is also a separate vent from each stage which is connected to a fume washing plant, or other detoxification system.

The digester can thus vary the operating conditions in each of the stages to provide just the right combination of air flow, temperature and agitation for the various composting stages. In single drum or windrow systems it is not possible to achieve such a fine degree of control because, for example, the degree of agitation cannot be varied during the composting period. A further advantage of the compartmentalised digester, is that if any toxic substance enters the digester, it can be kept within a single 50 ton batch without affecting the batches on the other stages.

COMPOSTING PHILOSOPHY

Questioning executives of a prominent British composting plant, manufacture the author extracted the following management statement of their marketing ethos. It is refreshing to note that the company did not doubt that sanitary landfill was probably the prime disposal solution in the great majority of cases and that their system, composting, must exist in the face of this reality.

Over 90% of the world's solid wastes are disposed of in landfills. Sanitary landfilling is the main method used in the West: crude dumping is very common in the developing countries.

There is no form of treatment that can entirely avoid the need for land for final deposit. Treatment often enables a proportion of the wastes to be utilised in some way, but there are residues from all forms of treatment, thus sanitary landflling is usually necessary, although on a reduced scale, whatever form of treatment may be adopted.
For most developing countries incineration and other high cost systems can be dismissed firmly as a rational solution to the problems of wastes disposal on the following grounds:

- wastes are too low in calorific value;
- they are probably too high in moisture content.

The wastes of Middle Eastern countries are often ideal for conversion into organic fertiliser because of their high vegetable putrescible content. Economic forces also favour composting in those countries where high food production is of great importance, and fertiliser imports are limited by foreign exchange constraints.

**Cost**

Given satisfactory standards for the protection of health and the environment, cost will always be the criterion of choice of a waste disposal method. It is necessary, therefore, to consider the probably comparative costs of the main systems. There are dangers in suggesting comparative costs except for a specific city because of wide variations in labour cost and other influences such as site conditions, economy of scale, and the standards of buildings used to house treatment plant.

However, an analysis of recent studies gives the following comparisons as gross capital and running costs, expressed as units of cost allowance has of course to be made for any revenue earned from the plant.

![](FIGURE 62)

<table>
<thead>
<tr>
<th>System</th>
<th>Order of Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanitary landfill</td>
<td>1</td>
</tr>
<tr>
<td>Pulverisation/landfill</td>
<td>4</td>
</tr>
<tr>
<td>Incineration</td>
<td>15</td>
</tr>
<tr>
<td><strong>Composting Variations:</strong></td>
<td></td>
</tr>
<tr>
<td>Accelerated windrowing</td>
<td>6</td>
</tr>
<tr>
<td>Totally enclosed digestion</td>
<td>10</td>
</tr>
</tbody>
</table>
Economic Importance

The possible economic importance of composting to certain developing countries has already been stressed. There may also be significant advantages to public health because it is often the custom for farmers to collect crude wastes and to use them as fertilisers without any proper treatment or control, thus causing risks which would be avoided if the wastes were processed into an hygienic product by the local authority.

In terms of both cost and environmental protection, sanitary landfill and composting emerge as the most suitable methods of solid wastes disposal for developing countries. In the case of sanitary landfill, the conclusion is the same as that reached by the great majority of cities in the industrialised countries. Composting, however, has been rejected in most of Europe and USA because of high production cost, and because of the ready availability at acceptable cost, of artificial fertilisers of guaranteed analysis. None of these factors apply at present in many of the developing countries. Thus in most cases both sanitary landfill and composting may be equally worthy of consideration.

There are two situations in which the production and use of compost may be of great importance to the agriculture of an area:

- for bringing into cultivation marginal land suffering from organic deficiency; such areas are most common in tropical climates where hot sunshine tends to destroy organic matter;
- in areas where artificial fertilisers are in short supply or are very expensive.
SPECIMEN CALCULATION
FOR
WASTE TREATMENT PLANT SIZING
VENEZUELAN CITY 1982

Population Served : 180,000
Empirical Waste Generation Rate : 1 kg/person/day
Population Growth Rate : 3% per annum
Refuse Generation Rate Growth : 1% per annum
Daily Generation of Waste - now : 180 tonnes/day
Daily Generation of Waste - 10 years : 257 tonnes/day

<table>
<thead>
<tr>
<th>Assumed Mechanical Availability of Treatment Plant</th>
<th>80%</th>
<th>70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed Treatment Capacity Required - now</td>
<td>225t</td>
<td>257t</td>
</tr>
<tr>
<td>Installed Treatment Capacity Required - 10 yrs</td>
<td>321t</td>
<td>367t</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assumed Operational Mode of Plant - 2 shifts</th>
</tr>
</thead>
<tbody>
<tr>
<td>= 16 hrs/day</td>
</tr>
<tr>
<td>Hourly Treatment Capacity - now</td>
</tr>
<tr>
<td>Hourly Treatment Capacity - 10 yrs</td>
</tr>
</tbody>
</table>

Practical Plant Size Decision (subject to manufacturer’s advice)

Initial Installation - \(2 \text{ streams} \times 10 \text{ tonnes/hr} = 20 \text{ t/hr}\)

Ten Years Forward - \(3 \text{ streams} \times 10 \text{ tonnes/hr} = 30 \text{ t/hr}\)

NOTE:– This calculation and the succeeding text on Factors in Plant Size Calculations are intended as a general guide to the methods by which a mechanical solid waste treatment system should be sized. It is based on practical exercises carried out by the author in 1982.
FACTORs IN TREATMENT PLANT SIZE CALCULATIONS

1. **Plant Sizing**

Each calculation must be done to meet local conditions: Refuse generation rates, hours of work, population growth (or decline), and many other operational factors will affect the issue. The above calculations based on an actual case in Venezuela are listed as a general management tool. The figures for mechanical availability are discounts to allow for servicing, routine maintenance, and breakdowns that impinge on the day to day operation of mechanical refuse treatment plants. The refuse generation rates are high because Venezuela is a prosperous oil exporting country. In India or Ceylon the calculation would be quite different.

2. **Mechanical Availability**

Long experience in the United States and Europe has shown that waste managers must discount the theoretical throughput of a waste treatment plant to take account of a myriad of practical factors that will, in the real world, tend to reduce its day to day operating abilities. The factors can be influenced by climate, availability of spare parts, competence levels of local technicians and similar matters. This discount factor may be allowed for by responsible plant manufacturers in their submissions to managements and public health authorities but this is not always the case. Prudent managers must always watch for this, quite naturally enthusiastic marketing executives encouraging you to invest in one process or another do not wish to point out that their plants do, from time to time, fail to function. These mechanical availability factors will range from 65 to 85% of the theoretically stated capacity of the plant. Availability factors are also influenced by the number of parallel treatment streams.

A serious mechanical failure on a single stream plant will bring the whole waste disposal operation to a stop. The same failure on a two stream plant will reduce the instantaneous treatment capacity to 50% or on a three stream plant the fault would only reduce the instantaneous treatment capacity by 33.3%. These are quite significant factors and they highlight some quite serious weaknesses in a decision to construct a single stream plant except where some bypass treatment facility exists.

Based on European practice the overall annual mechanical availability of refuse treatment plants give the following range of figures. These are to be used as a guide and should be discussed with experienced and independent consultants.
3. Numbers of Streams

Another issue that must be considered by managements and decision makers is the impact on capital cost of the numbers of treatment streams whose sum of capacity will give the authority its required plant size. A single stream plant of 10 tonnes/hour may well be cheaper than a 2 x 5 tonnes/hour configuration. The same would apply say, if the choice rested between a required treatment capacity of 30 tonnes/hour being provided by 2 x 15 tonnes/hour streams or 3 x 10 tonnes/hour streams. All these need to be explored in the light of local circumstances. Manufacturers and tendering companies should be asked to illustrate the financial and operational implications of these choices. Civil engineering costs, and use of land will also be affected by these technical choices.

Streaming will allow the plant to be expanded later in its life to take account of population and refuse generation growth. A two stream plant with room for a future third stream is a common choice. Unnecessary and premature capital expenditure can be thus avoided.
RESIDUES

It is vital to appreciate that all mechanical treatment plants produce residues that must be disposed to landfill. Some reference to this has been made in Section B4. The author does not wish to patronise his reader but it is true that many decision makers believe that treatment plants make refuse disappear. This is not so. Even in the most sophisticated plants significant tonnage of residue must be removed from the plant. The removal of residues and the transport and management required for this must be a part of the capital plant decision. An incineration plant may well discharge 30% of input tonnage as residue, with a composting plant it could be as high as 50%. These residues may be much reduced in bulk and aesthetically acceptable, but residues they are and their transport and disposal cannot be ignored in capital plant evaluations.
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B.7

INDUSTRIAL & HAZARDOUS WASTES
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<td>13. Sampling Frequencies &amp; Results</td>
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LEARNING FROM WESTERN MISTAKES

While it may be held that much of the text devoted to sophisticated industrial waste systems or highly developed landfill methods is inapplicable to most developing countries, the position may not necessarily hold true in every case.

Oil exporting countries are formulating industrial policies that include the onshore processing of the oil and its by-products. Other mineral extraction and refining processes generate wastes with very aggressive characteristics. These and a variety of other developments will compel the governments of these countries to become familiar with the problems of industrial wastes sooner than they think. The West has made its mistakes; it cannot preach to the developing world but at least the latter can learn from the former's mistakes.

Even at the earliest stages of development a country may be required to become familiar with industrial waste disposal techniques. In the author's experience a West African State with a primarily rural and agrarian economy with some gold and bauxite extraction industries came to have to make a critical decision on toxic waste policy. This arose because an American waste disposal company wanted to seek consent to landfill toxic industrial liquids and sludges in exhausted mineral extraction sites. The economics of the equation being that it was cheaper to ship these wastes across the Atlantic Ocean rather than treat and dispose of them within the United States with its stringent standards imposed by the EPA.

The issue posed a social ethical dilemma for this nation. Was it right to accept or to reject. Was the risk greater or less than emotive responses suggested and could the disposal royalty payments have been put to good use. In the event the consent was refused. But was it the sound decision. This will occur in other places at other times, and for these reasons at least, the principles of these issues appear in this thesis.
A EUROPEAN PHILOSOPHY

The Governments of developing countries cannot ignore the problem of industrial waste disposal and its regulation. As they climb the development ladder as their industries develop they will have to face the problem. The West does not have a good record in that many mistakes have been made and there are a number of very bad examples of gross irresponsibility and neglect in waste disposal. At least the developing world has a chance to learn from our mistakes. Philosophies vary from an easy laissez faire stance on the one hand to excessive Government control on the other. As ever, the right road is a middle path between the two and these notes set out a consensus of European views.

Site licensing and the regulation of industrial waste disposal has been enacted in most of the industrial countries of Europe. The legislation differs from country to country, it varies in the allocation of duties, the complementary roles of the private and public sector, its powers and penalties, but a number of common threads appear in them all. Basically these are:

(i) Regional control of waste disposal;
(ii) Some intervention in the free play of market forces;
(iii) Some element of direction as to the disposal of wastes.

All the legislations require a survey to be taken, and a plan to be prepared. They all enjoin the controlling regional authority to take account of the waste disposal problems of industry as well as domestic and commercial wastes. All this is to the good, and is exactly mirrored in the Control of Pollution Act in our own country. So, too, with site licensing, the setting of conditions, the balancing of interests between waste disposal on the land, the protection of potable water supplies and the requirements of industry and commerce. But there is a fundamental parting of the ways after this point. This parting is the power or lack of it, for the regional waste authority to influence and direct private investments in waste disposal, to participate jointly in public and private sector ventures and to direct the delivery of wastes to certain sites and plants. In some cases this power extends to imposing capital levies on industry for the development of treatment plants and sites, the provision of 'in-house' disposal systems and subsidies towards the disposal of special wastes by approved methods. The examples that I quote are taken from the most successful and thriving 'free market' economies in Europe. It is a paradox that those countries with the most pronounced 'free market' philosophies should also have such 'socialist' waste disposal legislation.
FIGURE 64

CITY OF HAMBURG
COLLECTION AND DISPOSAL OF NOTIFIABLE WASTES
DOCUMENTATION SYSTEM

INTERNAL RECORDS
WASTE PRODUCER

DOCUMENTATION COPIES
1 2 3 4 5 6

WASTE DISPOSAL AUTHORITY RECORDS OFFICE

WASTE TRANSPORTER
INTERNAL RECORDS

WASTE TREATMENT FACILITY
INDUSTRIAL WASTE DISPOSAL

Introduction

Dr Stephen Willetts, writing in Chapter 15 of Practical Waste Management and his contributions to the annual courses run by the National Association of Waste Disposal Contractors in the United Kingdom has said that modern industrial activity basically involves the separation and isolation of various substances and their subsequent manipulation. All natural materials exist as an amalgam with other substances and the isolation and purification of any one component necessarily generates waste. Also, the manipulation of materials and their use in various manufacturing processes generates waste.

Such wastes exist in all three of the physical states and it is probably generally accepted that the liquid wastes pose the greatest problems as far as disposal is concerned. Atmospheric emissions and gaseous wastes in general are discharged with the benefit of extremely large dilution to air: solid wastes are easy to contain, store and handle and relatively easy to dispose of. Liquid wastes, however, are far from easy to contain and safely dispose of. There are various methods now available for liquid waste treatment and disposal depending on the type of waste in question. These are briefly reviewed.

Types of Waste

The categorisation of wastes is complex. For treatment and disposal, the broad properties and classifications of importance are shown in Figure 65.

The Nature of Liquid Wastes

An important consideration for liquid wastes is the fact that they normally exist as mixtures of substances. Moreover, the nature of any particular waste may change from hour to hour or week to week, depending upon the process from which it is produced. Quality control of product manufacture can also affect the nature of a waste and systems malfunctions can totally change its character. Variations in nature can be large and should be taken into account when considering disposal.

Another factor of importance is the possibility of stratification in storage either at a producer’s premises or at the contractor’s disposal site. Sampling of a waste prior to deciding upon disposal method is a science and an art and the goal of “representativeness” is difficult to achieve. Nevertheless, realistic samples must be obtained to allow the contractor to properly assess the waste. It is often imperative to take top, middle and bottom samples to enable reasonable screening of a waste.
PROPERTIES OF WASTE

- aqueous or non-aqueous
- acid, neutral or alkaline
- solution, emulsion, colloidal or suspension
- inorganic or organic
- inflammability
- viscosity
- interactions with natural environment
- special storage, handling and transport requirements
- special treatment and disposal requirements
- general health and safety requirements
- etc
EXAMPLES OF TREATMENT OPTIONS

1. **In House Treatment**
   - Reduction
   - Recovery

2. **Biological Treatment**
   - Disposal to Sewer
   - Disposal to Sewage Plant

3. **Physical Treatment**
   - Coarse Filtration
   - Medium Filtration
   - Fine Filtration

4. **Chemical Treatment**
   - Neutralisation
   - Incineration
   - Solidification
   - Encapsulation

5. **Combination Techniques**
   - e.g. Biological/Chemical
   - e.g. Chemical/Physical

6. **Landfill Techniques**
   - Containment Sites
   - Dilution and Dispersion
   - Co-disposal with Other Wastes
   - Mineshaft Disposal

7. **Sea Disposal**
   - Controlled Physical Dilution
   - Container Disposal in Deeps

8. **Energy Recovery**
   - Waste Derived Fuel
   - Energy Recovery Incineration
In-House Treatment and Recovery

A strong case can be made for 'in-house' treatment on both environmental and economic grounds. A major conclusion of studies in the United Kingdom is that the disposal of liquid wastes was intrinsically more dangerous than the disposal of toxic solids. Clearly in house treatment will be constrained by economic factors but its principal advantages can be expressed as:-

(a) A reduction in the quantities of liquid wastes to landfill;
(b) A reduction in the toxicity of these wastes such that the residues of the treatment become suitable for disposal on a wider range of local landfill sites;
(c) A conversion of liquid wastes to a physical state more readily acceptable for landfill.
(d) The reduction in volume must reduce transport costs particularly wasteful long distance haulage.

The Range of Treatments

Many ranges of waste can effectively be treated by in-house technology and some better known examples are:-

- Oxidation of cyanide wastes
- Neutralisation of acid and alkaline wastes
- Reclamation of acid wastes
- Neutralisation and precipitation of toxic metal bearing wastes
- Reduction of some types of chromium wastes
- Dewatering of sludges
- Fixation of some wastes
- Incineration on site

Some researchers have indicated only a tenuous dividing line between what is regarded as suitable for treatment and discharge to sewer and what must be tankered away for remote disposal. In many cases a little forethought in the design of the in-house trades effluent plant would have accommodated many of the liquid wastes tankered to remote sites.
A SURVEY OF TREATMENT OPTIONS

The following text is a resum. of waste treatment options in most developed countries. While many will be inappropriate to the developing world the scope of these alternatives may have a fundamental affect on their future development policies.

1. Biological Treatment and Disposal

Biological methods of treatment rely upon bacteria and other micro-organisms to abstract various organic pollutants from an aqueous carrier medium and metabolise these to inorganic by-products. The aqueous effluent from a biological plant is thereby purified to an extent depending upon the efficiency of the biological system. There is always produced a sludge of debris comprising dead and decaying biological matter in need of separate disposal. This can be used agriculturally as a fertiliser, digested to produce methane and then landspread, incinerated, tipped on land or dumped at sea.

Being biological, this system of treatment is prone to upsets from toxic constituents and such things as heavy metals and exotic organic molecules must be restricted.

a) Sewer Discharge

In the United Kingdom any waste producer may apply to a Regional Water Authority (RWA) for consent to discharge an aqueous effluent to sewer. If the RWA has hydraulic capacity and ability for treatment at the sewage plant then consent may be granted: consents are always subject to restrictions. Such restrictions are becoming more severe in the face of the legislative and moral desires to abate pollution of our watercourses, the final recipients of effluent from sewage plant. Payments to an RWA for reception and treatment of an effluent are, of course, rising. Payments and penalties for non-compliance with consent conditions are also increasing.

b) Sewage Plant

Some waste disposal contractors, some private organisations and some RWA's will accept liquid wastes for treatment other than via the sewerage system: for example, by road tanker. Many wastes are welcomed for disposal using this method; a caustic waste, for instance, can be used to help neutralise an acidic influent to a sewage plant that is serving an engineering orientated area producing steel pickling swills, etc for sewer disposal. Gas-tar liquors and coke-oven liquors are sometimes accepted at British Steel Corporation plants that have their own sewage plant specifically designed for this type of effluent that they themselves generate.
2. **Physical Treatment/Disposal**

The use of physical forces for wastes treatment principally involves the separation of phases as a purification step; this is basically filtration.

**a) Coarse Filtration**

Bar-screens, rakes, coarse meshes and booms can all be inserted in an effluent stream to effect removal of detritus. Pyramidal settling chambers and baffled weirs serve the same purpose for heavy debris.

**b) Medium Filtration**

Separation of suspended solids can be achieved using cloth filter presses, centrifuges, hydrocyclones, rotary vacuum filters, disc filters, etc. Pre-treatment using inorganic coagulants such as various calcium iron or aluminium salts or polyelectrolyte flocculants is often required.

**c) Fine Filtration**

Colloidal suspensions and emulsions can be separated by plate separators, reverse osmosis, electrodialysis, air flotation using either compressed air or electrolytically generated gas bubbles, etc.

3. **Chemical Treatment/Disposal**

Chemical methods for waste treatment and disposal are many and varied using several different principles.

**a) Neutralisation**

Aqueous acidic effluents can be neutralised to precipitate various metal hydroxides from solution. These can then be coagulated and separated from the effluent. Purified liquors are then suitable for sewer disposal and the filter cake may be acceptable on landfill.

This form of chemical treatment is operated by many waste companies in the West and can be considered as the provision of a central treatment plant in lieu of several in-house plant. The principal is the same: aqueous effluents are purified to render them suitable for biological treatment and the separated solids are disposed of elsewhere.
b) Incineration

Many organic effluents can be incinerated as they are self-supporting in combustion or even exothermic and the heat generated can be used to evaporate water from aqueous wastes and incinerate the residues. The use of supplementary fuel is often required during start-up but its continued use for assisting waste incineration is obviously costly.

Wastes for incineration are broadly classified as chlorinated and non-chlorinated. The significance is that chlorinated wastes liberate hydrogen chloride gas on combustion which attacks the refractory linings and which forms hydrochloric acid in the atmosphere and the general public do not like acid rainfall. Thus, incinerators capable of burning chlorinated compounds have to be equipped with water scrubbers to the sophisticated equipment to remove the acid gas. The scrubbers also remove sulphur oxides and phosphorous oxides with the same result. This system, of course, produces an acidic scrubber liquor in need of disposal which also contains suspended particulates and other materials in solution. It is not suitable for direct sewer discharge and has to be considered as a waste product itself.

Handling considerations also affect the type of waste that an incinerator can accommodate. Most incinerators are suitable only for bulk liquid feed by direct injection. Drummed wastes can be handled at these facilities by decantation of contents into the bulk tanks. A few incinerators can be fed with whole drums which is the only way to burn out viscous resins, varnishes and the like and solid wastes such as capacitors. A number of other installations incinerate mixtures of solid and liquid wastes in such a way as the solid waste acts as a sponge to its liquid counterpart. Such plants operate in Hamburg and in Bavaria in the Federal Republic of Germany.

Marine Disposal

Marine-based incineration overcomes many of the objections to land based acid fall-out and at least two operations offer this service in Western Europe. One company in Europe operates a ship equipped with two stern-mounted open-bowl incinerators. Incineration efficiency is claimed to be 100% and temperature is claimed to be 1,500°C. Each of the two incinerators operates at 20-30 tonnes/hour being fed from one of 13 separate cargo tanks. The incinerator bowls are 4.5m diameter and 8m high. The principal wastes handled by this ship are the chlorinated hydrocarbon by-products from PVC manufacture in Europe.
Another company operates a vessel which is equipped with one burner. The vessel entered service in 1972 and was a larger version of the original ship that started work in 1969. Its successor has now been built and is designed to accommodate solid wastes in addition to liquids. This latest vessel is capable of incinerating 15,000 tonnes of liquid and 1,500 tonnes of solid waste during each voyage of 21 day duration.

All marine incinerator ships have to comply with International regulations which specify double-hulled vessel construction, isolation of engine room and other safety requirements. Additionally all control equipment has to be remotely photographed by sealed apparatus at 30 minute intervals with the film being removed on return by the authorities and the incineration location is strictly defined.

c) Solidification of Wastes

In Europe and North America there operate a number of solidification systems. All operate under patented trade names and are well regarded by many regulatory authorities.

The types of wastes suitable are those that are principally of aqueous nature but organic contamination of several percent can be safely handled. The patented process adds various reagents to the wastes. The treated product sets in about three days to a hard, impermeable solid. Installed capacity of one plant in the United Kingdom is around 500,000 tonnes per annum.

Much published work is available on these systems and several independent assessments have been conducted, both in the UK and abroad. The results of one such well established system claims the following results. (See Figure 66.)
The solidification processes described previously are based upon silicate chemistry and the formation of inorganic polymers. Organic wastes are not usually compatible with this system but various organic polymer based solidification and encapsulation techniques do exist. Most are based on epoxy resins and are expensive. None operate in the UK.

Glassification and silicate fusion in general, is a form of encapsulation that is usually reserved for radioactive wastes. There has been extensive research into the suitability of these systems for radioactive wastes solidification and results to date have been promising.
Various disposal outlets are available that make use of biological/chemical/physical techniques in combination.

1. **Landfill**

Landfill is, of course, the traditional method for waste disposal and most liquid wastes are still disposed of by this system. This is developed in great detail in other parts of this thesis. There are two basic operations for liquid landfill: firstly, there is the system of absorbing the liquid onto domestic refuse and dry industrial wastes and, secondly, there is the system of the "balanced lagoon" in which liquid seeps away.

Research conducted in the United Kingdom has shown that "dilute and disperse" is an acceptable method for waste disposal. This is the philosophy adopted for liquid landfill. The principle is that liquids are absorbed onto other waste materials and underlying minerals and undergo biological, chemical and physical filtration during their inevitable downward gravitational movement. Upon entering aquifers or watercourses, there is hopefully sufficient filtration of pollutant species and sufficient diluting water to make the resultant pollution environmentally insignificant. In spite of extensive research in the United Kingdom that liquid landfill can be a safe disposal method, there is much controversy over the research work and interpretation of results.

2. **Sea Disposal**

Sea disposal of wastes in bulk form is reserved for large volume, aqueous industrial wastes that are readily biodegradable. For example, many wastes disposed of to sea are suitable for normal sewer discharge but may be produced in an area where sewage purification works are already overloaded or where none exist. Sea dumping is one solution for the disposal of these wastes.

For such wastes, the disposal method relies upon physical dilution into the marine environment, chemical degradation, photochemical degradation and biochemical oxidation to effect dispersion and destruction of the waste. Vessels can release their loads over the side, into the wake or by bottom discharge.

In 1979 in the United Kingdom some 1,145,000 tonnes of industrial wastes were licensed for sea disposal.
The Regional Water Authorities are the largest sea dumpers and in 1979 some 8,800,000 tonnes of sewage sludge were licenced for disposal at sea. These sludges are normally so contaminated by industrial pollutants, such as heavy metals, that they are precluded from agricultural use.

The Dumping at Sea Act, 1974, is the vehicle of control and the Ministry of Agriculture, Fisheries and Food administer the Act. Applications to dump waste are submitted to Ministry of Agriculture, Fisheries and Food with a sample of the waste and MAFF undertake biotoxicity testing on the sample at their Burnham-on-Crouch laboratory. The usual standard is that a waste must have a 96 hour LC50* of more than 3,000 ppm unless very readily degradable when the limit may be relaxed to 1,000 ppm. Some wastes with a 96 hour LC50 of less than 1,000 ppm may be permitted for sea disposal at very slow rates of release but MAFF are obliged to take into account any land based alternatives for disposal that may exist.

Disposal into the wake of a vessel is the normal method for off-loading industrial wastes and the rate of discharge is usually specified by Ministry of Agriculture, Fisheries and Food so as to ensure at least a one-thousandfold dilution into the sea. The Ministry of Agriculture, Fisheries and Food also specify the dumping ground having regard to navigation, fishing and amenity interests and the tides.

The dumping of drummed wastes is also permitted. This relies upon initial containment and slow release at sea bed level. Cyanide, arsenic and antimony wastes have all been disposed of to sea.

The Ministry of Agriculture, Fisheries and Food, of course, are also responsible for the enforcement of the regulations of the Act and arrive unannounced at ports of departure to take samples, are empowered to travel with a vessel to observe the dumping and have their own patrol vessels.

Various International Conventions have been signed by most industrial nations and these seek to prohibit the dumping of certain wastes at sea and to restrict others.

Deep Mine Disposal

Close to the East German border, east of Bad Hersfeld in the State of Hesse, is the deep mine toxic waste storage facility operated by Kali and Salz A.G.

*NOTE:*- LC50 refers to lethal concentration of 50%. i.e. A lethal or toxic dose of such intensity that the mortality rate of the targeted life form (i.e. fish) shall not exceed 50% in a 96 hour test. (MAFF term.)
With access to the North/South Frankfurt-Hannover-Hamburg autobahn this important site provides unique and safe deep storage for a wide range of industrial waste from all parts of West Germany. On the international scene special consignments of waste from Switzerland, Holland, Austria, France, Belgium, Luxemburg, Denmark and Sweden all find a home here 700 metres below ground level. In one or two special cases wastes from the United Kingdom have also made the journey to the Herfa-Neurode mine shaft. (See Figure 67)

Kali and Salz A.G. started operations in 1972 and by May 1977 over 120,000 tonnes of solid toxic wastes had been deposited in the site. By the end of 1980 the figure had risen to 300,000 tonnes. The management estimate the mine shaft input to stabilise at 40,000 - 50,000 tonnes a year and that this will consume about 150,000m³ of air space in the old workings. On these calculations Herfa-Neurode's estimated 3,000,000m³ of air space will last at least 20 years.

The Zechstein salt strata in this area go back more than 200 million years and are about 300m thick. Bedded amongst them are seams of potash each about 2-3 metres thick and separated by layers of rock salt about 60m thick. The waste is stored in the lowest potash seams.

For various technical reasons backfilling was not practical when the seam was worked. Thus by an efficient system of propping the old workings are permanently accessible. Above both the upper and lower potash seams there is more than 100m of solid compact rock salt forming a block almost 300m thick. Above this is a 10m layer of salt clay deposit and then at least 35m of clay, topped by shale dolomite, clay and 200 - 500m of new red sandstone. By any environmental standards this must be a totally safe facility. Even earthquakes have no effect. The geological evidence shows that despite severe tectonic and thermal stresses about 25,000,000 years ago the deposits have remained undisturbed. West German mining technologists have established that trapped gases within the salt have been there for millions of years unable to escape from the natural 'glass' bottle.

All waste is delivered in clean and travel-proof packing usually in sealed steel or plastic drums on one way pallets capable of fork lift handling. Wastes must not form ignitable, explosive or toxic mixtures with gas and air within the enclosed mine workings. All liquid wastes and sludges must first be solidified by thickening or chemical fixation before deposit in its container. Checks are made to determine wastes that are incompatible or react one to the other. Such substances are deposited separately in segregated sections of the workings.
DEEP MINE STORAGE OF TOXIC INDUSTRIAL WASTES
HERFA • NEURODE, WEST GERMANY

FIGURE 67

upper and lower new red sandstone

sandstones bearing ground water

headworks and buildings of old mine

alluvium

toxic waste storage area in old workings at 705 m below ground level

DEEP MINE STORAGE OF TOXIC INDUSTRIAL WASTES
HERFA • NEURODE, WEST GERMANY

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The palleted waste containers travel to the 700m level in the mine cases and are then transferred to wagons en route to the storage area about 4km from the shaft. Once there the fork lifts stow pallets and drums in the various sections of the workings.

Careful planning and good management underground separates the various types of wastes: these include carburisation residues, galvanic sludges, dyestuff residues and distillation residues. Substances which may over the years form noxious gas/air mixtures are walled up in a separate part of the area to prevent them affecting mine ventilation and hampering work below ground. The mine now contains over 900 types of waste material. Some wastes come in quantities as high as 7,000 tonnes a year while others total no more than a few kg. These smaller amounts include arsenic compounds, laboratory residues and unwanted pharmaceutical products.

Some similar opportunities must exist in developing countries particularly those with extensive mining and mineral extraction industries. The experience of West Germany is worth consideration.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill</td>
<td>1 - 20/tonne</td>
</tr>
<tr>
<td>Solidification</td>
<td>5 - 150/tonne</td>
</tr>
<tr>
<td>Incineration</td>
<td>10 - 350/tonne</td>
</tr>
<tr>
<td>Sea Incineration</td>
<td>30 - 170/tonne</td>
</tr>
<tr>
<td>Chemical Treatment</td>
<td>10 - 250/tonne</td>
</tr>
</tbody>
</table>

**FIGURE 68**

A Range of Treatment Costs in the United Kingdom (1982)
LEGISLATIVE/ECONOMIC CONSTRAINTS

It is important for managements in developing countries to realise that two factors govern the choice of disposal method.

Firstly, there are legislative constraints administered by various statutory authorities. For liquid wastes in the United Kingdom various Acts relating to public health and water pollution exist on the Statute Book. In developing countries some form of legislative code may exist. This code (and this is discussed elsewhere in this thesis) will have to take account of local economic conditions and socio-economic factors.

Economic constraints are equally important to the industrialist. Direct costs for waste disposal are easy to obtain and interpret as it merely involves the obtaining of a quotation from a contractor. The indirect costs associated with the chosen method are, however, not easy to compute but these are beginning to play an increasing role in how the industrialist assesses his waste disposal route. For example, many waste producers take time to make themselves aware of the environmental consequences of a particular disposal option and are becoming anxious to reduce or obviate any risk of liability rebounding on them after the disposal event. Current reporting of public enquiries into planning and site licencing appeals and incidents such as "Love Canal"* in the United States reach the popular press and industrialists are conscious of the changing situation. As such, waste producers do not now always choose the lowest quotation.

NOTE:--*The Love Canal incident refers to the problems that arose in August 1978 in the Niagara Falls area of New York State after an alleged epidemic of miscarriages, birth defects and cancers in the residents of a housing development built on and adjacent to a completed toxic waste landfill dump. The waste was deposited over several years by the Hooker Chemical Company. Two hundred homes were permanently evacuated. A book on these problems was written by Michael H. Brown – see Bibliography Reference 5.
INDUSTRIAL WASTE SURVEYS

In the richer developing countries it will be necessary to take account of the needs of industry, and earlier text in this chapter has gone in to some detail setting out the types of industrial wastes, particularly hazardous wastes that are likely to arise. The treatment of these wastes have been discussed. Before any such plans can be drawn up it will be necessary to establish the size of the industrial sector. How big is it now, how big will it grow, what are the industries, what wastes do they generate, what resources do they need to collect and dispose of these wastes and how much shall industry be charged for the services provided. These are some of the questions to be answered. The following notes give some guidelines as to how a survey team may approach the problem.

The industrial sector in most developing countries, because it is so vital to the nation’s economy, will be surprisingly well documented. While it may be hard to discover how many doctors, nurses or public health inspectors there are in the countryside the existence of factories, their functions, employees, capital investment, ownership, location and output will be on record. Several countries will possess national industrial plans and industrial directories updated at regular intervals. The Federal Republic of Nigeria is a model in this respect. The Nigerian Investment Information & Promotion Centre controlled by the Federal Ministry of Industries issues a very professional record of the country’s industrial base. The 8th Edition dated 1980 runs to 250 pages and details State by State the:

- Name of Establishment
- Address
- Year Operations Started
- Products Manufactured
- No’s of Employees
- Plant Installed
- Capacity Utilised
- Capital Investment
- Shareholdings

Industries are split into 13 main groups and these include:

- Mining & Quarrying
- Food, Beverages & Tobacco
- Textiles, Wearing Apparel & Leather
- Wood & Wood Products including Furniture
- Paper & Paper Products, Printing & Publishings
- Chemicals, Petroleum, Coal, Rubber & Plastics Products
- Non Metallic Mineral Products, Pottery & Glass
- Basic Metal Industries
- Fabricated Metal Products & Machinery
- Electrical & Communication Equipment
- Miscellaneous Manufacturing Industries
- Electricity, Gas & Water Utilities
- Repair Services
These 13 main groups are further sub-divided into 71 sub-headings.

Most industrial waste surveys in the West are based on sample analyses from a selected segment of companies in each of the principal categories. Numbers of employees is a common correlation factor and although caution must be exercised in avoiding a too liberal use of multipliers based on employees they can form a useful guide to the waste produced. There is an abundance of technical literature in the West on computing industrial waste arisings and the following notes are intended to point the way and suggest in outline how the task may be tackled. The United Kingdom’s Department of the Environment has published one of its series of Waste Management Papers on the Subject of Waste Surveys (Management Paper No. 2) and these are available from Her Majesty’s Stationery Offices. Public Health Officers and City Managers should refer to these when necessary.

LAGOS

For the purposes of illustration the following tables illustrate a survey of industrial wastes in Lagos. The industrial sector was estimated to be 1500 companies and the facts and figures given relate to the provision of a comprehensive industrial waste service for the 4,000,000 population capital city of Nigeria.
Ensure that all major waste producers are included.

Ensure that the predominant waste producing industries are surveyed in depth.

Ensure that all the biggest employing industries are surveyed in depth.

Ensure that you establish the name of the person responsible for wastes handling.

Ensure that you arrange a personal interview with this person.

Ensure that you inspect the premises to see for yourself the wastes arising, quantities, storage, access and other waste handling aspects.

Ensure that a standard questionnaire is used for survey interviews. Record all evidence and data accurately.
INDUSTRIAL WASTES

ACTIONS TAKEN ON SURVEY

Identify types of industries from which waste is to be collected.

Identify all producers of waste within each industrial category from best available sources.

Identify the scale of operation of each producer using best denominator available - e.g. numbers of employees.

Decide the depth of survey and sampling of each type of industry and scale of operation of producers.

Identify the types and quantities of waste at each sample.

Decide the most suitable unit for measuring the waste quantity - e.g. weight, volume, loads.

Relate quantities of waste to common denominator e.g. weight per employee, size of premises, investment levels.

Interpolate the data from the types of industry, numbers of producers, size of producers and quantities of waste to arrive at the quantities of waste in each industry. This should be classified by type and weight and/or volume.

Decide most suitable form of storage and transport for each type of waste.

Decide the allocation of waste containers to each industrial producer.

Calculate the collection load the producer will make on the service and use this to build up the composite picture of the vehicle and plant resources required.
Take special note of special wastes, liquids and sludges and try to establish the demand for provision of special tankers and controlled landfills and treatment plants. In most developing countries this is still a minimum problem.

Collate and produce comprehensive industrial waste plan identifying producers of waste by industry, size of operation, waste generated, physical location, storage and transport required and disposal facilities.

Where a regular industrial waste service is to be instituted define the collection frequencies, routes and charging policies.

SOME WASTE CLASSIFICATIONS

Food, drink and tobacco
Coal and petroleum products
Chemical and allied industries
Metal manufacture
Mechanical Engineering
Instrument Engineering
Electrical Engineering
Shipping
Vehicles
Other metal goods
Textiles
Leather and furs
Clothing and footwear
Bricks, pottery, glass and cement
Paper printing and publishing
Other miscellaneous industries

OTHER GENERATORS OF WASTE

Civil, building and construction wastes
Agricultural and allied industries
Quarries and mining
Power stations
PRINCIPAL FEATURES OF INDUSTRIAL WASTE
FROM VARIOUS SOURCES

Food, Drinks and Tobacco Manufacture

Principally organic wastes in solid, sludge and liquid forms. Many of these wastes are recycled in developed countries either directly for animal food stuffs, fertilisers or indirectly as raw materials for another industry. Because of their high organic content, particularly in their sludge and liquid forms, these wastes have a high chemical and bio-chemical oxygen demand and are therefore difficult to handle and dispose. Particular care must be exercised when these wastes are placed in sanitary landfill sites.

Coal and Petroleum Products

The composition of these wastes is linked naturally to the type of treatment systems of coal or petroleum or its derivatives. Commonly the wastes generated are oils, greases and phenolic contaminated residue. Many of these are difficult to handle particularly in liquid form. In some industries waste oils are recycled or incinerated on site.

Chemical and Allied Industries

These industries are the principal producers of chemically contaminated wastes in all physical forms. This is in addition to quantities of general factory waste. This can consist of paper, packaging, floor sweepings, discarded metal components and stores. In some advanced industries wastes are pre-treated on site with effluents discharged to sewer. When this happens filter cakes and sludges are generated, these may be contaminated.

Metal Manufacture

Basic metal industries produce considerable quantities of waste including metals and foundry sand. Many of these sands contain phenols and other organic binding agents which can pose a serious risk from polluted leachate if these wastes are disposed on hydro-geologically sensitive landfill sites. Pickling bath liquors are also a problem. Metal industries also produce slag some of which are high in chloride content and soluble. This too can produce problems on landfill sites.
Another example of Bulk Waste Container and handling system used on commercial and industrial wastes.

Courtesy: Leigh Interests Ltd.

Figure 2 A demountable bulk container system for industrial wastes. (Courtesy of Thomas Black Ltd)
**Mechanical Engineering**

The principal waste produced is general metal scrap particular to the industry. Some chemically contaminated wastes are produced including waste oils and oil-water mixes. Galvanising and other processes including degreasing and cleaning can produce acidic cake and sludges. These require careful handling. Occasionally oils are reclaimed from oil-water mixes. Effluent treatment cakes and sludges can arise and these may be contaminated by metal compounds including heavy metals.

In addition to these wastes will be general factory waste, discards, office wastes and food wastes from canteens.

**Instrument Engineering**

These industries are not major waste producers although it is conceivable that from time to time they may generate small quantities of difficult wastes such as mercury. The principal waste arisings tend to be general factory waste, packaging and sweepings.

**Electrical Engineering**

Principal wastes tend to be cable scrap, insulation materials, insulating oils from switchgear and transformers and cable insulating compounds. In the electronics industry considerable quantities of plastic board and component cases may be discharged. In electric lamp manufacture there may be quantities of fluorescent tubes and glassware. Battery charging can create quantities of spent electrolyte and chemicals. Metal scrap may be recycled. In addition to this will be quantities of food wastes and office wastes.

**Shipbuilding Industries**

The principal wastes generated are metal scrap and timber. But it can include electrical wastes, furniture, fittings and metal components. Food and office wastes will also arise.

**Vehicle Fabrication and Parts**

The principal wastes are metal scrap, plastics, paints, electrical cabling and other objects such as car upholstery textiles. Various industrial effluents will also arise and it may be necessary to dispose of filter cakes and sludges. The
cleaned liquors may be discharged to sewer. Metal degreasing, corrosion inhibiting and protective processes may give rise to chemical wastes. There may be considerable quantities of packaging, office and canteen wastes.

Textiles
The principal wastes are paper, cardboard and yarn wastes. Some of these wastes can be recycled. In wool industries particularly where the fleeces are processed considerable quantities of lanolin wastes are generated. These may be treated in effluent plants and the lanolin sludges may require to be landfilled. They can be a problem. General office, material offcuts and food wastes.

Leather, Leather Goods and Fur
These industries can produce highly polluting organic liquid and sludge wastes requiring pre-treatment before disposal. Offcuts of leather and fur will be generated together with general factory waste, office and canteen wastes. Occasionally some tanning wastes can be used as fertiliser on the land.

Clothing & Footwear Industries
The principal wastes generated are fabrics, leather, plastics, packaging, paper and cardboard. Some of these materials may have secondary uses in other industries. The 'shoddy' industry in the United Kingdom is an example. General factory wastes, office and canteen wastes will also be generated.

Non-Metallic Mineral Products
These are wastes from the bricks, pottery, glass and structural earthenware industries. The wastes are large quantities of fired ceramics, plastic moulds and liquid clay slip. Some of these wastes may be disposed of 'in-situ'. Some may require external disposal. Clay slip can be a problem; there will also be the usual additions of office and food wastes.
Timber & Furniture

The principal wastes are wood, sawdust, fabrics and plastics. Some of these wastes can be used by other industries. Occasionally wood and sawdust are used as a fuel within the factory. Other uses of the wastes are in the manufacture of chipboard, packaging and animal bedding. Food and office wastes will also be generated.

Paper & Printing Industries

The principal wastes are paper offcuts and discarded paper products. Some of these wastes are recycled to the board mills. Paper manufacture produces large quantities of sewer borne liquid wastes. These are high in organics. The filter cakes resulting from pre-treatment of liquid effluents will require external disposal. Paper wastes can be low in density and may require on site compaction equipment. Food and office wastes will be present.

Rubber & Plastics Industries

These industries produce large quantities of rubber and plastics discards. Resulting from these there may also be effluent treatment sludges and other chemically contaminated liquid and sludge wastes. In large quantities scrap tyres can be a problem particularly in landfill sites. Occasionally tyres are shredded before disposal. Specialist incinerators are available to incinerate rubber tyres and plastic wastes. These incinerators by virtue of their gas cleaning plant can produce aggressive liquors that need treatment.

NOTE

In all the earlier groupings of industrial waste general factory waste will be present. This is the ‘domestic’ type waste generated by the presence of employees and office staff. This waste may resemble domestic waste with additions of floor sweepings, packaging, paper dust, metal containers and similar debris. This waste bears a strong correlation to the number of employees.
TYPICAL SAMPLING FREQUENCIES

<table>
<thead>
<tr>
<th>Employees</th>
<th>Sample</th>
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<tbody>
<tr>
<td>Over 100</td>
<td>100%</td>
</tr>
<tr>
<td>50 - 99 Employees</td>
<td>50%</td>
</tr>
<tr>
<td>25 - 49 Employees</td>
<td>25%</td>
</tr>
<tr>
<td>0 - 25 Employees</td>
<td>10%</td>
</tr>
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</table>

NIGERIA
Industrial Directory

<table>
<thead>
<tr>
<th>Category</th>
<th>Employees</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>10 - 24</td>
<td>5%</td>
</tr>
<tr>
<td>C</td>
<td>25 - 49</td>
<td>10%</td>
</tr>
<tr>
<td>D</td>
<td>50 - 99</td>
<td>25%</td>
</tr>
<tr>
<td>E</td>
<td>100 - 199</td>
<td>25%</td>
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<tr>
<td>F</td>
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<td>G</td>
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<tr>
<td>H</td>
<td>1000 - 1999</td>
<td>100%</td>
</tr>
<tr>
<td>I</td>
<td>2000+</td>
<td>100%</td>
</tr>
</tbody>
</table>
**FIGURE 72**

Lagos State Industrial Review

Size of Industrial Section - 1982

*(estimates based on 1980 Industrial Review)*

Classified by Firm Size - Number of Employees

<table>
<thead>
<tr>
<th>Reference</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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<th>H</th>
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<th>TOTALS</th>
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**FIGURE 73**

Lagos State Industrial Review (estimates based on 1980 District Directory)
Chapter References

1. The Scientific Management of Hazardous Wastes
   Cambridge University Press
   : C B Cope, W M Fuller, S L Willetts

2. Practical Waste Management Course
   Proceedings - National Association of Waste Disposal Contractors
   United Kingdom
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3. Practical Waste Management
   John Wiley & Sons Ltd
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4. Industrial Waste Survey, Lagos
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   : Powell Duffryn Pollution Control Limited

5. Laying Waste - The Poisoning of America by Toxic Chemicals
   : Michael H. Brown
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SECTION C

THE FUTURE
We are a long way from the optimistic decades of the 1950's and 1960's. Then everybody seemed to think that the rate of growth and prosperity would not diminish. The present reality is that the economic and environmental situation in the greater part of the developing world is not getting better by any standard of measurement - financial, social economic or political. Standards of public cleanliness are inextricably linked to these facts and so one is led to say that the somewhat simplistic and manual systems described in this thesis will continue to be the norm well into the foreseeable future.

Sophisticated treatment plants, complex transport systems and pious hopes for extensive recycling and reclamation will be illusory for the majority. The developing world will have to learn to keep itself clean with limited resources and perhaps limited commitment on the part of its political masters. It will have to make do and mend.

For this reason there is a case to continue and develop simple low cost systems and bring to bear on these the intellectual efforts hitherto devoted to sophistication. Loughborough University's WEDC Unit is a leader in the field and others must follow their example. There is a lot more to be learnt on effective uses of manpower and management, the development of indigenous vehicles, containers and tools. Our friends must acquire skills in adapting western technology and methods to suit the special conditions in developing countries. Equally there is a lot to be learnt from the western mistakes and this thesis has tried to show where these mistakes are most likely to occur.

The exporters of western technology have a great responsibility to see that when they are called upon to advise they do so cautiously with a proper appreciation of the apt solution to the problem. The indiscriminate injection of western methods is not the way forward.
SECTION D
PHOTOGRAPHS AND SUPPORTING LITERATURE
CAPTIONS:

1. Refuse collection methods, prosperous OPEC city. Middle East 1981.


6. Abandoned car collection systems introduced by Lagos State Waste Disposal Board.


