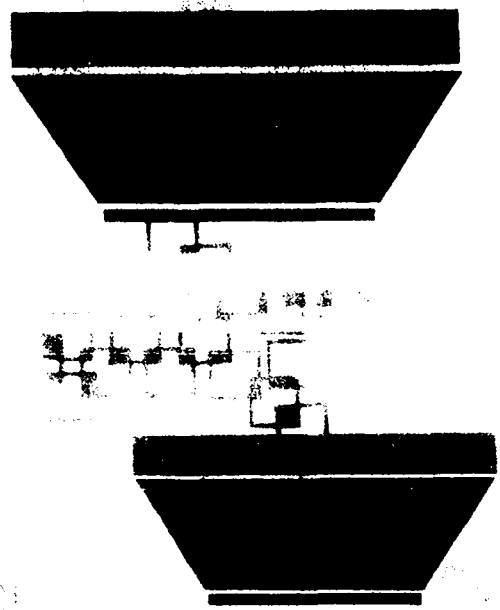


# SOLID WASTE MANAGEMENT IN DEVELOPING COUNTRIES

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# SOLID WASTE MANAGEMENT IN DEVELOPING COUNTRIES

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## FOREWORD

Indians are second to no other people in the world when it comes to personal cleanliness. Our habit of taking daily bath, washing our clothes, cleaning our houses, especially the kitchen, has traditionally been of the highest order and yet we did not pay adequate attention to the problem of environmental hygiene. As we became poor, poverty itself contributed to the degradation of the environment.

2. To fight against poverty and squalor development becomes necessary. Industrialisation and urbanisation lead to generation of wastes in liquid, solid and gaseous forms, a good part of which could be recycled and reused. We should not make the mistakes of some of the industrially advanced countries which had to pay a very heavy price for not paying due attention to the protection of the environment.

3. Environmental degradation in our urban centres has also reached alarming proportions due to indiscriminate and unregulated disposal of solid wastes. The data compiled at all India level and the methodology followed in the choice of suitable technology for urban solid waste management attempted in this book is one of the forerunners to make the country self reliant in this area. CSIR and its laboratories have always been emphasising self reliance in Science and Technology and it is hoped that this approach followed in India will have wider acceptance and adaptation in other developing countries which face similar problems.



Professor S. Nurul Hasan  
Vice-President  
Council of Scientific and Industrial Research

## FOREWORD

Often in the past and even today, the supply of safe drinking water to all people in towns and villages seems to get all the attention while the disposal of wastes is neglected. This is wrong and so for many reasons. Wastes can carry diseases and make water unfit for human consumption. Wastes also harbour vectors of diseases some of which may contaminate food if the waste is infected. Waste management both liquid and solid is an imperative in the developing countries where the incidence of water and waste-borne diseases is highest and where particularly infant mortality and morbidity can be reduced by sound sanitary practices.

But wastes also contain valuable material in amounts large enough to command their reuse or recycling. Waste management is therefore not only an imperative for public health but also a matter of good house-keeping. Solid wastes are increasing in number and complexity and much more attention needs to be focused on that sort of wastes. Indeed, without sound solid waste management how would it be possible to maintain decent standards of public health and beyond that a quality of life?

Today, the concern about the quality of the environment involves many aspects of the life of the individual and the community. The pollution of the air and of water, noise, the psycho-social aspects of life in large cities, the life-supporting capacity of our planet, energy resources and consumption, and the balance between our spaceship earth and the universe are on our minds. But let us not forget that in terms of the health and life of about two billions of people or more, basic environmental sanitation is priority which affects them now as it did yesterday and which must be attended to aggressively in the fight against poverty and ill-health. The management of solid wastes in developing countries is thus a matter of utmost concern.



Dr. B.H. Dieterich  
Director, Division of  
Environmental Health  
World Health Organization  
Geneva, Switzerland

## P R E F A C E

Solid waste management involves activities associated with generation, storage, collection, transfer and transport, processing and disposal of solid wastes which are environmentally compatible, adopting principles of economy, aesthetics, energy and conservation. It encompasses planning, organisation, administration, financial, legal and engineering aspects involving inter-disciplinary relationships. In spite of the large expenditure involved, it has received scant attention in developing countries resulting in insanitary conditions in most of the towns and cities. Technological solutions available in developed countries in this field cannot be directly adopted in developing countries due to differences in waste characteristics, degree of industrial and economic development, financial constraints and socio-cultural aspects. Even with these constraints, it should be possible to provide better services with good management. This book deals with the basic principles involved in management of solid wastes highlighting indigenous solutions appropriate to the conditions in developing countries. Model design and cost calculations have been presented to help the designers.

Some of the constituents of solid wastes can be recycled and reused, resulting in overall economy. This has been stressed as a common theme throughout this book. Special emphasis has been given on legislation, planning and management aspects which are essential to ensure an effective system.

Absence of such a book with references and data for wider application in developing country situations is keenly felt by students, researchers, designers, managers of public health agencies and administrators. It should prove useful towards better management of solid wastes in developing countries.

## ACKNOWLEDGEMENTS

Data collected by several specialists in India has been used in preparing this book and cited at appropriate places. S/Shri S.K. Titus, A.V. Shekdar, B.Z. Alone, M.S. Olaniya, A.D. Patil, R.V. Bhoyar and V.U. Muley, Scientists, NEERI deserve special mention for their valuable help and co-operation.

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## PUBLISHER'S NOTE

INSDOC has a programme to publish state-of-the-art reports on subjects of national importance and relevance. The state-of-the-art reports are intended to provide a synoptic view of recent developments and current trends in selected subjects. The subjects are selected carefully upon the advice of learned scientists and science agencies. Experts in the subjects are identified and are requested to write the reports. Insdoc provides bibliographical and literature support to the experts, if required.

This first report in the state-of-the-art series of Insdoc is on Wind Energy. It was published in July 1982. The present volume, which is the second in the series, relates to Solid Waste Management and is written by Dr. B.B.Sundaresan, Director and Shri A.D. Bhide, Scientist & Head, Solid Wastes Division, National Environmental Engineering Research Institute, Nagpur. Another report on Carbon Technology is under preparation. A few more subjects such as *Plant Tissue Culture and Fibre Optics* are also being taken up.

This report on Solid Waste Management provides valuable information on management techniques suitable for application in developing countries. A bibliography of 86 references and a glossary of terms relating to solid wastes are appended to the report. Other annexures relate to Collection and Analysis of Refuse Samples, Preparation of Refuse Samples for Microscopic Analysis and Municipal Acts of Bombay, Calcutta, Sri Lanka and Singapore.

It is hoped that this report, besides giving current status of the subject, will serve as a practical tool for the effective and economic management of solid wastes in developing countries.

Suggestions and comments, if any, for the improvement of the state-of-the-art series are welcome.

New Delhi,  
April, 1983

Scientist-in-Charge  
INSDOC

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## ERRATA

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10, 3rd line from bottom	incorporating suitable material in their curriculum
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83, 4th line from bottom	anaerobic conditions would set in if the moisture content is too high. It
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106, 3rd line	Section 11.11 deals with the design of a multiple chamber
111, 4th line	tonne of refuse burnt depending on the type of unit.
154, Reference 41	41 Gotaas H.B. 'Composting' WHO Monograph Series no.31, 1956.
164, 8th line	$DS = (e/c) \times 100$
166, 3rd line	1. SCOPE
171	
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201, 23rd line	(2) The corporation may by regulations determine
205, 5 (h) 2nd line	mosquitoes and other disease bearing insects;
209, 10th line	(3) The authority shall have and may exercise all the powers conferred on the commissioner, a Medical
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## CHAPTER 1

### INTRODUCTION

#### 1.1 General

Solid wastes are being produced since the beginning of civilisation. During the early period, solid wastes were conveniently and unobtrusively disposed of as the density of population was low with large open land space. With the advent of industrialisation and urbanisation, the problems of waste disposal increased. High population density, intensive land use for residential, commercial and industrial activities led to adverse impact on the environment. Environmental impact due to gaseous and liquid discharges has received greater attention than that by solid wastes. This third pollution or land pollution (as it mainly affects land) received limited public attention though it is significant.

The term 'waste' implies that it is of no concern to anyone and is of no value. The intrinsic value of the material as a resource or as an object of further utility has not been fully recognised. The net result is to reduce the expenditure involved for its disposal by meagre allocation of resources. This does not mean that no expenditure is incurred for this purpose and it is reported that in some developed countries the expenditure incurred for solid waste management is quite substantial.

The collection, transport, processing and disposal of solid wastes (which is a highly visible and important municipal service) involve a large expenditure but receive scant attention. The citizens get accustomed to live with this nuisance, though avoidable. The attention provided falls far short of the known and desired practice which could be attributed to public apathy, entrenched habits and traditions and vested interests leading to ineffective management. Adequate information on the management techniques adopted in developed countries is available, which could be applied to developing countries with suitable modifications. Such an effort is now made to enunciate technological aspects taking into account the differences in waste characteristics, degree of industrial and economic development, financial constraints and socio-cultural aspects.

## **1.2 Solid Waste Management**

It involves management of activities associated with generation, storage, collection, transfer and transport, processing and disposal of solid waste which is environmentally compatible adopting principles of economy, aesthetics, energy and conservation. It encompasses planning, organisation, administration, financial, legal and engineering aspects involving interdisciplinary relationships. Annexure-I defines some common terms used.

### **1.3 Outline of Functional Elements**

#### ***1.3.1 Generation***

Wastes differ in the rate of generation, quantity and quality depending upon the area of generation. The quantity and quality from residential areas may not vary appreciably. On the other hand, wastes from commercial and industrial areas may vary in quality and quantity at different times of the year. This will have a marked effect on the selection of method for its collection, processing and disposal.

#### ***1.3.2 Storage***

The generated waste is stored within the premises in commercial and industrial areas; whereas in residential areas, occupants take it out and transfer to community storage bins.

#### ***1.3.3 Collection***

Citizens deposit the wastes by the roadside from where the conservancy staff transfer it to the community bins using wheelbarrow or other equipment. Such primary collection is common in India and other developing countries which need a large number of workers and small number of equipment.

#### ***1.3.4 Transportation***

The material collected in community dustbins is transferred to transport vehicles for transport to the processing or disposal site. The fleet of transport vehicles should have sufficient capacity for average and peak loads and should be utilised at optimum levels. In big cities the material is conveyed to a transfer station from where another set of vehicles transport it further. This movement of vehicle is often taken as a part of collection as the vehicles collect waste from individual sources (houses). In most of the developing countries, the waste is collected from well dispersed discrete points and hence referred to as transportation.

### *1.3.5 Processing and Recovery*

A large quantity of waste has to be processed before suitable disposal to reduce its potential nuisance value. Occasionally recovery of useful constituents is also carried out as an independent process.

### *1.3.6 Disposal*

The waste may come for disposal either directly after its transportation, or after processing. Disposal could be on land or water logged areas for reclamation. The different functions are interdependent and interrelated which could be better managed by a systems approach. Disposal method costing less may not always be the best, which may be offset by higher transport or processing cost.

## **1.4 Problems in Developing Countries**

The waste characteristics in developing countries are known to differ considerably from that in developed countries due to differing food habits, culture, traditions and socio-economic aspects. The organic matter is found to be higher due to the use of fresh and unprocessed vegetables and has a high moisture content. Unpaved roads and seasonal variation in climatic conditions tend to increase the ash and soil content increasing the density of the waste. Correspondingly lower calorific value has been observed. Urban centres in developing countries are mostly modern outgrowths of ancient cities with narrow winding streets requiring small slow moving vehicles for collection and transport.

In developed countries, due to exposure to industrial and urban activities for well over a century, the population became aware of the problem much earlier. Suitable legislation and regulations provide an effective working system for taxation and its realisation. Developing countries have just started facing these problems, for which necessary legislative action and financial inputs are required. A high degree of mechanisation may not meet with the approval of the citizens. Environmental awareness has yet to manifest itself and several towns continue to have the old conservancy system of sanitation. The conditions prevalent are so different that it will not be prudent to attempt direct transfer of technological solutions.

## CHAPTER 2

### ORGANISATION AND MANAGEMENT

#### 2.1 Introduction

The solid waste management committee of the National Research Council in its report to U.S. Bureau of Solid Waste Management in 1970 stated 'Much of the problem of solid waste management derives from the continued reluctance of those concerned to come to grips with it and apply existing technology, systems, and organisational know-how to its solution and above all to pay for these services'. Solid waste management involves interplay of six functional elements - generation of waste, storage, collection, transfer & transport, processing, recovery and disposal. Planning should be undertaken at local, state and national levels for organising an effective programme. This will involve investigations and decisions to be taken regarding various aspects of the system to obtain optimum level of performance. In most of the developing countries, the existing methods of collection, processing and disposal are labour intensive and large amounts are spent directly and indirectly on this activity. The level of service provided does not meet sanitary requirements as well as citizens' satisfaction. With the passage of time, the waste quantities will increase, become more complex and the degree of mechanisation will increase needing skilled personnel. As in other technological developments, the professionals should anticipate the future requirements and plan appropriate programmes well suited to the local requirements at the least cost.

#### 2.2 Planning

In addition to these activities, a separate planning section should be provided, though day-to-day planning need be performed by the respective sections. The planning section may also be assigned special technical service tasks. In the case of smaller civic agencies, instead of a separate planning unit, the central planning unit of the agency could provide required support. Decisions on short term (3-5 years) and long term (10-20 years) design period, planning on various operational elements of the system should also be the functions of this section. It should work in close colla-

boration with other planning agencies at local, state and national levels to ensure better coordination in allocation of priorities and resources. The collection, transportation, processing and disposal aspects, the facilities, augmentation and replacement of equipment and sites, allocation of priorities and resources should form part of its activities.

### 2.3 Organisation

The basic principles of sound organisation in other fields of activities are equally applicable to solid waste management. However, no single type of organisational structure and no standard distribution of responsibilities can be considered to be the best as the conditions vary from city to city in respect of quantity and quality of solid wastes, population and its area, type of collection system, codes and bye-laws. The main objective is to collect, process and dispose of the solid waste effectively at least cost. This task should be divided logically into different workable parts such as section and division with specific authority and responsibility assigned to each with coordination of all functions.

The broad principles to be considered are:

- i) The lines of authority and responsibility should be clearly laid down and authority should be commensurate with responsibilities.
- ii) Responsibility should be so distributed as to avoid overlapping, duplication and dual accountability.
- iii) The division of responsibility should be so made as to serve the basic function of the whole system in the best possible manner.
- iv) Rewards for good work should be immediate (quick) so as to keep the good workers satisfied.
- v) The work should be divided into different groups, each containing positions requiring similar abilities and facilities.

Solid waste management basically involves management of the activities which are mainly engineering functions such as collection, transportation, operation of processing and disposal facility. It is hence desirable that necessary professional leadership is provided for good organisation. In most of the Indian towns (90% of towns and cities) the Health Officer has been assigned to manage this activity. It is the same case in most of the other developing countries. The recent trend is towards entrusting this work to a qualified engineer, e.g., in the cities of Bombay, Calcutta and Delhi. It

might have an independent position in metropolitan areas; whereas it may be under a Chief Engineer in smaller municipal agencies. The solid waste group has to seek help from other specialised agencies for doing relevant tasks.

The line type of organisation provides good results when each one has to perform similar work and the degree of responsibility varies with the position held in the hierarchy. However, as specialised skills for specific jobs are also required, a 'staff' type of organisation will also be needed. Commonly a 'staff' type organisation is used in conjunction with a 'line' type organisation.

The internal organisation of a solid waste management unit can be divided into four sections such as collection, transportation, processing and disposal. It is desirable that sectional authority is provided for each of these activities. In smaller towns, the processing and disposal functions can be assigned to the same section. Figs. 2.3.1 and 2.3.2 give the typical organisational charts suggested for towns having population upto and greater than 1 million respectively. If the refuse collection is to be carried out by contractors the organisation will be different. Presently in most of the Indian cities the street cleansing staff as well as the cleansing staff on vehicles come under one section, while the vehicle drivers and vehicles come under another section. It is found that proper coordination is lacking. The performance can be improved by assigning all the tasks to one section as indicated in the organisational charts.

## **2.4 Manpower Development**

Personnel administration should ensure that employees are well trained and suitably motivated to perform the jobs allotted to them, particularly so in this programme. In developing countries, social stigma attached to jobs in waste management does not attract proper talent unless provided with suitable financial incentives and promotional avenues. It could be done by:

- i) ensuring good remuneration, favourable working condition and career opportunity (more than that in other similar vocations);
- ii) training to improve chances for advancement; and
- iii) providing suitable insurance and compensation plan.

### **2.4.1 Training**

A good training programme is rewarding both to the employee as well as the employer. The time in learning new procedure and methods or techniques is more than compensated by improved performance. Orientation

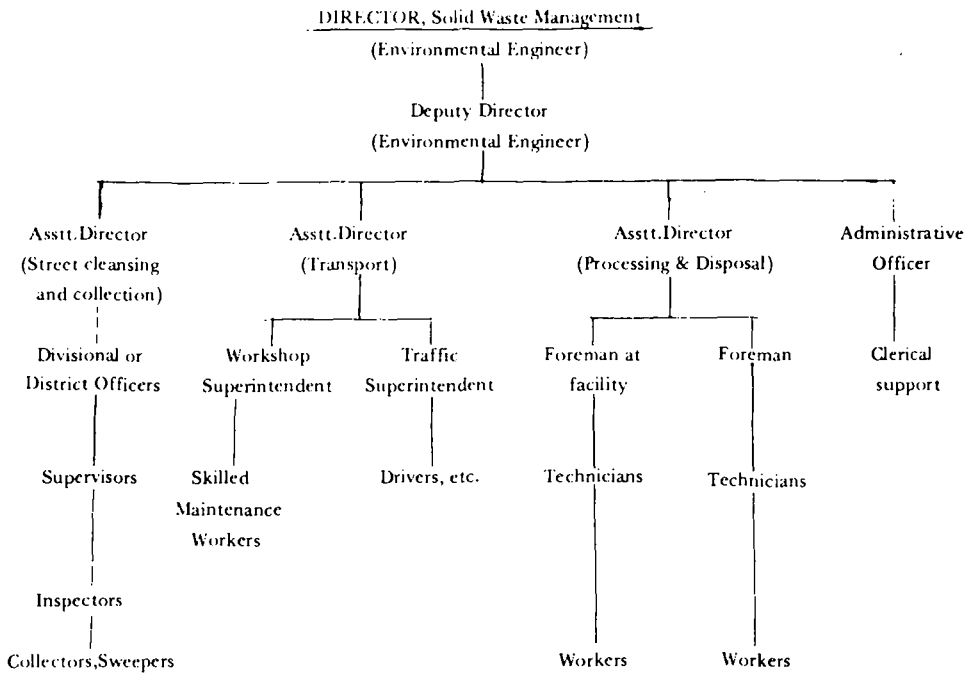


Fig. 2.3.1 : Organisational pattern for a town having a population upto 1 million

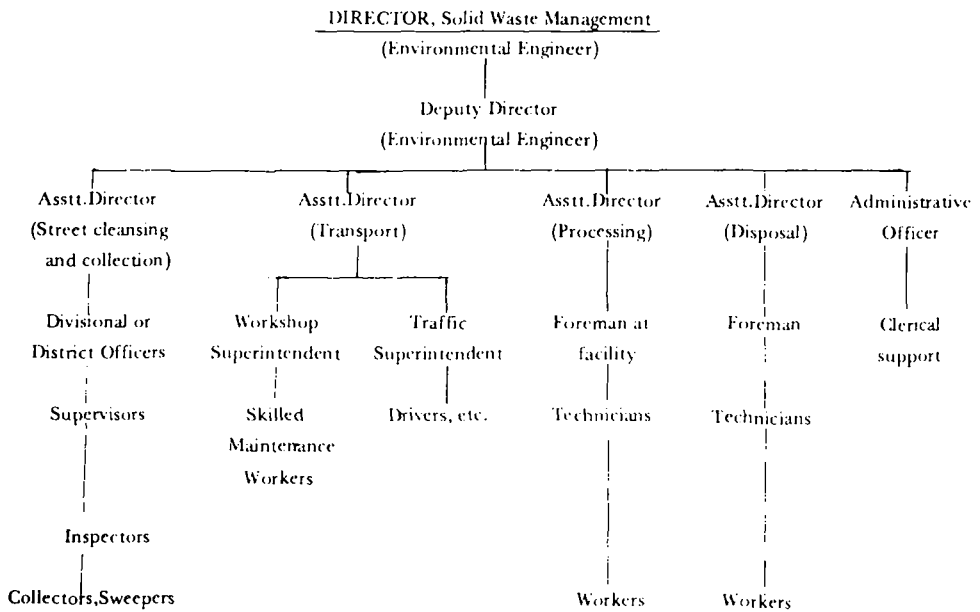


Fig 2.3.2 Organisational pattern for a town having a population greater than 1 million



courses to new employees at the beginning will prevent costly mistakes and wasted time. Visits to other operating facilities and discussions with others will enable broadening the understanding beyond the employees immediate operation.

Besides suitable equipment and facilities, it is necessary to have properly trained and well motivated personnel at all levels of management. The training should be provided at three levels: (i) technicians, (ii) professional engineers and (iii) managers.

i) **Technicians** : The technicians supervise skilled and unskilled labour in cleansing and transportation fleet, enforcement of bye-laws, processing and disposal sections. They form the backbone of the entire organisation and should be well trained in all the relevant aspects. The technicians should be post-matriculantes with a diploma in Civil and/or Mechanical Engineering followed by a short orientation course in solid wastes.

ii) **Professional Engineers** : Graduate engineers preferably with post-graduate training in Environmental Engineering form the middle level management personnel and are responsible for planning, design, operation and maintenance of the system. Current post-graduate programmes in engineering including environmental engineering do not provide courses in solid waste management. It is hence necessary to have short course of 10 to 12 weeks which will cover all elements of solid waste management for such engineers. As a long term measure, one year post-graduate course would prove useful in bringing about professionalism in solid waste management.

iii) **Managers** : Engineers with long years of service occupy top positions at decision-making level. An advanced level refresher course of one to two weeks covering legal aspects, planning policies, systems approach, data collection and evaluation, public relations and recent developments would prove useful. Senior level staff in supporting sectors such as Health and Agriculture should also be exposed to such advanced level courses.

#### *2.4.2 Employee-Management Relations*

A large number of skilled and unskilled workers will be employed in various activities for which an effective employee-management relationship should be built in. This should include several staff welfare measures, work incentives, accident prevention measures, upgrading of skills, etc. similar to other organisations which employ a large labour force.

## 2.5 Reporting and Records

Record keeping is one of the weak links in most of the developing countries, for which special care and attention should be bestowed. Primary data is invaluable for future planning to ensure optimum utilisation of resources, equipment and manpower at present and in future at least cost. The records help disposal of claims, supervision and suitable allocation and control of workers. Accident records in themselves cannot prevent accidents but are useful to identify causes of accidents. Data collection and analysis of information on refuse collection and disposal will help in planning for new equipment, facilities, replacement of old ones, staffing and financing.

## 2.6 Cost Accounting and Budgeting

Reliable cost data is essential for monitoring the performance of a system. All costs attributed to the entire programme, whether they are borne by the household, the municipal agency, local or national government, should be taken into account to arrive at meaningful economic cost to society. The level of service should be indicated while reporting the unit cost. Unit cost for effective removal, transport, processing and disposal of solid wastes from a city should include the direct as well as indirect costs such as loan interest, amortisation, ancillary support services, cost involved in further processing such as composting, incineration (if needed), depreciation of machinery and plants. It should also indicate benefits derived from sale of compost, steam or electricity or such other products.

## 2.7 Special Considerations

i) **Equipment** : In refuse disposal facility the equipment should be simple, sufficiently rugged to withstand wear and tear and dependable in operation under the widely varying loads. While purchasing equipments, operation and maintenance aspects should also be considered. A sound maintenance programme is essential to get optimum performance which involves periodic inspections including complete overhaul.

ii) **Standby Facility** : Standby capacity to take care of peak loads, heavy seasonal loads and breakdowns is necessary to avoid nuisance and insanitary conditions.

iii) **Prevention of Nuisance and Hazards**: Standard precautions such as arrangements for fire fighting, insect and rodent control should be taken at all processing and disposal facilities.

iv) **Accident Prevention** : In addition to the money spent in settling the claims for injuries or damages incurred in an accident, additional expenditure

is incurred for repairs to vehicles and machines, purchase of new ones, interruption of services, loss of public goodwill, cost of court appearance, etc.

Hence safety programme should form an integral part, ensuring co-operation of the staff.

Some of the common types of accidents can be avoided by

- i) Encouraging the workers to use gumboots and gloves. The collection workers have to handle materials which may cause cuts, infection and injuries and hence use of gumboots, gloves as well as helmets is essential.
- ii) The workers sitting in a separate cabin of the vehicle and not along with the driver.
- iii) Keeping away from moving parts of vehicles.
- iv) Providing for immediate treatment of cuts and bites of insects and animals.
- v) Undertaking regular protective vaccination.
- vi) Providing the workers a simple manual with suggestions and hints for safe handling of materials.

**2.8 Public Relations :** Refuse disposal deals with materials which have become synonymus in the public mind with obnoxious disposal method. Adequate co-operation of the citizens should be solicited through effective public relation programme. It could be carried out by impressing on the citizens the undesirable effects (breeding of flies, rodents and other insects) of improper storage and disposal through mass media such as radio, TV, press and posters. Campaigns among school and college students need be organised to avoid littering public places and streets. The importance of proper cleaning and storage should be impressed on school children by incorporating suitable material in their curriculam. Citizens should be informed about the type of waste which cannot be accepted for disposal, charges for disposal and fines for non-compliance of regulations.

## CHAPTER 3

### QUANTITY OF SOLID WASTES

#### 3.1 Introduction

The quantity of municipal solid waste generated depends upon a number of factors such as food habits, standard of living, degree of commercial and industrial activity. 'Municipal solid waste' includes wastes generated in residential and commercial areas; whereas wastes from industrial and agricultural operations are separately considered. Out of the waste that is produced in residences, a part is recycled within the premises, a part reclaimed by the sweepers and unauthorised scavengers during collection and transportation stages and another part at the disposal site by unauthorised persons, leaving only a portion to reach the disposal site.

Various commercial establishments generate different categories of wastes depending upon the type of activity. Shops and other establishments generate waste containing large amount of paper, straw, card-board packing cases which are generally non-decomposable. Small commercial establishments may discharge the waste along with the municipal waste.

**Street Wastes** : In addition to the waste originating from premises, the waste from streets is also included in the municipal solid wastes. Street wastes fall into three main categories - natural, road traffic and behavioural.

i) *Natural wastes* : These include the dust blown from unused land and roads, dead and decaying vegetation, seeds originating either from avenue or blown from marginal areas. It cannot be controlled as it originates from sources other than the streets.

ii) *Road traffic wastes* : These originate from wear and tear of road surface and that from transport vehicles. The motor vehicles while moving on the road deposit petrol, oil and at times, spill their contents on roads. In developing countries multiplicity of vehicles are in use including animal drawn vehicles which often come from surrounding rural areas. These vehicles deposit mud, animal excrement, etc. on the road adding to the road traffic wastes.

iii) *Behavioural wastes* : These originate from wastes thrown by pedestrians, or by persons using the streets and from wastes from adjoining houses, shops and other premises which spill out due to improper storage. It also includes dried excrement of domestic animals which poses danger to the sweeping staff when the disease organisms become air-borne. Much of this waste can be prevented by a sustained health education programme backed by suitable legislation and enforcement.

*Demolition and construction wastes*: These are not normally expected to be dumped in the collection bin and the agencies are required to bring the material directly to specific disposal sites for its disposal.

Industries produce different categories of wastes which include those from processes, packaging (packing cases, straw, etc.), office, canteen and plant. With the exception of process solid waste, the disposal of the remaining categories can be effected along with municipal wastes. Process wastes vary from industry to industry and are often subjected to large scale recycling (conversion into entirely new products for use) and reuse (using again without drastically changing the commodity) in the plant itself. At times, these wastes may be toxic when the disposal should be well regulated. It should be ensured that only such industrial solid wastes which are not toxic reach the common disposal site. Agricultural wastes are normally not encountered within municipal limits. However, similar types of wastes could be expected from institutional gardens, nurseries and experimental farms within municipal limits. The quantity produced can be assessed accurately in house to house collection system. In most of the developing countries including India, such a system is being practised only in selected parts of a few metropolitan cities, making it difficult to assess the quantity correctly.

### **3.2 Urban Solid Waste**

The quantity of urban solid wastes is known to vary seasonally. During festive occasions, the amount of refuse shows an increase, e.g., the rubbish generated during Diwali in India is considerably higher than in other seasons. During monsoon, tree and hedge cuttings have been recorded to be high. Quantity generated during winter and summer seasons also vary. In industrialised countries, collection routes are well organised due to which variation in quantities can be identified. The situation being not so in developing countries, interpretation of the variation in daily quantities could at best be a guess.

Data on quantity variation will be useful in planning the collection and disposal systems. The collection system should be so regulated as to have the overhauling and major repairs of vehicles undertaken during lean

periods. At the same time, the management should ensure effective removal during peak generation periods. Similar scheduling will be required at the disposal site as well. Manpower deployment (number, leave schedule, etc.) should be regulated to match with quantity generation of wastes.

In the absence of house to house collection the quantity of waste could be assessed in an indirect way. Identify an area in the city, which is representative of the city. Ensure complete and effective refuse removal for at least three consecutive days. The quantity removed is determined either by weighing the trucks on a weigh-bridge or using the density and correction factor method (refer 3.3). The value obtained on first day is to be neglected as it may include unremoved collection of previous days and the average of the next two days quantities taken. Measurement for about 8 consecutive days would take care of variation on week-days, which should be preferred, if feasible. Knowing the population of selected area, per capita waste generation is computed for further planning of the programme.

### 3.3 Quantity at Disposal Site

The quantity of waste measured at the disposal site should not be relied upon as it would not represent the generated quantity. Absence of weigh-bridges at disposal sites is a common problem in developing countries. In such cases, density of the waste multiplied by the volumetric capacity of the vehicles provides the weight of the wastes.

**Measurement of density :** The refuse is collected in a small box from the refuse mass (from dustbin or truck or disposal site) weighed by a spring balance and emptied in a box of one cubic metre capacity. This procedure is continued till the cubic metre box is full. It should be ensured that the refuse is not compacted. The cubic metre box is filled and weighed thrice to get the weight in  $\text{kg/m}^3$ . The density value so obtained is of uncompact refuse whereas in the collection vehicle moving from place to place upto the disposal site, the refuse gets compacted due to self-weight and vibrations during movement. In Calcutta[24], it was observed that the increase due to truck movement was about 11%, the density value having increased from  $463 \text{ kg/m}^3$  to  $517 \text{ kg/m}^3$ .

Where no weighbridge is available at the disposal site, the following procedure can be adopted. The correct volume of a representative truck which moves through the average transportation distance is measured. The contents are unloaded and weighed using a spring balance to give the density value of the material inside the truck. Density should also be measured by the cubic metre box method repeatedly for different vehicles and the average value adopted. The correct quantity of refuse transported by different trucks could then be calculated by using these values.

### 3.4 Density of Refuse from different Countries

The density of refuse depends upon constituents such as organic content, inorganic content, paper, etc. In developing countries, the percentage of inorganics has been observed to be high. It is partly due to the fact that proper storage bins are not provided and street sweepings and ash tend to get collected along with the refuse. It is also a common practice to include street sweepings in the refuse, increasing the density.

Density value in India and other developing countries range from 300 to 560 kg/m<sup>3</sup> (Table 3.4.1). In Singapore, it is as low as 175 kg/m<sup>3</sup>, while in Kathmandu and Dacca 600 kg/m<sup>3</sup> have been reported [54]. In general the value is around 400-500 kg/m<sup>3</sup> as measured by cubic metre box.

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*Table 3.4.1 - Density of Municipal Solid Wastes in Some Cities*

Sr.No	City	Density (Kg/m <sup>3</sup> )
1	Dacca, Bangladesh	600
2	Rangoon, Burma	400
3	Kathmandu, Nepal	600
4	Hyderabad, India	369
5	Bangalore, India	390
6	Jabalpur, India	395
7	Raipur, India	405
8	Delhi, India	422
9	Baroda, India	457
10	Jaipur, India	537
11	Bangkok, Thailand	250
12	Singapore	175

---

In most of the developed countries, the density values as obtained in the vehicle, at the point of discharge are given. It is hence necessary to record the method of computation before comparing these values.

### 3.5 Quantity Forecast

While planning a processing or disposal facility as well as the total solid waste management system, forecasting the future load becomes necessary. Increased commercial and industrial activities would result in increased release of wastes and is known to increase per capita waste generation as

well. It is reported that an increase of 1-5% per annum occurs in USA[77].

In the absence of information of the past trend, it is necessary to rely on recognised trends as observed in existing conditions. NEERI observations during 1969-70 in Calcutta showed a per capita increase of 1.33 per cent per year<sup>(24)</sup>. In Hongkong[85], the per capita generation rate in 1977 was 0.73 kg/head/day which was expected to go up to 1.13 kg/head/day in 1986 indicating an increase of 6.08 per cent per year.

Various models have been tried in the developed countries to predict future quantities and characteristics. Early efforts mainly relied on 'output' sampling approach which analysed the composition of solid wastes after generation and after delivery to the disposal site. Research emphasis switched to the material flow approach known as 'input' approach which estimates the solid waste composition from industry production data. More recently, consumer expenditure data was used as a basis for predicting the quantity of waste generation.

The International Research and Technology Corporation[47] (IR & T) used the input-output analysis to estimate and forecast material consumption and waste generation industry-wise. The study used physical materials purchased by producing sectors in the economy to estimate flows to the household or commercial sectors. A dynamic model was developed to forecast future purchase by these sectors. Waste flows to storage and disposal sites were also accounted. It further combined desirable features of the materials flow approach and input-output concepts with economic forecasting to better reflect anticipated economic growth and structural changes (e.g. recycling, reuse and material changes) that affect the solid waste stream. All these methods have limited application in developing countries.

### **3.6 Per Capita Refuse from Selected Cities**

NEERI observations indicated that the per capita waste reaching disposal site was about 0.5 kg/capita/day in Bombay and Calcutta. In the 3 cities of Andhra Pradesh, the per capita values were more or less equal and ranged between 0.17-0.2 kg/capita/day. In Hyderabad, which is a large city in the same State, due to its cosmopolitan nature and higher standard of living, the per capita value was 0.33 kg/capita/day. The per capita contribution ranged from 0.15 to 0.35 kg/day[7] for the different Indian cities.

In other developing countries the values varied from 0.25 kg/capita/day at Kathmandu and Rangoon to 0.85 and 0.87 kg/capita/day in Hongkong and Singapore respectively[54] (Table 3.6.1; Fig. 3.6.2).



Table 3.6.1 - Per Capita Municipal Waste

City	Kg/head/day
Kathmandu, Nepal	0.25
Rangoon, Burma	0.25
Colombo, Sri Lanka	0.42
Bangkok, Thailand	0.45
Manila, Phillipines	0.50
Hongkong	0.85
Singapore	0.87

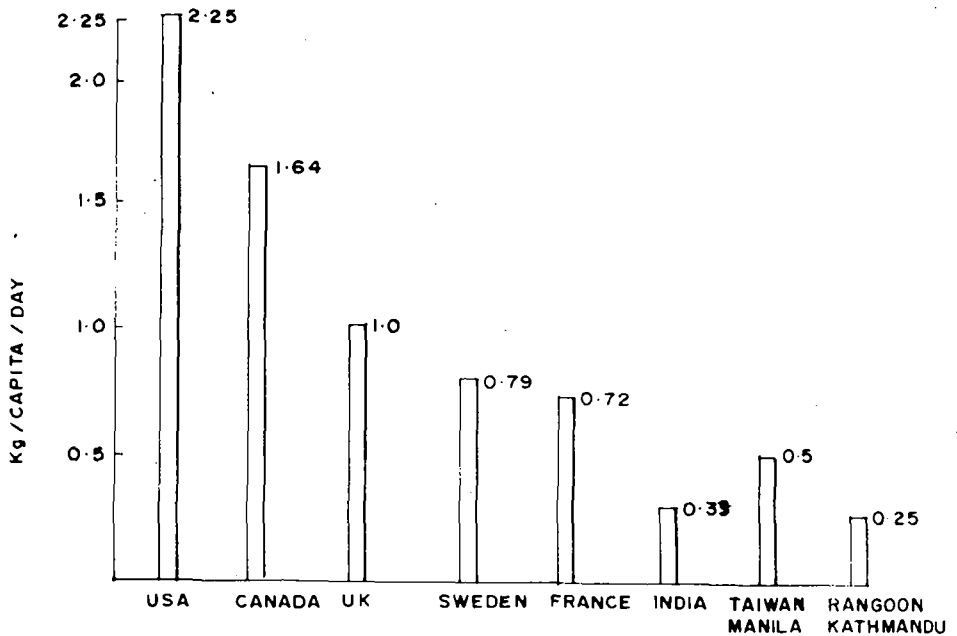


Fig. 3.6.2 Average per capita solid waste rate in different countries

## CHAPTER 4

### CHARACTERISTICS OF SOLID WASTE

#### 4.1 Introduction

Refuse characteristics depend on a number of factors such as food habits, cultural traditions, socio-economic and climatic conditions. Refuse characteristics vary not only from city to city but even within the same city itself and also seasonally. Quality of refuse should be assessed taking into account seasonal variation, zonal characteristics, etc. Sampling points should be truly representative of the given occupation sub-group. In residential area, the sampling point should represent waste coming from at least 100 families. If an average value of refuse characteristics for the full city is to be given, weightage factors are calculated. The weightage factor for a specific occupation category will be the ratio of weight of refuse produced from that occupation group divided by the total weight produced from the city. The average values of characteristics from different occupation sub-groups are then multiplied by the weightage factor to compute the average value for the city.

#### 4.2 Sample Size

In studies carried out in USA with 100 kg to 1000 kg samples it was found that a 100 kg sample gave as much accuracy as a 1000 kg sample [21]. When the collection at a point is small and a 100 kg sample cannot be obtained, smaller samples could be used for analysis. Repetitive sampling and analysis would provide a more representative data. At least ten grab samples should be taken from a number of points in the refuse mass both horizontally as well as vertically and then mixed to get the composite sample.

#### 4.3 Number of Samples

Carruth and Klee [21] have given the following method for determining the number of samples:

$$n = \left( \frac{Z.S}{d} \right)^2$$

Where  $n$  = number of samples required.

$Z$  = standard normal deviate for the confidence level desired.

$S$  = estimated standard deviation (transformed basis).

$d$  = sensitivity (transformed basis).

At 90% confidence,  $Z = 1.645$ ,  $S = 0.1413$ . The sensitivity transformed basis is determined as follows : transform  $x$  and either  $x + \Delta$  or  $x - \Delta$  by the arcsin transformation, where  $x$  is the expected percentage of component in question and  $\Delta$  is the desired precision for the percentage to be estimated. The choice of sign for  $x \pm \Delta$  is +ve for  $x < 0.50$  and -ve if  $x > 0.50$ .

$$d = 2 \arcsin x - 2 \arcsin (x \pm \Delta)$$

It is necessary to identify the probable value of the component of interest and the accuracy with which it is to be estimated. The value of  $d$  and  $n$  are then calculated. If a number of parameters are involved  $n$  values for each need be found out and the maximum figure is then adopted. The number of samples to be collected will vary depending upon the expected percentage of that component in the waste and the accuracy with which it is to be estimated.

#### 4.4 Physical Analysis

The sample so collected should be sorted out physically into various ingredients such as paper, glass, plastics, etc. on a sorting platform. The individual components are separated, stored in bins and weighed. The weights are then expressed as a per cent of the original sample. The density of the material is measured by using the method already described earlier (Art.3.3). The physical analysis is on wet weight basis which helps in choosing the system for collection and processing. A large organic content indicates the necessity for frequent collection and removal. Larger amount of paper indicates that the waste can be thermally treated. Plastics in high concentration indicate possible problems in their disposal. A large percentage of ash indicates that putrefaction will not readily occur and that collection frequency could be less. In such a case, sanitary landfilling would be a better method.

Tables 4.4.1 and 4.4.2 give some of the important physical characteristics of city refuse in India and other developing countries. The table 4.4.1 gives average values for the 33 Indian cities observed by NEERI in their studies during 1971-73 [7]. Annexure-III gives physical characteristics from 40 Indian cities observed by NEERI. Tables 4.4.1 and 4.4.2 also show that

Table 4.4.1 - Physical Characteristics of City Refuse (All values in per cent by wet weight)

Characteristics	India <sup>(7)</sup> Population				Other developing countries <sup>(54)</sup>	USA	West Germany
	< 0.2x10 <sup>6</sup>	0.2-0.5x10 <sup>6</sup>	0.5-2x10 <sup>6</sup>	> 2x10 <sup>6</sup>			
Paper	3.09	4.76	3.80	7.07	2-7.5**	40-55	20-35
Plastics	0.57	0.59	0.81	0.86	2-6	2-3	2-3
Metals	0.51	0.39	0.64	1.03	0.5-3	6-13	4-9
Glass	0.29	0.34	0.44	0.76	0.15-2+	3-10	3-10
Ash & fine earth	46.6	39.97	41.81	31.74	40-75	3-10	3-10
Total compostable matter	33.41	39.76	40.15	41.69	15-50	10-15	10-20

\* Average values  
 \*\* Singapore 43%, Hongkong 32%  
 + Hongkong 8%

Table 4.4.2 - Physical Characteristics of Refuse from some Cities<sup>(27,54)</sup>  
 (All values in per cent by wet weight)

City	Characteristics Population in million (1971)	Paper	Plastics	Metals	Glass	Ash and fine	Total Compostable matter
INDIA							
Calcutta	(3.20)	3.18	0.65	0.66	0.38	34.0	47.0
Delhi	(3.20)	6.29	0.85	1.21	0.57	36.0	35.0
Madras	(2.47)	7.85	0.88	0.95	0.96	28.0	48.0
Hyderabad	(1.80)	4.81	0.83	1.22	0.93	36.0	37.0
Ahmedabad	(1.59)	3.02	0.84	0.42	0.23	34.0	49.0
Kanpur	(1.27)	2.97	0.62	0.45	0.37	46.0	41.0
Jaipur	(0.65)	3.02	0.80	0.64	0.39	50.0	26.0
Jabalpur	(0.44)	2.02	0.69	0.38	0.35	43.0	40.0
Chandigarh	(0.22)	6.17	0.33	0.22	0.20	39.0	35.0
Sangli	(0.12)	3.04	0.35	0.20	0.36	41.0	50.0
OTHER DEVELOPING COUNTRIES							
Bangkok	(3.3)	24.6	7.0	1.0	1.0	8.3	44.0
Hongkong	(4.5)	32.4	6.2	2.1	9.7	29.5	9.4
Jakarta	(5.0)	2.0	2.0	2.0	2.0	25.0	60.0
Seoul	-	4.0	1.8	0.4	0.1	78.0	-
Taiwan	-	7.5	2.3	1.1	2.8	56.0	24.6
Singapore	(2.3)	43.1	6.1	3.0	1.3	32.6	4.6

the paper content increases with increase in population though the values are lower than that recorded in industrialised countries. The plastics and glass contents also increase with increase in population. The low values of plastics should be welcome as the problems during composting, incineration or landfilling will be less. The ash and fine earth show an inverse trend which

is due to the local habit of including street sweepings in refuse. In bigger cities the proportion of paved roads being high, the ash and fine earth appear to be low. In India, bulk of the paper, glass and metals are recycled and do not reach the collection bin. Similar situation exists for glass and metals. Plastic content in refuse is less, thus avoiding problems in its processing and disposal.

The trend in other developing countries appears to be similar. For example, the paper content is low in countries with lower GNP per capita (\$ 60-160) and is high when GNP per capita (\$ 2700) is high as in Singapore. Plastics, metal and glass contents also show similar trend in Singapore, Taiwan and Hongkong. The compostable matter is high in countries with low GNP per capita and tends to decrease as GNP per capita increases.

Table 4.4.3 gives some of the physical characteristics of refuse from Pune (India) as observed during 1970 and 1978. As the corresponding quantities of rags, glass, metals, plastics, etc. increased in 1978, the proportion of compostable matter decreased. The decrease in proportion of compostable matter is also due to increased urbanisation and industrialisation during the intervening period.

Table 4.4.3 - Changes in Physical Characteristics of City Refuse in Pune, India

Characteristics	Years	
	1970 <sup>(23)</sup> (%)	1978 <sup>(60)</sup> (%)
Compostable material	67.00	60.66
Paper	8.74	7.00
Glass	0.58	0.67
Rags	1.63	4.21
Plastics	0.72	0.89
Metals	0.59	0.77

#### 4.5 Chemical Analysis

From the mass used for physical analysis a 500 gms sample is taken for moisture determination and heated overnight at 100°C to obtain weight loss. This loss is expressed as a percentage of total weight. Normally moisture content is determined as soon as the sample is collected which helps in the choice of processing and disposal methods.

The total of 100 kg sample used for physical analysis is now reduced

to 12.5 kg by using the method of quartering in which the mass is divided into 4 parts and 2 diagonally opposite parts are taken and mixed while the other 2 are discarded. The sample is again mixed and similar procedure repeated, but this time the other diagonal parts are taken. The 12.5 kg sample is dried, ground in a hammermill or a grinder till it passes through a sieve having a pore size of 0.45 mm (BSS 36 or ASTM 40). A 5 gm powdered sample is mixed in 50 ml of distilled water by stirring for pH measurement by a pH meter. Normal pH of fresh refuse is around 7. On decomposing, it tends to become acidic and a stabilised refuse has normally alkaline pH. A 10 gm portion of the dried ground sample is placed in a silica dish and slowly heated in an electric furnace to 700°C for 30 min. The residue is weighed and the loss of weight is indicated as organic matter and expressed as per cent by weight. The organic content of refuse indicates the amount of compost that could be produced from it. The carbon percentage is found out by using New Zealand formula [46] in which the per cent organic matter is divided by 1.724. Total nitrogen is obtained by the Kjeldahl method and the phosphorous and potassium estimated by using phosphomolybdic and flame photometric method. Nitrogen, phosphorous and potash values are important for composting.

Table 4.5.1 - Some Chemical Characteristics\* of Indian City Refuse<sup>(7)</sup>

Characteristics (%)	INDIA				USA	West German y
	Population					
	<0.2x10 <sup>6</sup>	0.2-0.5x10 <sup>6</sup>	0.5-2x10 <sup>6</sup>	>2x10 <sup>6</sup>		
Moisture content(%)	22.12	25.05	22.45	31.18	20-30	-
Organic matter(%)	22.01	22.51	21.51	27.57	30-35	16-30
C (%)	12.56	12.51	11.95	15.32	25-30	-
N (%)	0.60	0.61	0.55	0.58	0.6	0.1
P as P <sub>2</sub> O <sub>5</sub> (%)	0.70	0.71	0.67	0.59	-	0.1
K as K <sub>2</sub> O(%)	0.70	0.73	0.72	0.67	-	0.4
C/N	20.35	20.47	21.45	26.23	48-50	-
HCV in Kcal/Kg	800	874	865	1140	3330	2775

\* All values except moisture content on dry weight basis.  
Moisture content is on wet weight basis

Calorific value of the material is determined on dry inert free basis using a bomb calorimeter (Annexure-II). Knowledge of the calorific value of waste will indicate its suitability for incineration.

Table 4.5.1 gives the chemical characteristics of the city refuse in India, based on the data [7] collected by NEERI from 33 Indian cities during 1971-73. Annexure-III gives chemical characteristics of waste observed from 40 Indian cities. The calorific value, in general, tends to go up with increase in population. The chemical characteristics of wastes from developed countries show that C/N ratio is high. The NPK content of waste in these countries is low. In addition, knowledge of some specific characteristics (e.g., existence of copper, manganese, boron, etc.) is also useful.

#### 4.6 Biological Analysis

Refuse as it is produced does not normally contain human intestinal parasites. In India and other developing countries, it is common to find refuse lying at such points where it is liable to come in contact with material containing parasites. In cities, which do not have a sewerage system, night-soil is often deposited along with refuse which transmits parasites.

The sample collected for biological analysis is immediately transferred to a plastic bag and sealed. In the laboratory the material is thoroughly mixed with the moisture of bag and a suspension prepared by using modified formol ether technique [27]. The suspension is taken in a sedgewick rafter counting cell and subjected to microscopic observation for various human intestinal parasites.

The samples collected from 33 Indian cities indicated *A. lumbricoides* and *T. trichiura* to be the dominant parasites. Most of the towns were not sewered and night-soil contamination was frequent. Table 4.6.1 gives the results of microscopic analysis for the different seasons and for the towns in various zones. Samples collected during the monsoon season gave maximum positive samples while it was low during summer.

Table 4.6.1 - Seasonal Variation in % of the Positive Samples for Parasites

Group	Range of Population	Season	A. lumbricoides			T. trichiura		
			Slum+Low income group	Middle income group	High income group	Slum+Low income group	Middle income group	High income group
I	< 0.2 x 10 <sup>6</sup>	Summer	5.6	Nil	Nil	Nil	Nil	Nil
		Winter	3.3	4.4	Nil	7.4	Nil	Nil
		Monsoon	21.8	7.8	Nil	14.6	Nil	Nil
II	0.2 x 10 <sup>6</sup> to 0.5 x 10 <sup>6</sup>	Summer	2.2	Nil	Nil	1.3	Nil	Nil
		Winter	25.2	7.3	3.1	7.5	Nil	3.3
		Monsoon	20.9	7.3	1.3	14	4.3	1.7
III	0.5 x 10 <sup>6</sup> to 2 x 10 <sup>6</sup>	Summer	Nil	Nil	Nil	Nil	Nil	Nil
		Winter	12	3.6	Nil	Nil	Nil	Nil
		Monsoon	21.6	15	Nil	4.9	5.7	Nil
IV	> 2 x 10 <sup>6</sup>	Summer	Nil	Nil	Nil	Nil	Nil	Nil
		Winter	5	Nil	Nil	15	10	Nil
		Monsoon	30	20	Nil	15	20	Nil



## CHAPTER 5

### INDUSTRIAL SOLID WASTES

#### 5.1 Introduction

Solid wastes generated from industrial sources are heterogenous ranging from inert inorganics as in those produced in mining, collieries, to organics from those producing basic consumer products, and may include even hazardous wastes as in nuclear industry.

Waste products from an industry may get recycled and reused in the same industry or may be a source of raw material for another industry. Industries are known to recycle and reuse a part of their wastes. The recycling and reuse of solid waste resulting from industrial processes depends upon the quality of the reusable by-products and its cost. At times, a by-product may not find a ready market within a short distance. Consumers located farther away may find it uneconomic due to transport cost and taxes. In such cases, concessions (tax incentive and benefits, reduction in transport costs) could be granted when the secondary materials are being reused. The tax and transport concessions are justified as the use of secondary material leads to reduction in pollution, conservation of energy and resources. In some developed countries the use of recycled material is actively encouraged by various methods, e.g., US EPA Guidelines of 1976 require separation of paper at source at federal facilities and encourage use of recycled paper for Government work. To bring the producer and the possible user of the waste together, Industrial Waste Information Exchange Centres were first started in 1972 in Netherlands. It is now common in most of the developed countries and in 1980, 23 such organisations, either managed locally or by Government agencies were operating in USA.

The problem of disposal of solid wastes varies from industry to industry and each case need be studied separately. The wastes can be grouped as i) biodegradable, ii) non-biodegradable, and iii) hazardous. Industrial sources producing biodegradable and non-biodegradable wastes from a few selected industries are discussed in this Chapter while the hazardous wastes are discussed separately. It is mainly aimed at identifying the sources, composition of the waste, disposal problems and methods recommended and recycling limitations.

## 5.2 Biodegradable Wastes

### 5.2.1 *Fruit Processing*

According to Commonwealth Secretariate[57], the world production in 1980 of fresh, canned and frozen fruit was nearly 4.5 million tonnes/year. These industries are seasonal and the wastes produced are organic in nature.

The simplest method of disposal will be to feed it to cattle. If it has to be stored its moisture content should be reduced from about 90% value. It should be used with caution as the pesticides tend to get concentrated in peels or skin of tomato and such other fruits. The wastes could be used for producing alcohol to a limited extent. It could be added to municipal refuse or such other low moisture, biodegradable material for composting when there is a market for compost. The organic waste can also be pyrolysed and the char used for briquets. One such plant is reported to be in operation at South San Francisco Bay, USA[58]. Whenever the waste cannot be reused, dumping on land is resorted to, which may lead to insect breeding.

### 5.2.2 *Slaughterhouse Waste*

In a slaughterhouse, wastes are produced in every operation, most of which are reused. Such wastes which cannot be reused, need be processed and disposed as they are highly putrescible. Hides and skins from slaughterhouses have been in use since a long time. Blood, bile, pancreas, etc. can all be used for pharmaceutical purposes. A number of useful products such as glue, gelatin, glycerine, trypsin, etc. are produced which have a ready market. In addition to the commercial use of hides and skins, processed blood-meal and bone-meal are used as poultry feed as well as fertilizer.

### 5.2.3 *Cotton Ginning and Textile Mills*

**Cotton Ginning :** Cotton ginning is a seasonal industry which operates for a few weeks each year. The type of waste and quantity depend on the method of harvesting cotton. The manual method of picking of seed cotton by hand produces least waste, comprising of portions of the boll and occasional leaf parts. In the ginning process the cotton fibre is separated from foreign matter and seed. Some cotton fibre remains in the waste when the ginned cotton is further processed through a lint cleaner, some small pieces of cotton occur as waste. The total waste thus produced varies from 5% in handpicking to 20% in machine scrapped, of the material processed.

Disposal of gin waste may be by burning or used as a soil conditioner (after ploughing inside the soil). If incinerators are used air velocities need be kept low to prevent the material from getting air-borne. If arsenic containing compounds have been used as insecticides they may get released

with the waste gases causing air pollution. In USA, about 37% of this wastes is burned, 59% returned to land and 4% disposed by other methods[57].

**Textile Mills :** Cotton textile mills produce large amount of cotton dust in blowrooms to the extent of about 20-50 tonnes/year/25000 spindles. The textile mills in India produce about 30,000-33,000 tonnes/year of this waste; 20% of which is produced in Bombay and 15% each in Ahmedabad and Coimbatore.

The waste essentially consists of unrecoverable cotton fibres and broken cotton seed coats. Sieve analysis of the waste shows 54% of the material to be finer than 0.707 mm, 13% between 0.707 and 2 mm and remaining of a size larger than 2 mm. It contains about 70% organic matter and N : P : K in the proportion of 1.4 : 0.6 : 1.2 (Table 5.2.3.1).

Table 5.2.3.1 - Chemical Analysis of Raw Cotton Dust<sup>(5)</sup>

Item	% by weight
Moisture	8.00
Organic matter	70.00
Carbon	41.00
Nitrogen	1.40
Phosphorous as P <sub>2</sub> O <sub>5</sub>	0.60
Potash as K <sub>2</sub> O	1.20
C/N ratio	29.28

Normally this waste is disposed of along with other sweepings from mill or used as fuel in boilers or sometimes a portion is used as a cheap filling in quilt blankets. Compost could also be prepared[5]. As cotton dust is more or less homogenous and fine, good quality fine textured compost was obtained. The economic analysis showed that the material could be composted and sold at substantial profit for use in horticulture. The clean nature of raw material obviates aesthetic objections and ensures better acceptance.

### 5.3 Non-biodegradable Wastes

#### 5.3.1 Colliery Wastes

Colliery wastes include coal and stone, timber and metal scrap, rejected brattice and belting, sludges and other miscellaneous wastes. In UK, nearly 3,000 million tonnes of wastes covering about 50 sq. miles had accumulated

during 1968 and more than 50 million tonnes/year of discard from washeries accumulate. The estimated cost of production, handling and disposal of these is about \$ 1000 million/year [59]. In France, about 500 million tonnes had accumulated which further increased at the rate of 14 million tonnes per year. The proportion of rejects from coal washeries varies from 15-30%. Normally, medium size reject (3 cm x ½ cm) dominates the reject fraction while coarse and fine rejects form about 25% of the total.

These heaps may start burning causing air pollution (CO, H<sub>2</sub>S, SO<sub>2</sub>) and leachates from them may cause water pollution. The wastes can be disposed of by emplacement and utilisation.

Emplacement : involves disposition of material elsewhere away from the mine.

- i) Spoil heaps are formed of these wastes but they involve transfer of the problem from one area to another.
- ii) Landfill in low lands, marshes or irregular lands can be carried out. In Australia, cor, swamp oaks, eucalyptus trees have been grown on such landfill sites.
- iii) Underground stowage, where waste is returned and left underground. It is practised in thin and non-mechanised seams to avoid surface subsidence. In Germany, France, UK and India, it is used to varying degrees.
- iv) In tailing dams (lagoons) the draining and dewatering of fine sizes produced in coal washeries poses several problems. These can be disposed of in water courses, lagoons, etc. without thickening or into tanks or lagoons after thickening.

Utilisation : The material can be used in the fluidized combustion process and burnt; spoil material can be used as a road base and embankments. Inerts from fluidized bed and crushed, burnt spoils can be used as aggregates. It can also be used for brick manufacture in such a case where C > 5% is acceptable. The most practicable solution to colliery waste disposal lies in using it for landfill taking precautions regarding environmental quality.

### 5.3.2 Solid Wastes from Refineries

Crude oil contains some basic substance and water (BS & W) constituting a mixture of water, iron, rust, iron sulphide, clay, etc. produced with the crude oil or accumulated during transit of crude oil. A portion of BS & W is charged to crude oil unit and settles out, the liquid allowed to enter

oily water sewer system. The rest is settled out in storage tanks and removed. Sludges are also produced during treatment of water for supply to refineries. Wastewater from refineries contains metal ions such as Fe, Al, Cu and Mg from corrosion of refinery equipment, chemicals used in treating cooling water, salts in intake water and chemicals used in processing. When waste containing calcium is discharged into sewers, it reacts with soluble sulphate, sulphites, phosphates, carbonates and organic acids resulting in precipitation of insoluble calcium. Occasionally, black water conditions are created in sewers when iron and sulphide in the sewer react to form colloidal iron sulphide [1]. Precipitation in sewer normally occurs when alkaline wastes (containing high concentration of phenols, sulphides and emulsifying agents) are discharged which could be controlled by separating alkaline wastes for treatment and disposal.

Removal from electrostatic precipitators or external cyclones produces inert granular solids containing a small amount of hydrocarbons and carbon which is normally inert. Waste catalyst is also released as periodic reject from the process and disposed on land. Water used to remove coke from coking units entrains coke fines which can be settled out. Wax tailings from coking processes pose problems if allowed to enter the oily water system and tend to deposit. In addition to the above wastes, combustibles - such as paper, wood, garbage and rags and non-combustibles such as bricks, bottles, etc. are produced.

Solid wastes from refineries can be grouped as:

- i) inert dry solids - trash, silt, spent catalysts;
- ii) combustible dry solids - trash, waste paper, scrap lumber;
- iii) sludge from water softener and sanitary sludge;
- iv) sludge containing oil such as spent clays; and
- v) sludge containing oil, water and solids - from water separator bottoms.

#### 5.3.2.1 Treatment and Disposal

When the sludges containing solids and water come in contact with oily water, solids get coated with oil. Hence it is desirable to avoid mixing of the two. The sludge should not be allowed to flow in oily water drains but dewatered by gravity in sludge thickeners or pond. The sludge may also be reused for neutralizing some wastes or in cement manufacture, etc.

The first step consists of gravity settling in a continuous operating thickener or in a batch operated hopper bottom settling tank. In the case of

wastes containing solids, oil as well as water, centrifugation is necessary. Before the sludge is sent to the centrifuges, it is screened and then subjected to primary centrifugation in scroll type centrifuges. After the process, the oil water mixture contains about 5-10% solids and is subjected to secondary centrifugation. Secondary centrifugation can be carried out either by using a basket type or a disc type unit. The basket centrifuge is used in intermittent method while disc type is used for continuous operation. The solid cake obtained after centrifugation is taken to the landfill site or incinerated.

In the case of sludges which do not contain oil, filtration is carried out either on sand beds or in filter press in vacuum filtration. When the sludge contains materials which tend to clog or blind the filter medium precoat filtration is used. The sludges after filtration can be incinerated or dumped on landfill sites.

### 5.3.3 Steel Plants

Blast furnaces produce hot metal for steel making and pig iron. The amount of slag produced is about half a tonne per tonne of pig iron produced. A large amount of dust is also produced from the blast furnace. In USA, about 25 kgs of dust is produced and collected for each tonne of pig iron produced. Pig iron produced in the blast furnace goes either to an open hearth furnace or to the basic oxygen furnace (BOF) for conversion into steel. Both these processes produce a large amount of dust. In the basic oxygen furnace, approximately 22 kg of dust is produced per tonne of steel. The chemical composition of BOF dust differs from that of blast furnace and even from one BOF to another depending on the type. The dust collected from blast furnace and BOF is processed through a sintering plant to convert it into a form suitable for recycling into the blast furnace. Recovered material from BOF emissions has a high concentration of Zn (especially if scrap metal charge is used). The solid waste problem is due to the sludge resulting from lime neutralization of spent pickle liquor. The electric furnace method of steel making uses recyclable scrap and generates large quantities of dust. When good dust collection devices are used about 22 kg of dust per tonne of steel gets collected.

The characteristics and use of such wastes produced from Indian steel plants are shown in Table 5.7.1 Part of the wastes is recycled and reused in the following way [72].

- i) Air cooled slag is produced in pits or when slag is allowed to flow down an embankment. It can be used as aggregate for portland cement concrete (as replacement of gravel upto 35-40% of total).

Its unit weight should be  $1170 \text{ kg/m}^3$  for use as coarse aggregate and  $1270 \text{ kg/m}^3$  for fine aggregate. It can also be used as aggregate for road construction when its density should be between  $1130$  to  $1150 \text{ kg/m}^3$  as rail-road ballast, roofing material and trickling filter media.

- ii) When the slag is cooled in a controlled quantity of water a porous or light product is obtained which is crushed, graded and used as light weight aggregate for concrete. It can also be used as a good filling material for insulation purposes.
- iii) When chilled in large quantity of water, granulated slag (slag sand) is obtained which is used for slag cement manufacture and as glass sand for manufacture of glass.

Table 5.7.1 - Solid Wastes from Steel Plants in India

Sr No	Type of waste	Quantity	Chemical Composition %	Method of disposal/use
1	Blast furnace flue dust	30-40 kg/tonne hot metal	SiO <sub>2</sub> 9-12% Al <sub>2</sub> O <sub>3</sub> 3-6% Total Fe 25-40% MnO 1-2% MgO 2-9% LOI 15-25% Lime 6-7%	Some used in sintering plant and some dumped outside the plant.
2	Blast furnace slag	500-600 kg/tonne of hot metal	SiO <sub>2</sub> 30-35% CaO 30-37% MgO 4-8% Al <sub>2</sub> O <sub>3</sub> 19-25% Fe 0-5-1%	Partly sold to cement plants, can be used as railroad ballast, concrete aggregate, filter material in sewage treatment plant unused part dumped in slag yard.
3	Blast furnace classifier sludge	About 20% of blast furnace flue dust	SiO <sub>2</sub> 10-11% Al <sub>2</sub> O <sub>3</sub> 8-10% Total Fe 20-35% MnO 0-5-1% MgO 1-3%	Disposed of on slag banks
4	L.D.Dust	1.5 tonnes/heat	Fe(Total) 40-56% CaO 10-12% SiO <sub>2</sub> 2-3.5% Al <sub>2</sub> O <sub>3</sub> 2-3% LOI 3-5%	Used for filling low-lying areas
5	SMS slag	20 kg/tonne of steel	SiO <sub>2</sub> 10-20% Fe 8-10% CaO 30-40% MgO 3-10% Al <sub>2</sub> O <sub>3</sub> 4-10%	Dumped in slag yard
6	Mill scale	...	Fe 90-95% Si 0.2-0.9% C 0.05-2%	Used in sintering plant and in ferro alloy plants
7	Acetylene plant sludge	...	CaO 60-70% SiO <sub>2</sub> 2-5% Fe 0.1-1.0% Al <sub>2</sub> O <sub>3</sub> 0.5-1.5% MgO 0.1-1.0% LOI 20-25%	Dumped in low-lying land

#### 5.3.4 Thermal Power Plants

Most of the thermal power plants in India used lump coal in the boilers and were disposing coal residue as bottom ash commonly referred to as furnace clinker (or cinder), coal breeze or ash prior to 1947. Pulverised coal has now replaced lump coal due to ease of blending coals of widely different ash contents and greater efficiency of boilers. The pulverised coal on combustion produces a fine residue known as fly ash. The ash content of Indian coals ranges between 25 and 40%. About 40 thermal power plants produce nearly  $5.5 \times 10^6$  tonnes/year of fly ash. Out of the total, 20% is bottom ash while remaining is fly ash. The bottom ash is slurried in water to flow through pipes. The fly ash from collectors and precipitators, on the other hand, is collected in dry state. The Indian fly ash has the following chemical composition -  $\text{SiO}_2$  - 41-58%;  $\text{Al}_2\text{O}_3$  - 21-27%;  $\text{FeSO}_3$  - 4-17%;  $\text{CaO}$  - 3-6% and 90% of which is finer than BSS 100 sieve.

The fly ash generated from thermal power plants would need about  $0.035 \text{ m}^3$  of dumping space per tonne and its transportation to such sites will add to the cost. The first known attempt at using fly ash was as pozzolona in mass concrete constructions, e.g., in Rihand dam[28]. Fly ash cement can be obtained by intergrinding portland cement clinker and fly ash or by blending cement with flyash. The product satisfies requirements of portland pozzolona cement (IS : 1489 - 1967) for physical and chemical properties. In the flyash concrete, 20% of the cement is replaced by fly ash for optimum performance. Flyash can be sintered and though various publications are available on the use of flyash, much of it is simply dumped possibly because of:

- i) consumers' reluctance; and
- ii) absence of an agency to market flyash satisfying ISI specifications.

#### 5.3.5 Lead-Zinc Industry

Lead is produced from the ore by lead blast furnace and zinc by electrolytic process. Dust from lead blast furnace poses public health problems. The solid waste produced from these industries consists of i) dust from lead blast furnace and ii) slag. Dust has to be collected from hoods placed over sinter machine furnaces and other equipment. The dust is collected in a bag house and reused. The sludge contains Zn, Pb, Cd, As & CN and hence care should be taken during its disposal. The slag from lead manufacturing plant contains[67].



FeO - 38-47%    Al<sub>2</sub>O<sub>3</sub> - 4-6%    S - 2%    SiO<sub>2</sub> - 22-26%  
MgO upto 2.5%    MnO - 1%    CaO - 11%    Zn - 2.5-3.5%  
Na<sub>2</sub>O - 1% and small amounts of Pb, Cu, AS & K<sub>2</sub>O.

Presently most of the slag produced is stored in dumps. From these piles dust gets blown off and rain water produces leachate leading to water pollution. These dumps contain valuable ingredients. In Belgium, slags from lead are reduced to give copper, silver matts, iron slags and zinc and lead oxide which are used for byproduct recovery such as germanium in semiconductor industry. The final waste is let off as a liquid. In Russia, upto 20% of slag from lead manufacture is added to the raw material to obtain portland cement. A two stage process has been developed for copper extraction, recovery of zinc and lead in the zinc slag, the remaining slag being used for slag pumica.

### 5.3.6 Paper Industry

Solid wastes are produced from the following sources:

- i) Boiler cinder;
- ii) Chip screen dust;
- iii) Lime mud from soda recovery plant;
- iv) Sludge from bleach making plant; and
- v) Other sources.

*Boiler cinder* : The coal used in the boilers after combustion gets converted to boiler cinder. The cinder contains 5 to 25% combustible matter depending on the quality of coal and the condition of the boiler. In integrated paper and pulp mill quantity of boiler cinder varies from 0.5 to 1 tonne per tonne of paper.

*Chip screen dust* : Depending on the quality and condition of raw material such as wood, bamboo, etc., as much as 25 kg is lost as fines from the chip screens per tonne of the material. In an integrated paper and pulp mill the quantity so lost may be upto 6 to 7 tonnes per 100 tonnes of the paper.

*Lime mud from soda recovery plant* : In the process of causticising green liquor with fresh lime, lime mud consisting mainly of calcium carbonate is produced amounting to about 500 kg per tonne of paper in an integrated pulp and paper mill based on soda or sulphate pulp.

*Sludge from bleach making plant* : A large amount of lime sludge is released from bleach making plant where calcium hypochlorite is produced by chlorinating lime.

*Other sources* : Inert solid wastes such as soiled paper, sweepings, grit from China clay mixing tank, sand tables and centri-cleaners do not have any reuse potential and hence are either used for landfilling or are burnt down:

The boiler cinder is used for landfilling. A process for making bricks from boiler cinder has been developed by Central Building Research Institute, Roorkee. The chip screen dust has high fuel value and hence is used as an auxiliary fuel or for making hot water for the process. If no such use can be found it is used for landfilling. The material is also used for making cheap boards and fillers in plastics. Due to the high concentration of silica in bamboo, straw and lime, it is difficult to recalcinate the lime mud from soda recovery plant. However, when hard wood and soft wood are used to produce pulp no such problem is encountered and a rotary kiln for lime recovery is used. The lime mud can also be used for manufacture of portland cement, provided the caustic alkali is reduced to a minimum by use of proper washing and dewatering system. The lime sludge can also be used in certain ceramic industries but is not popular in India. It consists mostly of silica, calcium silicate, calcium carbonate and small quantity of residual lime. The quantity of this waste produced from an integrated paper and pulp mill is about 5% of the output and is used for landfilling.

### 5.3.7 Aluminium Industry

Aluminium is produced by Bayer's process from bauxite or from secondary aluminium. Secondary aluminium is produced by remelting scraps and is mainly used for making alloys for foundry work as well as aluminium ingots.

i) **Red mud** : In the Bayer's process red mud, the leached residue of bauxite is produced [70]. The quantity of red mud produced is about 0.1 to 0.3 tonne per tonne of bauxite treated. Besides the undissolved alumina, red mud contains alkali insoluble oxides like  $\text{Fe}_2\text{O}_3$ ,  $\text{TiO}_2$  and small amounts of vanadium.

ii) **Waste from secondary aluminium industry** : Maximum amount of waste is produced from the pot rooms where the electrolytic cells are housed and remelt and cast into ingots. The waste can be grouped as metallic and chemical wastes. Metallic wastes consist of heavy scrap and light scrap, swarf (turning, boring, trimming, foil, etc. and dross that contains about 50% Al).

**Recycling** : A process has been developed by National Metallurgical Laboratory, Jamshedpur for recovery of  $\text{Al}_2\text{O}_3$  from red mud [71]. Vanadium can be concentrated as a complex salt from which it can be recovered.

The residue resulting from the lime soda sinter process is very light, fine and can be treated for recovery of Fe and Ti or for the production of Ferrotitanium. Light and heavy scrap from secondary aluminium industry is again molten by charging into melting furnace. Dross is treated with an 'ignitor flux' and then in a rotary or open well furnace to recover nearly 90% Al. The cathode lining of cells are known to contain about 20% fluorine. Flue gases on an average contain 50 mg of  $F_2/m^3$  of gas. A combined fluorine recovery plant provided on Al smelters recovers 95% of fluorine.

## CHAPTER 6

### HAZARDOUS SOLID WASTES

#### 6.1 Introduction

Solid wastes generated from urban and industrial sources contain a large number of ingredients, some of which are toxic. The substances are considered toxic when the concentration exceeds a particular value below which it may not endanger public health. However, for this discussion, the concentration of waste at which it normally occurs is taken while classifying it as toxic. The waste may or may not contain any proportion of the final product but may contain impurities present in the raw material, and recovery of the same may be uneconomical in the industrial process.

#### 6.2 Identification of Toxic and Hazardous Waste

Various tests and criteria [68] have been devised by different agencies to determine as to whether a given substance is toxic or hazardous. It is necessary to assess the intrinsic properties of the waste to judge whether its uncontrolled release in the environment would lead to toxic effects on human or other living organisms. The possible toxic effect also depends upon the quantity of the waste.

A preliminary decision model for screening and selecting hazardous compounds and ranking of hazardous wastes has been developed by EPA [68] (Fig.6.2.0.1). The criteria used in the screening model relate to only the intrinsic hazard of the wastes on uncontrolled release to the environment in respect of its quantity or the pathway to humans or other critical organisms. The criteria such as toxicity, phytotoxicity, genetic activity and bioconcentration are used for this purpose.

Substances or materials can be classified as hazardous or otherwise depending on the dose administration, exposure mode and time of exposure. On this basis EPA has given the following scale of activity [68].

LD <sub>50</sub> value	Scale of Toxicity
< 1 mg/kg	Poisons

1 to 50 mg/kg	highly toxic
50 to 100 mg/kg	very toxic
100 to 500 mg/kg	moderately toxic
0.5 to 5 gm/kg	slightly toxic
> 5 gm/kg	essentially non-toxic

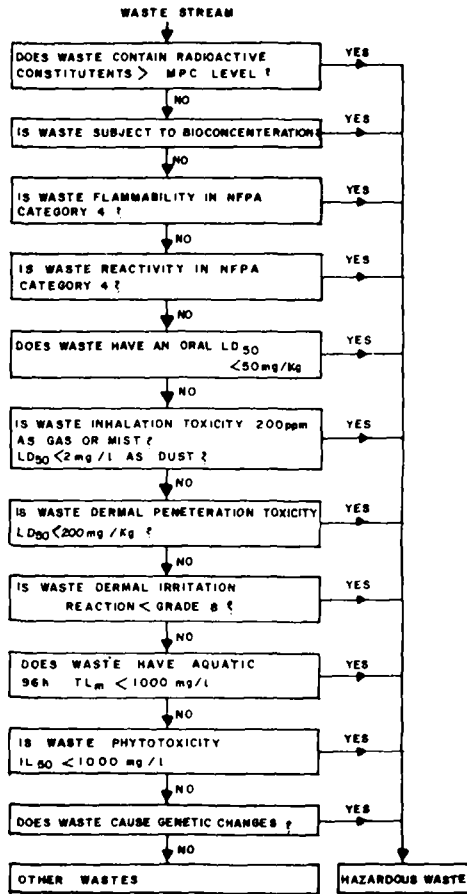
LD<sub>50</sub> = Lethal Dose to kill 50% population

### 6.2.1 Classification of Wastes

As there are a number of compounds, products and product combinations, which can be termed as toxic it is difficult to list them individually. However, they can be grouped into five categories, viz. [84] i) chemicals, ii) biological wastes, iii) flammable wastes, iv) explosives and v) radioactive wastes. Table 6.2.1.1 gives some common examples of these different categories.

**Table 6.2.1.1 : Sources and some Examples of Toxic and Hazardous Wastes**

I	Chemical	i)	Synthetic organics
		ii)	Inorganic metals, salts, acids and alkalies
		iii)	Inflammables
		iv)	Explosives
		A complete list of such toxic substances is given in ref. (68)	
II	Biological	i)	Hospitals – malignant tissues, contaminated material like hypodermic needles, bandages, etc.
		ii)	Wastes from biological research facilities.
III	Flammable	Mostly in liquid form, but may exist along with solid chemicals, e.g., organic solvents, oils, plasticisers and organic sludges.	
IV	Explosive	Wastes from ordnance factories, etc.	
V	Radioactive	Regulated by Atomic Energy Commission and separately disposed of.	



6.2.0.1 Flowchart for hazardous waste screening model

### 6.3 Source of Toxic Wastes

These are generated in varying quantities in a community and hence it is necessary to identify the sources and the quantities. As bulk of them are generated in the industries and the records of such industries being proprietary, it is difficult to quantify such wastes. Generation of toxic wastes outside the organised industry is irregular and hence difficult to quantify. It is desirable to prepare an inventory of sources of such waste and measure the quantity at different sources.

In cases where the industries treat their liquid wastes, sludges contain hazardous substances. In 1980, out of the 57 million tonnes of hazardous solid wastes produced in USA 60% were from chemical industries. Out of the total hazardous wastes, about 60% appears in the sludges. Table 6.3.1 gives hazardous chemical constituents contained in some common industrial wastes.

Table 6.3.1 - Some Hazardous Material in Industrial Waste Stream<sup>(68)</sup>

	As	Cd	CHc <sup>a</sup>	Cr	Cu	CN	Pb	Hg	Other Organics <sup>b</sup>	Se	Zn
Mining & Metallurgy	x	x	-	x	x	x	x	x	-	x	x
Paints & dyes		x	x	x	x	x	x	x	x	x	
Pesticides	x		x			x	x	x	x		x
Electrical & electronic			x		x	x	x	x		x	
Printing & duplicating	x		x	x	x		x		x	x	
Electroplating & metal finishing				x	x	x					x
Chemical manufacturing			x	x	x			x	x		
Explosives	x				x		x	x	x		
Rubber & plastics			x			x	-	x	x		x
Batteries		x					x	x			x
Pharmaceuticals	x							x	x		
Textile				x	x				x		
Petroleum & coal	x		x					x			
Pulp & paper								x	x		
Leather				x					x		

a = Chlorinated hydrocarbons

b = Aerolein, chloropicerin, dimethyl sulfate, dinitrobenzene, dinitrophenol, nitroaniline & pentachlorophenol

## 6.4 Storage

Method of storage and equipment used depend upon the quantity generated and rate of generation. When large quantities are produced, special equipment is often provided to store it safely for a sufficiently long time. The containers should be fibreglass or glass-lined if the material is corrosive[77]. It is necessary to avoid storage of incompatible wastes in the same container or site. In general, the containers should be such that the contents do not spill out or come in contact with workers while being shifted within the premises or to different vehicles and during transportation in the vehicles.

## 6.5 Transportation

Such wastes should be transported in special vehicles to the processing or disposal facility. If the quantities at individual source are small, the contents should be emptied into the vehicle with adequate precaution. In the case of large quantities generated at individual sources, it is desirable to load the containers on to a flatbed truck or suitable vehicle for further

transport. In no case the material be allowed to come in contact with the workers. It is hence desirable that this work is handled by persons who are experienced and specially trained for such work. To avoid accidents and possible danger to life, at least two persons should form a team.

## 6.6 Problems Posed by Present Disposal Methods

When the industry is not able to obtain useful products from the waste, least cost method such as land disposal is adopted. When disposed on land, the toxic ingredients leach out polluting ground water and surface water sources. Experience in developed countries has shown a number of such instances of pollution. Some of the well-known episodes are the Love Canal and Valley of Drums in USA[69]. Though incineration is one of the safest methods of disposal, it is not so much preferred. A survey carried out in the UK in 1970 showed that in about 90 per cent of the cases, waste is disposed on land while incineration was adopted for about 10 per cent cases. Some of the toxic wastes, besides causing water pollution, may also cause fire if they are inflammable. They may also cause explosions, or release poisonous gases. Some wastes are such that they may degrade the soil and make it unfit for cultivation. Hence utmost care should be taken in the disposal of such wastes.

## 6.7 Pre-treatment

*Proper control and regulation of disposal of toxic solid wastes would encourage the industry to become aware of the expenditure involved and methods would become more effective. In such cases, a re-appraisal of manufacturing process will help identify methods to reduce quantities of the waste. The weaker wastes can be treated separately. Three types of processes can be used to render a hazardous waste less hazardous or non-hazardous:*

- i) Physical : such as carbon adsorption, distillation, ultrafiltration, etc.
- ii) Chemical : such as neutralisation, fixation into solids that can be easily disposed, etc.
- iii) Biological : such as activated sludge process, trickling filters, land farming, etc.

Segregation will enable adoption of suitable methods for different types of wastes. Reclamation of some constituents which normally would not be economical may be encouraged to save on disposal cost and for conservation of resources. For example, waste oils are not reclaimed due to high cost of



collection and treatment and relatively low cost of fuel oil. But if such waste oils can be used in boilers, besides reducing some cost of boiler operation, oil could be saved along with avoidance of nuisance on landfill sites.

### **6.8 Detoxification**

Toxic substances are seldom chemically inert and hence can be converted to a non-toxic or less toxic compound by chemical treatment. However, solids have often to be brought into solution before subjecting it to chemical treatment followed by effective sludge disposal. Some of the toxic metals have a resale value, and hence effort should be made to recover and reuse them.

### **6.9 Prevention of Water Pollution from Landfills Receiving Toxic Waste**

As wastes are commonly disposed on land, it should be ensured that water pollution (surface water by runoff & ground water by leachates) does not occur from such sites. It could be ensured by:

- i) proper consolidation of the waste to reduce spaces and permeability;
- ii) disposing the waste at a sufficient depth to prevent water pollution;
- iii) depositing waste in impervious zone at a certain depth so that leachate will not gain access to aquifer; geologic investigations would be useful in such cases;
- iv) providing a layer of impervious soil on top and sides to prevent percolation of water; and
- v) mixing with municipal solid waste for composting if the waste is amenable for biological decomposition.

### **6.10 Oil and Tarry Wastes**

They are highly viscous making it difficult to permeate through the pore space in the soil. Less viscous oils may travel fast posing pollution problems. In the case of viscous wastes, it is noticed that they turn into an emulsion (if filled with water) or foam (if filled with air). In either case, viscosity would further be increased and rate of percolation decreased, thereby reducing leaching effect.

### **6.11 Incineration**

It is an effective way of disposal of combustible organic and chemical wastes. The residue left is quite small which can be disposed of. Incinera-

tion has the advantage that when the toxic constituents are burnt or otherwise decomposed they cease to be toxic. During incineration, the organic chemicals are converted to gas, moisture and simple compounds of  $N_2$ , S, P,  $Cl_2$ . At the incineration temperature, toxic materials may alter physically so that the toxic constituents are not so readily available, e.g., a powder converted to slag, when the toxic constituents would not be easily soluble in water. Though incineration is likely to cause air pollution, technology is available to keep it below permissible limits [39].

Oily wastes including acid tars having a high calorific value can be incinerated. When wastes of high calorific value are burnt along with those of low calorific value it is likely to pose problems in plant operation. After-burners would be required and a solid hearth with primary air for combustion being injected over the top, is used. Where the emission is noxious or offensive such as HCl, water or soda scrubber is used preceded by some form of cooler, since the gases leave at elevated temperatures in a hollow tower down which water is sprayed. The scrubber, fan and final chimney should be corrosion resistant such as fibre glass. At times, highly toxic wastes have to be disposed by permanent safe storage. However, this is not desirable as with the passage of time people tend to forget the location where it has been stored. It may pose danger due to inadvertent excavation.

### **6.12 Disposal in Sea**

This method may not always be possible and at times, ocean currents may wash it back to the shore. Sea provides a large dilution and if disposal is carried out in deep regions the waste would not easily reach the surface layers. Every care should be taken to ensure that the disposal is done by taking all necessary precautions. Disposal by incineration at sea on specially designed ships could be carried out in special cases such as polychlorinated biphenyls.

### **6.13 Authorisation for Disposal**

In most of the developing countries, legislation to control and regulate disposal of solid toxic wastes does not exist. The solid toxic waste, when converted to liquid (i.e. dissolved in water), can partly be regulated by the use of Water Pollution Control Act.

Independent authorities with sufficient regulatory powers and infrastructure would be needed to ensure safe disposal of toxic solid wastes. Before any toxic solid waste is disposed, approval for the method and sites proposed to be used must be taken from regulatory agency which can have a list of common types of wastes for landfilling or incineration. Complete information about the sources of the waste should be provided. Where the

industry does not wish to part with this information to protect patent rights, the charges for municipal disposal should be made heavier or a clause be provided in the Act to the effect that such information will be treated as confidential and stiff penalties provided for any lapse.

The disposal facility may be provided by the concerned industry or it may be provided by the authority or it can be privately operated which can levy fees for disposal. Even if the site is owned by the industry, approval for its location and use will be essential. If the site is operated by the authority or private party, unauthorised disposal of other toxic wastes may take place. In such cases, the carriers of waste should be licensed by the authority. A standing committee of advisers will be useful in dealing with unusual wastes, especially if they are in need of immediate disposal.

Good examples of such a legislation is the Resources Conservation & Recovery Act (RCRA) which has been effective since 1980 in USA. As per this Act, a cradle to grave control system regulates the waste from the time it is first generated to its final treatment or disposal destination. Every generator has to first go through a list of over 200 wastes that have been identified for control. The waste can be disposed of at such a site which satisfies the requirements of the Act. Transport to the site can be through an approved transport agency only which takes part in a "manifest system". When the transporter receives the waste one has to sign a receipt and get a receipt at disposal site to be returned to the generator which prevents disposal at unauthorised sites. If the generator does not receive back the manifest within a reasonable time EPA should be informed.

Specific operating standards which include proper safety measures, development of emergency procedures, monitoring and training of employees and participation in manifest system have been laid down. Liquids draining out of the site should be treated and disposed. A superfund legislation is also being contemplated to clean up existing hazardous sites and compensate local victims. Funds would be obtained in the form of fees from industries. Major portion of the fund is to be used to clean up existing sites (estimated to be about 2000) and the remainder for compensating victims of the wastes.

## CHAPTER 7

### COLLECTION OF SOLID WASTES

#### 7.1 Introduction

Waste produced from individual households is removed initially by the owner or an employee and later by municipal staff. In the case of community bin system adopted in most of the developing countries, waste is collected and taken to the community bin by the houseowner or an employee from where it is removed by conservancy staff. Wastes from the streets are collected and removed by the conservancy staff. Wastes from industries are collected and taken to the specific collection and disposal site by the industry itself. In house-to-house collection system as adopted in most of the developed countries, the workman collects the waste from individual premises where it is stored by the owners in standardised containers.

#### 7.2 House-to-house Collection

In house-to-house collection, refuse generated and stored in individual premises is collected by several methods, some of which are indicated here (Table 7.2.1).

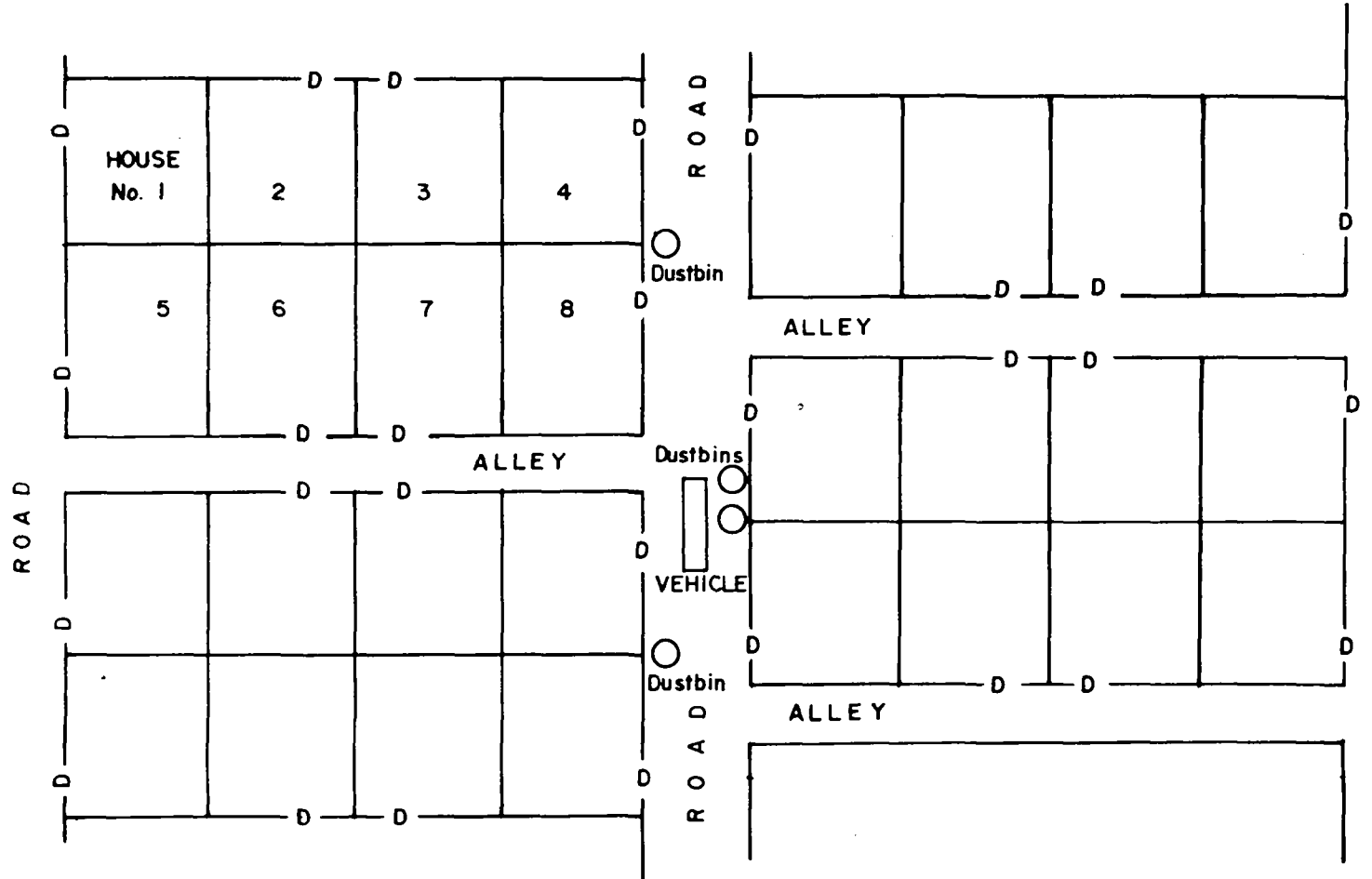
i) *Curb Service* : The houseowner is responsible for placing the refuse containers at the curb on the scheduled day, when the workmen from refuse vehicles collect and empty the containers in the vehicle and place them back at the curb. The houseowner is required to take back the empty containers to his house (Fig. 7.2.2).

ii) *Alley Service* : The containers are placed at the alley line from where they are picked up by workmen from refuse vehicles who deposit back the empty containers (Fig.7.2.3).

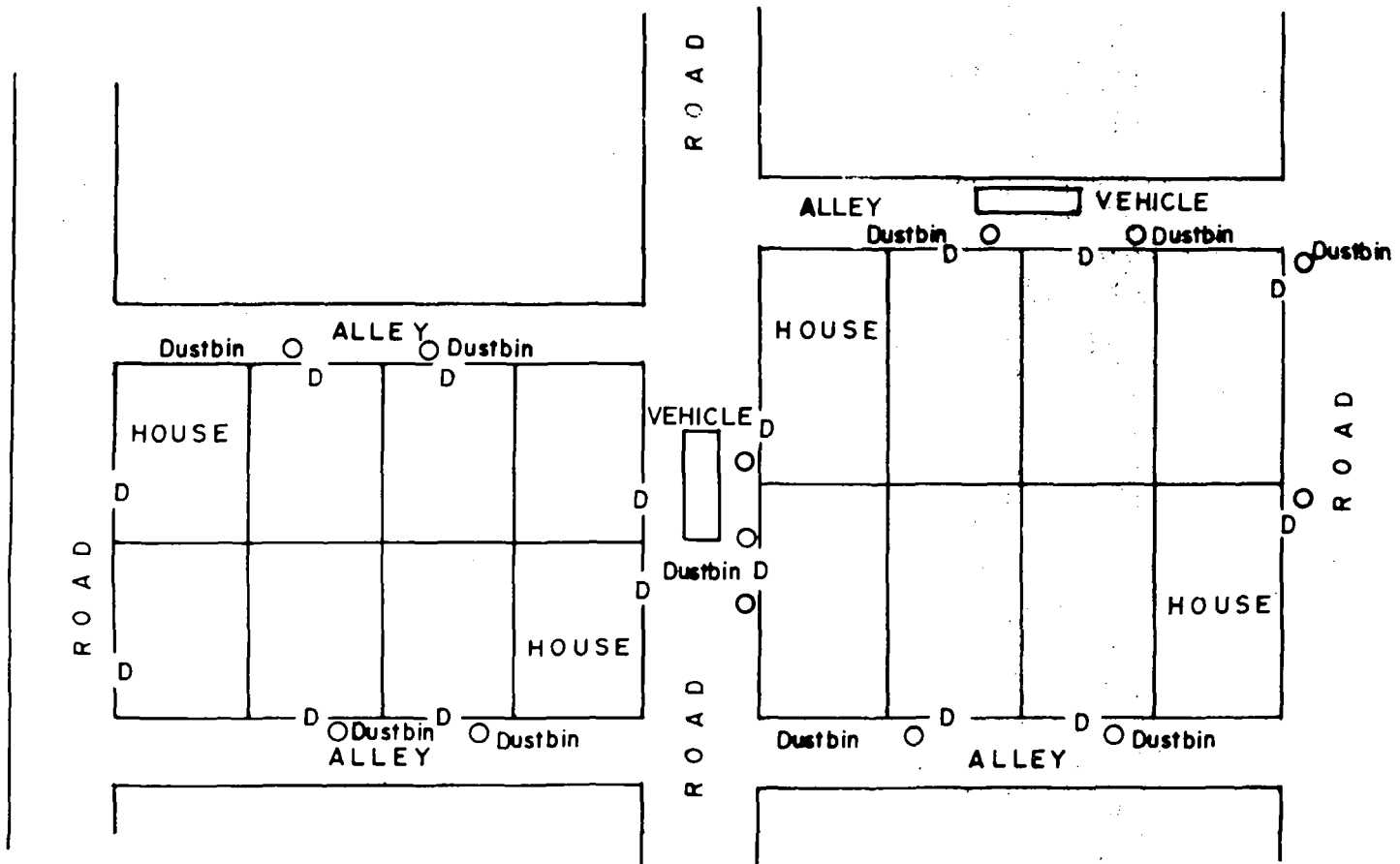
iii) *Set-out, Set-back Service* : Set-out men go to individual houses, collect the containers and empty them in the refuse vehicle. Another group of persons return them to houseowners' yard (Fig. 7.2.4).

Table 7.2.1 : Comparison of various Methods of House-to-House Collection

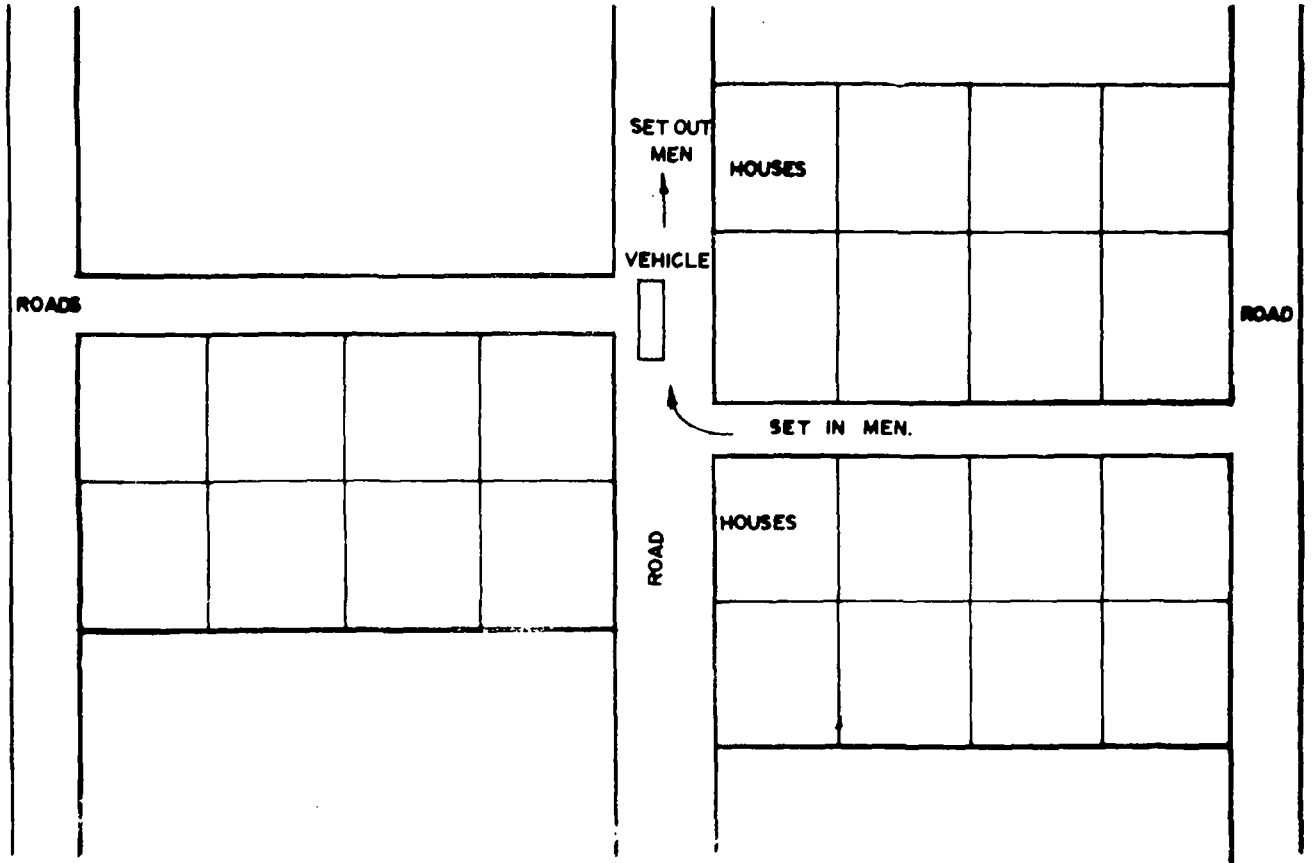
Sr No.	Description	Curb service	Alley service	Setout, set-back service	Setout service	Backyard service
1	Houseowners' cooperation is required :					
	i) to carry full cans	Yes	Optional	No	No	No
	ii) to carry empty cans	Yes	Optional	No	Yes	No
2	Scheduled service is necessary for obtaining houseowners' cooperation	Yes	No	No	Yes	No
3	Prone to upset	Yes	Yes	No	Yes	No
4	Average crew size	1-3	1-3	3-7	1-5	3-5
5	Complaints regarding trespassing	Low	Low	High	High	High
6	Special services	-	Requires special vehicle	-	-	-
7	Evaluation with reference to:					
	i) service to citizens	poor	Fair	Good	Fair	Good
	ii) crew cost	Low	Low	High	Medium	Medium



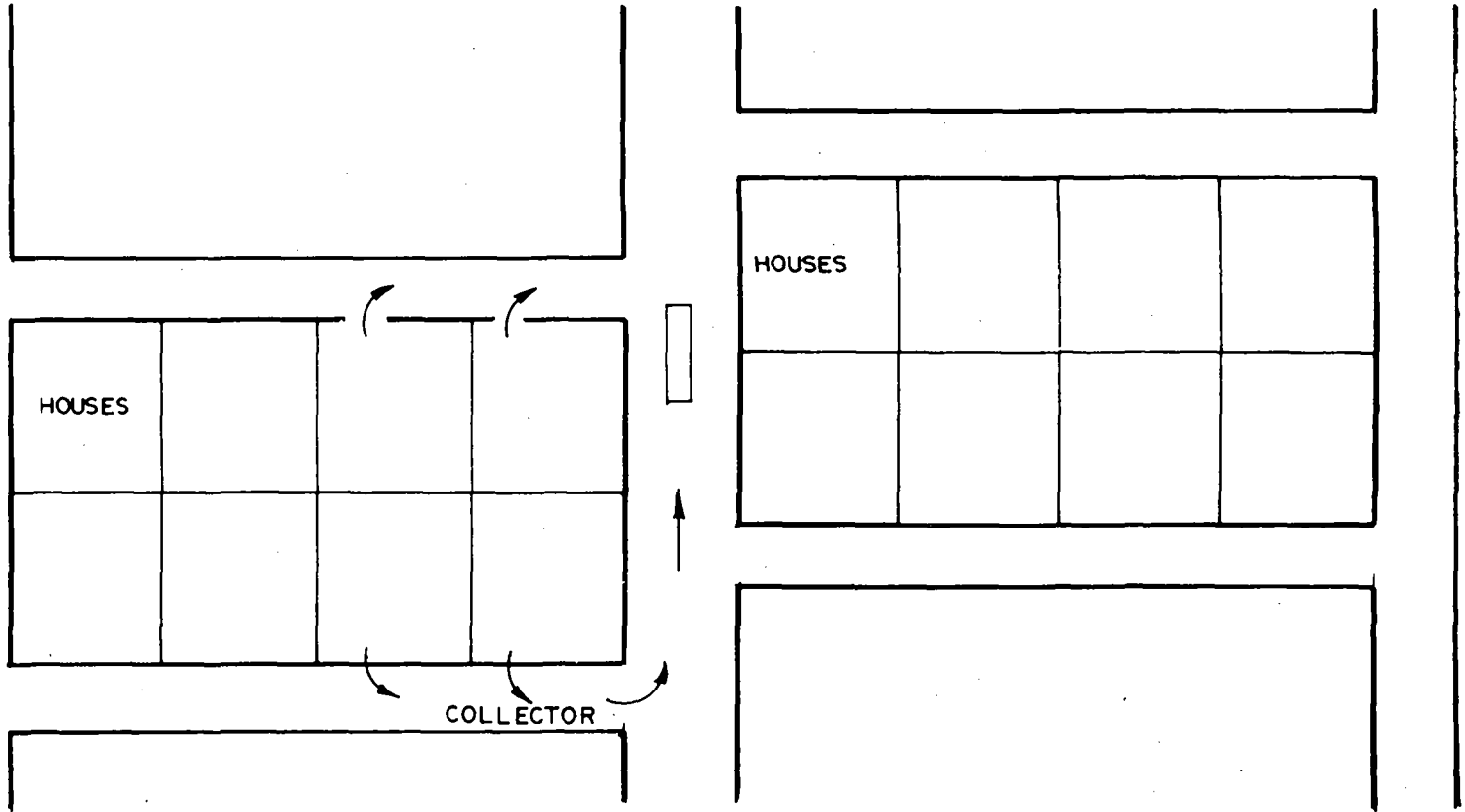
7.2.2 Curb service



7.2.3 Alley service







7.2.5 Backyard service

iv) *Set-out Service* : The workers with refuse vehicles collect the containers from individual houses and empty them in refuse vehicles. The houseowner has to take back the empty containers.

v) *Backyard Service* : The workers with the vehicle carry a bin, wheelbarrow or sack or cloth to the yard and empty the refuse container in it. The wheelbarrow or bin is then taken to refuse vehicle where it is emptied (Fig.7.2.5).

If wastes have to be stored in individual houses, as in house-to-house collection, every premises must be provided with specific containers having specific size and airtight lids. When these are provided and located at specified points in individual premises the house-to-house collection system would be effective. Cities in developing countries being outgrowths of small towns with narrow streets and crowded localities, it is difficult to provide specific locations outside the house for the refuse containers and it will be necessary to store them inside the houses. This poses a number of problems from aesthetic and sociological aspects. Further, if the house-to-house collection system is to be effective standard containers need be used by individuals. This is quite difficult to achieve because of comparatively low purchasing power of majority of citizens. The citizens should fully cooperate for which extensive health and environmental education will be required.

As the collection has to be made frequently, quantity from each household would be less and the collection vehicle will have to make more halts to get completely filled as compared to lesser halts needed in the weekly or biweekly system. This will result in increasing the cost of collection per tonne. Hence house-to-house collection system can be successful only in such areas where daily collection of refuse per unit is more and where better civic sense prevails as in high income group areas or in areas having predominantly commercial or industrial activity. Adoption of house-to-house collection system is thus limited to a few areas in Bombay, Calcutta, Taiwan, Singapore, Manila, Colombo, Jakarta, Bangkok and Rangoon [78]. While adopting house-to-house collection, it is desirable that the waste is collected from individual houses in a smaller vehicle, preferably manually operated, which can then be transferred to collection vehicle.

A modified form, i.e., 'Block Collection' can also be adopted in which a collection vehicle stops at selected locations on specific days. The houseowner empties the waste in the vehicle which then moves ahead.

### **7.3 Community Bin System**

In the community bin system, workers sweep the roads and collect the material at specific points. If the point has not been marked, depending upon the convenience of local citizens, a suitable point gets fixed. It should be recognised that most of the citizens would be averse to locating such points in front of their houses. Such spots where no resistance is offered get evolved as collection points. Obviously, these may not be near public places. The capacity of community bins should be at least 50% in excess when collection is daily and 100% in excess for 6 days a week collection. The spacing of the containers has to be accordingly fixed which in no case should be more than 100 metres apart. Larger spacing encourages workers to avoid transporting wastes to the community bin and private sweepers start working in such cases.

### **7.4 Collection of Waste from Streets**

In addition to the waste generated in individual premises, wastes are generated on streets also, the collection of which is the responsibility of civic authorities. In most of the developing countries, collection from streets is by manual labour while in developed countries mechanical equipment is used. When mechanical equipment is used it sweeps the road, collects the waste and takes it away for disposal. In manual methods, the collection from the street is deposited in communal storage bins from where separate vehicles collect for transport to processing or disposal site. In manual operation it is desirable to have a group of not more than three persons. One should clean the footpath, the second to sweep the road and collect the material into heaps in the channels and the third person to transfer it to a wheelbarrow. Larger groups may be needed when quantities to be cleaned become large or the work has to be done in a short time.

### **7.5 Frequency of Collection**

The waste in solid state is generated continuously in residences, commercial and industrial establishments. In order to keep the environment clean, it should be removed quickly as in water carriage system of transporting human faeces. Though pneumatic transport has been successfully tried for small communities as the Olympic village at Munich, West Germany and in Sweden[83], the system is capital intensive and needs to be further tested for wider adoption. In a discontinuous system, it is necessary to provide storage where material is held before being removed.

The municipal agencies assume the responsibility for removal of solid waste from domestic and commercial (including hotels, restaurants, etc.)

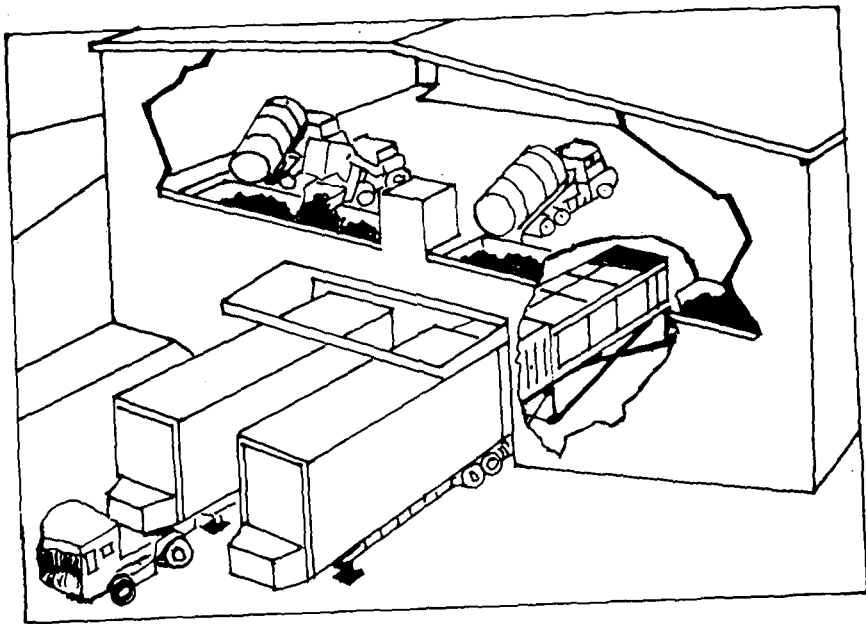
areas, small factories and street sweepings. Domestic waste and street sweepings represent the predominant fractions. Though the constituents of refuse do not change much, their proportion changes from city to city. It has been observed that the percentage of paper, glass, plastics, etc. increases with increase in the population of the city and standard of living. The organic matter in solid waste from India and other developing countries is much higher than that in the waste from developed countries. This large organic fraction tends to decompose at a faster rate at the higher ambient temperatures encountered. It is thus necessary to collect and remove this material as quickly as possible.

The higher the density of waste the smaller would be the volume at individual houses. Hence a lower volumetric capacity of vehicles will be required to collect and remove the material at greater frequency. Another potential problem is the possibility of fly breeding. The eggs of *M. domestica* hatch in 1-2 days, and the larvae feeds for about 5 days before pupation. The adult emerges from the pupa after 3 more days. The weekly collection prevents the production of adult flies as the waste is stored in airtight containers from where the larvae cannot migrate. In India and other developing countries the waste stored at individual house (for a few days) is deposited in community bin. The houseowners can ensure that fly larvae do not migrate, but it is difficult to achieve in community dust bin. It is, hence, necessary to remove the waste from the site as early as possible, daily or at least thrice a week.

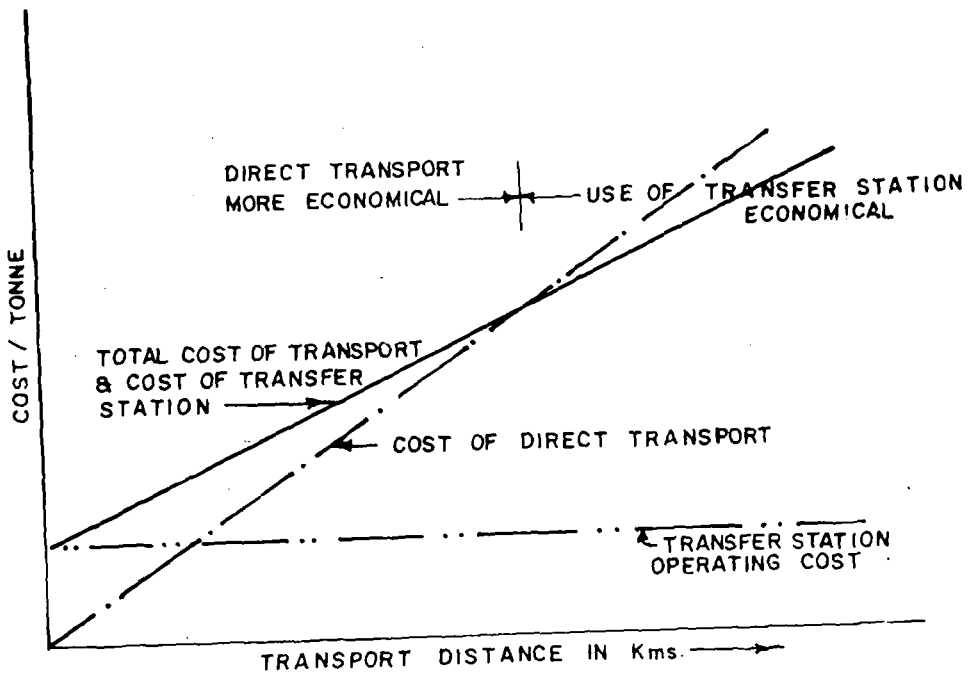
In house-to-house collection, if the dwellings have adequate space to store in closed containers, daily collection may not be necessary. However, if the dwelling is small or in clusters and outside storage space is limited daily collection should be encouraged.

## 7.6 Transfer Stations

These are provided for transfer of waste to large transportation vehicles which transport it to processing or disposal site (Fig. 7.6.0.1). The movement of refuse in these large vehicles is referred to as secondary collection. The large capacity secondary vehicles move over large distance directly to processing and disposal site and are found to be economic to operate. Although the transfer operation offers potential savings, it involves an additional material handling step and the construction of the transfer facility. Before deciding the use of a transfer station the cost of bulk transportation to the final disposal site, plus the cost of operating the transfer station should be compared with the cost of conveying the refuse directly to the disposal site in the collection vehicle (Fig. 7.6.0.2). The short range transfer station are of two types.



7.6.0.1 Transfer station



7.6.0.2 Economics of use of transfer station

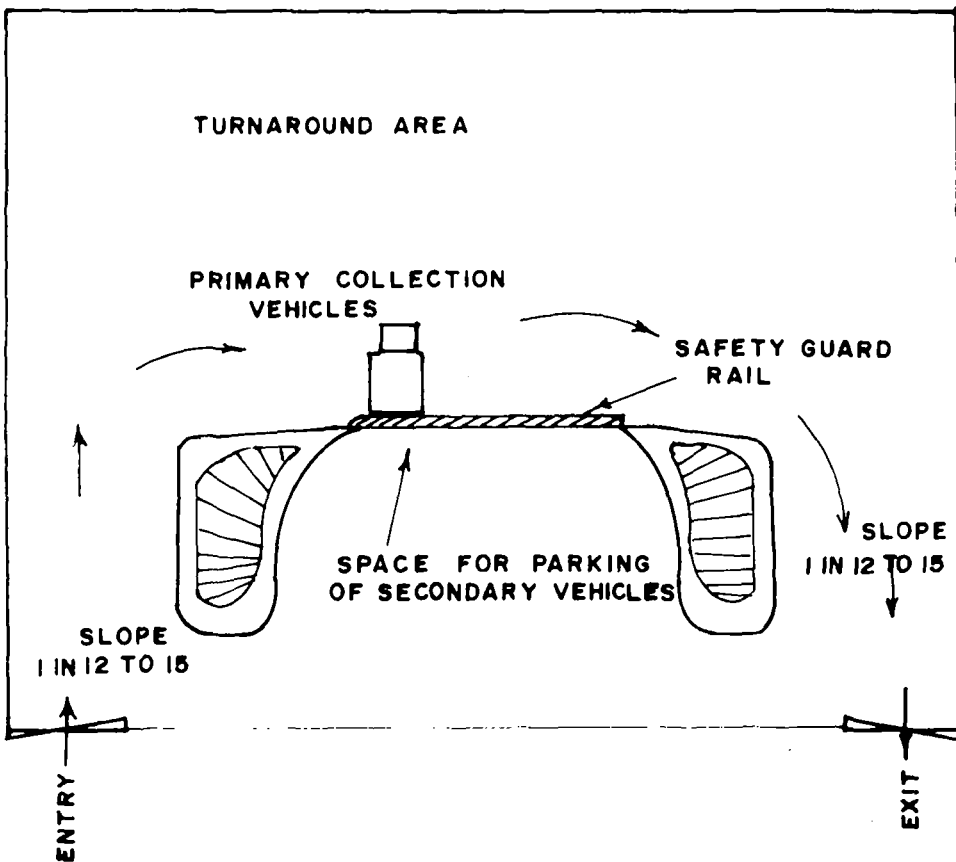
### 7.6.1 Level Sites

Refuse is transferred from one vehicle to another manually at such sites where a trailer or a bigger vehicle is parked. The smaller vehicle unloads its

contents which are then manually transferred to the other vehicle. The contents of any incoming hand carts can also be directly tipped inside the bigger vehicle. Due to manual handling, the site is likely to get littered which could be minimised with a suitable enclosure.

### 7.6.2 Split Level Site

When a direct discharge of the refuse from primary collection vehicle into another is desired, split level sites become necessary. Such a site consists of a loading platform at a height of 3 to 4 metres above the ground level and with a ramp having a slope of 1 in 12 to 1 in 15 (Fig. 7.6.2.1). The vehicles climb up this ramp and unload their contents from specific points into the vehicles standing at a lower elevation. A backhoe is used to compact and distribute the refuse after it is placed in the vehicle below. The smaller collection vehicle climbs down from the other side of the ramp after unloading. In some cases, the smaller collection vehicle unloads its contents on the platform and the waste is then pushed by a tractor or bulldozer



7.6.2.1 Plan of a simple direct discharge split level transfer station

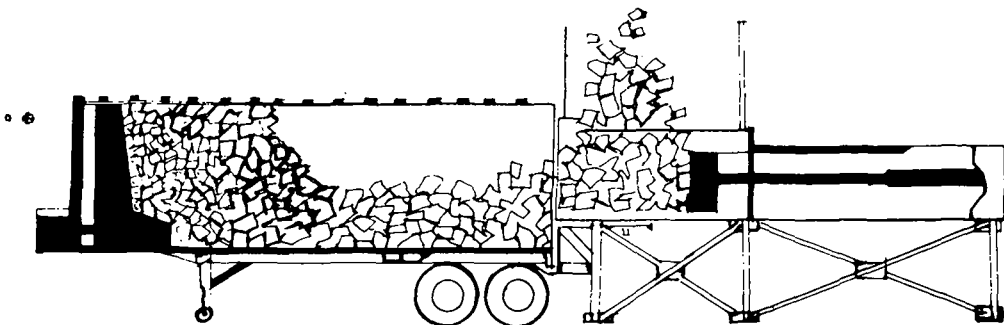
through an opening into the vehicle placed below. Though the appearance of such a site may not be good, the operation of primary and secondary vehicles need not be synchronised allowing the primary collection vehicle to make more number of trips.

In Bombay and Calcutta such split level sites are being used to transfer the waste from auto-vehicles to railway wagons. In Bombay the waste is being taken to a site located nearly 20 kilometers away. In Calcutta the railway system transports the waste through a distance of about 5 kilometers, thus increasing the unit transportation cost. In Madras, four such stations are used to transfer the waste from bullock-carts, which collect it from narrow byelanes to trucks.

### *7.6.3 Volume Reduction at Transfer Stations*

In order to reduce the capacity of the secondary collection vehicles, the volume of the waste is reduced at the transfer station. This is adopted in the developed countries as the refuse is light in weight and bulky containing bulky objects such as furniture pieces, television sets, refrigerators, etc. The reduction in volume can be achieved by i) extraction of bulky and salvageable materials, ii) compression by bulldozer or similar equipment, and iii) size reduction or compaction by static compactor or within the vehicle. Removal of these objects can reduce the volume. In developing countries, such items are seldom present where this method will not have much application.

Reduction of volume by bulldozer or tractor will occur when the material dumped on the platform is over-run by the bulldozer during its normal work of re-arranging and discharging the material into the hopper. Such incidental compaction can result in reduction in volume of the light waste material. However, the solid waste from developing countries has otherwise a high initial density and not much volume reduction is expected from such incidental compaction. If the material has to be compacted within the transportation vehicle a stronger body and chassis construction is required. Further the weight of the compaction equipment will result in reducing the volume of the waste that can be transported. When the waste density is already high further increase in the compaction vehicle can only be marginal. Static compactors provided at such sites will have better acceptability (Fig. 7.6.3.1). Compaction of waste material helps increase the density so that a much larger weight of refuse can be carried by the same secondary collection vehicle. In such a transfer station, refuse from the incoming vehicles is unloaded in a hopper which then falls into a chamber. The material in the chamber is forced by a hydraulic ram against a penstock door. The secondary collection vehicle is anchored to the press and ram of



#### *7.6.3.1 Loading of bulk transfer trailer by a stationary compactor*

the static compactor. The compacted bale is pushed into the vehicle by the hydraulic ram. Large capacity trailers having a volume of 45 to 60 m<sup>3</sup> capacity are filled in this manner. Such a site is provided with the necessary pressure gauges to ensure that the static compactor works effectively. The compacted material is to be fully covered for transport to the final disposal site. Normally the secondary collection vehicle has a body size slightly larger than the compacted bale prepared by static compactor. Within each vehicle is provided a single acting hydraulically actuated piston for discharge of bale at the disposal site.

Some common examples of systems using static compactors are M.P.L. (Maximum Pay Load) system, Dempster system, Dinossuer system, etc. A refuse compaction plant designed and patented by Tezuka Company Limited, Tokyo hydraulically compresses and automatically covers the bales in airtight vinyl film reinforced with wiremesh. The material is normally compressed in two stages and final product has a density of about 930 kg/m<sup>3</sup> or more. These bales are being dumped in Tokyo Bay for reclamation of land.

#### *7.6.4 Vehicles for Secondary Collection*

Such vehicles are not in common use in developing countries. However, in some countries with comparatively higher standard of living, large sized open top vehicles and roll on containers of large size may be used. Other types are:

- i) trailers which can be towed by farm type tractors; and
- ii) semi-trailors of large capacity.



## CHAPTER 8

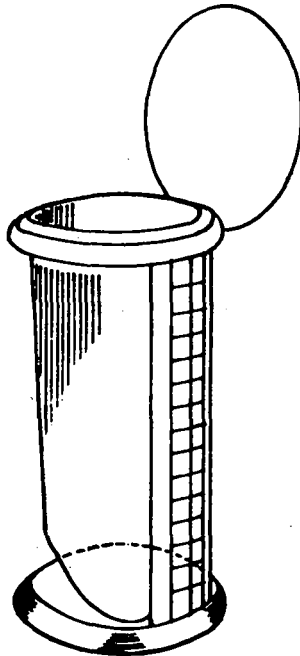
### TOOLS AND EQUIPMENT

#### 8.1 Introduction

Refuse collection service involves use of a wide variety of tools, equipment and facilities. Proper selection of equipment and its utilisation are essential for optimum performance of the system. Most of the equipments in use have not been properly designed contributing to the inefficiency of the system, nor have they been standardised.

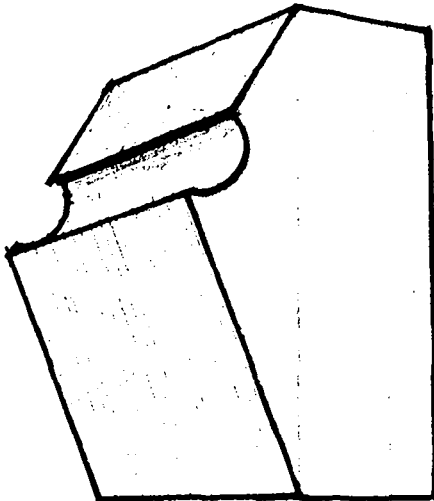
#### 8.2 Household Storage

In house-to-house collection system, waste is collected in containers, bins or plastic sacks (Fig. 8.2.1). These bins or sacks are directly emptied in the collection vehicles. Individual household may also store its waste in used



8.2.1 Sack system

metal tins or plastic buckets of 5-7 litres capacity which are adequate for an average family when daily collection of waste is carried out. In case of storage at individual premises, it is desirable to use plastic containers with tight fitting lids. In Colombo and Jakarta, improvised oil drums or similar metal containers are used for storage of refuse in individual houses. In Bangkok, baskets and plastic bins are used instead. Larger capacity will be needed if collection is to be made less frequently. Adoption of standardised containers by homeowners will help obtain better efficiency of collection. The civic authorities do not provide municipal containers as this will result in losses due to theft, diversion of containers for some other use by the homeowners, and increased expenditure by civic authority to keep a record of distribution and replacement. In commercial establishments, schools, hotels, offices and for multiple dwelling units, large size bins of 50-100 litre capacity can be provided with handle for lifting and wheels for easy movement.



8.3.1 Litter bin

### 8.3 Storage of Street Wastes

Litter bins are required to contain behavioural wastes from streets, and should be made of non-inflammable material. The bins should comprise of 2 parts - the outer part of standard design and colour and a separate inner part for lifting and emptying. The larger bins are upto 100 litre capacity while the smaller bins are of 30-50 litres. The top aperture of the bins should be shielded to avoid rain water entering and prevent lighter material getting air-borne. The spacing of the litter bins will depend upon the quantity of litter generated, importance of the road and frequency of cleaning. Larger

litter bins should be mounted on pavements and spaced farther apart while smaller bins could be located closer together (Fig. 8.3.1).

## 8.4 Equipment for Street Cleansing

### 8.4.1 Manual Cleansing

The equipment in use for manual cleansing consists mainly of brooms, shovels and handcarts.

i) *Brooms* : These are mainly of 2 types : a) one consists of a bunch of long and flexible fibres and is used by the workers standing erect. The brooms are used with long strokes without exerting much pressure and are good for sweeping light material such as paper, litter, etc. It does not remove heavy materials like sand, silt but workers prefer this due to lesser exertion. b) The second consists of a wooden handle to which a large number of short tufts or filaments are bound. The worker bends a little and gives short but vigorous strokes for cleaning. As a greater force is exerted, heavy dirt and silt get dislodged. It is strenuous for the worker and if used indiscriminately large amount of dust will get air-borne posing danger to the health of the workers. Small brooms or wire brushes are used for cleaning of channels.

ii) *Shovels* : The material collected at a place is to be lifted which is carried out by using a shovel. Conventionally a straight blade shovel is used for this purpose, but it is observed that light materials like tree leaves, paper, etc. tend to fall off. Flat boards made of G.I. sheets are also used which are found to be better.

iii) *Hand-carts* : The hand-carts in common use are of three types - single wheeled, double wheeled and three wheeled. In single and double wheeled hand-carts, the worker has to exert force both in horizontal and vertical direction for transporting the material. In three wheeled hand-cart, the third or castor wheel takes care of the vertical force and only horizontal force is needed. However, the castor wheel poses a number of problems due to wear and tear, especially due to the uneven road surfaces (Fig. 8.4.1.1 and 8.4.1.2). The design of hand-cart should be such that loading and unloading is easy. The hand-cart should have a frame of light tube structure or angle iron. The wheels should be of large diameter with rubber tyres and mounted on ball or roller bearings and provided with brackets for holding brooms, baskets and other equipment.

### 8.4.2 Mechanical Sweepers

These work mainly on suction principle and consist of one or more rapidly revolving brushes which dislodge materials and sweep them which are then

on the foot-path such as lamp-posts, etc. Channel sweepers are efficient but cannot be used for sweeping foot-paths. Thus, it is necessary to provide manual sweeping in addition to the mechanical sweepers. Mechanical sweepers perform well on a smooth road surface. Heavy objects lying in the path of the vehicles damage the brushes. The brushes wear out easily for which a regular replacement will be required. The capital cost as well as the operating cost of these units is very high and have to be used in combination with manual sweeping. Even in big cities of the developing countries the roads are narrow where such mechanical sweeper would be an obstruction to traffic. The road surfaces are often rough leading to quicker wear of the brushes. In such cases where roads are even and well paved, waste is lighter and wages of labour are high, these may be used as in Singapore [54]. In the rest of the towns, they have limited application.

### **8.5 Transfer Facilities**

The job of a road sweeper consists of i) sweeping the roads and collecting the material and ii) transporting the collected material to a community dust bin or transport vehicles.

The sweepers are provided with baskets which can take only a small quantity, making it necessary to take a number of trips to the community dust bin. A hand-cart of suitable design and capacity should prove more effective. The handcart, community bin or collection vehicle in use are such that the sweeper has to dump the contents again on the ground before it is put into community bin or the vehicle resulting in too many steps in handling besides increasing the workload and dust problem. This could be overcome by either designing the community bin or vehicle in such a way that the hand-cart dumps its contents directly, or providing a number of containers in the hand-cart in such a way that the containers are individually filled while sweeping the roads and then emptied in the community dust-bin or transport vehicle. Cycle rikshaw units with containers can be used which are convenient for short distances and can move through lanes.

### **8.6 Ward Office/Depots**

Each ward office should have office space, storage space for hand-carts, tools, toilets and other facilities for workers. A ward office can serve an area within a radius of 3-4 kms or 30,000 population depending upon local conditions. It can also be used as a transfer facility for transfer to a stationary trailer of large capacity. The hand-card and stationary trailer or vessel should be such that the material could be transferred directly.



*8.4.1.1 Two wheeled wheelbarrow*



*8.4.1.2 Three wheeled wheelbarrow*

sucked up. In larger units, a separate engine is used to provide suction and move at a speed of 5-10 kmph. The mechanical sweepers are used to clean the main pavement and cannot be used in foot-paths due to the obstructions

## 8.7 Storage Containers in Community Bin System

The community storage can be in any one of the following ways:

i) *Unenclosed Point* : In many cities at locations, where thefts and loss of containers occur frequently, civic authorities avoid putting fresh containers. The material is then allowed to collect on the roadside and collected by municipal refuse vehicles. Such sites are observed to be in low income group areas.

ii) *Portable G.I. Containers* : Galvanised Iron containers 1 m x 1 m x 1 m high having both ends open are placed directly on soil. The users as well as workers are expected to drop the waste inside them which seldom occurs. These containers are liable to theft and need frequent replacement. Sometimes old drums are provided with a lid which the houseowner or worker has to lift, drop the waste inside and then replace the lid. However, the lid is rarely replaced and the chances of theft are again more.

iii) *Concrete Pipe Sections* : Concrete pipe sections of about 1 m dia and 1 m high could be used which is heavy and hence cannot be easily stolen. While transferring the contents to the transport vehicle, the pipe section has to be tilted, turned on its edge to clean the deposited mass and the waste transferred to the vehicle. The refuse in this container is exposed giving rise to attendant problems.

iv) *Fixed Storage Containers* : In order to avoid theft of C.I. containers, they can be provided in fixed position. The contents are removed using a tilting arrangement. This type of bins is being successfully used in India. R.C.C. storage bins are also provided which are fixed to the ground with an opening and a shutter on its side. Material is dropped inside the bins from the open top. The shutter often gets corroded or stolen and the material spills out from the opening. Even when this flap is functioning it is difficult to rake out the waste.

v) *Uncovered Enclosures of Bricks, Steel or Concretes* : An enclosure consisting of a wall about 1 m high is provided with varying capacity by roadside or in the edge of an open space. The wall towards the road is shallow and provided with one or two openings on either side (Fig. 8.7.1). The citizens walk into the enclosure to deposit the contents. The collection crew collects the contents in baskets and deposit them in vehicles. When the waste is dumped at the entrance further quantities get collected outside. A large width at right angles to the road does not serve any useful purpose. The waste also has a free access to rats, flies, birds and ragpickers. In course of time, this place turns insanitary due to nuisance.



8.7.1 *Vat*



8.7.2 *Dalao*

vi) *Depots* : These are nothing but enclosed rooms with one or 2 doors located in areas where a large collection of waste is expected, e.g., in market places and in densely populated areas with narrow lanes inaccess-

sible to vehicles. These are known by various names – ‘Chambers’ in Ajmer, ‘Dalao’ in Delhi, etc. (Fig.8.7.2). A worker is posted at such a site to ensure that the wastes are properly deposited. Due to the enclosed space, wastes are protected from rains. The cattle, birds also do not have an easy access to the waste. However, the waste has to be lifted again from floor for transfer to refuse vehicles. The cost of land in market area or densely populated area being high, there will be competing demand for land use.

vii) *Parked Trailers* : Where a large quantity of waste is to be collected every day a trailer is parked in which waste can be directly deposited, which is hauled by a tractor. This system has been in successful operation in Bombay for a number of years. Though these are located in areas with heavy traffic, vandalism is common. The trailer located below the ground level for convenient dropping of the waste should prove effective (Fig.9.4.1). The depressed portion is enclosed with locking arrangements and is provided with ramps on either side for ease in pulling the trailer out by tractors.

viii) *Large Sized Wheelless Container* : There are 2 types of systems in operation in India, both of which help avoid the chances of theft and vandalism encountered while using tractor trailer system. In one type, 4-6 m<sup>3</sup> containers are placed at site. The refuse is dropped inside through openings in the sides having flaps. When the container is full a tractor with a hydraulically operated carrier lifts and tows it to disposal site. As the loading height of the container is more (> 1.0 m) the waste gets deposited around causing insanitary conditions.

In the second type, an 8-10 m<sup>3</sup> container without wheels is directly placed at site. The container has a low loading height (< 1.0 m) with a number of flaps kept open for loading. Due to its large size, the municipal authorities post a worker near it who ensures that the waste is deposited in the container. A truck prime mover lifts the container and locks it on the body for transportation.

In spite of the large variety of community storage containers in use, none appears to be fully satisfactory. Its usage could be improved through health education and community participation.



## CHAPTER 9

### REFUSE TRANSPORTATION VEHICLES AND THEIR ROUTES

#### 9.1 Introduction

The refuse collected at the roadside dust bins has to be collected and transported to the processing and disposal site by using a variety of vehicles. In general, these vehicles can be grouped into 2 types:

- i) Vehicles which move through narrow streets and bylanes and do not travel a long distance before unloading their contents at a transfer station, processing or disposal facility.
- ii) Vehicles which move through wider roads and travel long distances before discharging their contents at processing or disposal site.

In developed countries, both the types of vehicles are used together. The vehicles collecting refuse from individual premises go to a transfer station where the load is discharged into another set of vehicles to be taken to the processing or disposal facility. However, in India and other developing countries, transfer stations (except in a few cases as in Madras and Bombay) are not used and the same vehicle which collects refuse from individual dust bins takes it to the processing or disposal site. It is often seen that only one type (long haul type or short haul type) of vehicles are used; whereas a combination of the two would have given better results.

NEERI studies[13] show that most of the Indian cities provided transport capacities between 100-300 m<sup>3</sup> per million population served, incurring heavy expenditure. It is hence necessary to carefully select the type of vehicle to be used. In addition to reliability and economy in operation, a number of other factors need be considered. The vehicles should have:

- i) low loading height which in any case should not exceed 1.5 meters;
- ii) facility for taking portable/exchangeable containers for house-to-house collection;
- iii) covered body or simple arrangement for covering (Fig.9.1.1); and



*9.1.1 A refuse truck covered by tarpoulin*

- iv) tipping gears (preferably double shaft type) for quick unloading.

The transportation of the wastes collected in the various community bins, accounts for about 60-80% of the total expenditure incurred in solid waste management. The vehicles make a number of trips every day to the disposal site on routes which are often unspecified. Though instructions are given to the vehicle operator to collect wastes from specific collection points, it is not uncommon to see that the vehicle is simply directed to collect waste from a ward or an area. The work can be carried out more effectively with the use of available funds, vehicles and staff by adopting better techniques.

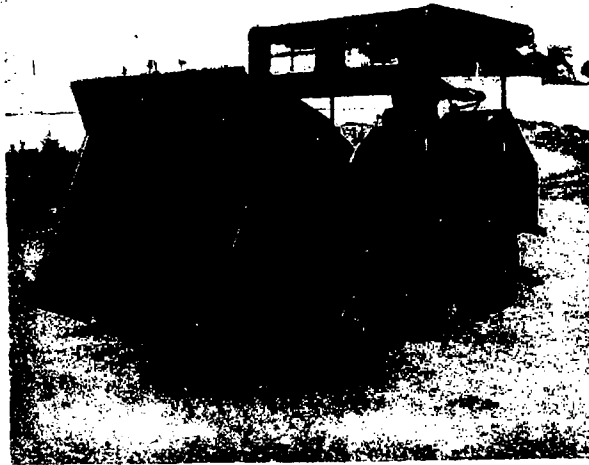
## **9.2 Animal Carts**

Carts driven by bullocks, buffaloes are used in small towns and cities (upto 200,000 population) as well as in some large cities like Madras, India. NEERI studies[27] during 1971-73 showed that in 10 out of 33 cities studied bullock carts were used for collecting part of the refuse from narrow by-lanes. Bullock carts are being used in these cases with one person to drive the cart and transfer of material from bins to cart. Further, the use of bullock cart results in savings on fuel (petrol/diesel). The capacity of bullock cart is about  $1 \text{ m}^3$  and due to its slow speed it tends to obstruct traffic on main roads. The wheels are found to have iron rims for use on country roads which damage the asphalt and concrete pavements. Where local situation is favourable for use of this mode of transport, ball bearing from wheels

and rubber or pneumatic tyres should be used. Improved designs are now available which result in higher productivity. In Madras, the bullock carts collect refuse from narrow bylanes and take it to a transfer station where the bullock cart goes up a ramp and discharges its contents into trucks waiting below. Though this system is likely to be discontinued in Madras, it can be used in smaller towns.

### 9.3 Short Range Diesel Vehicles

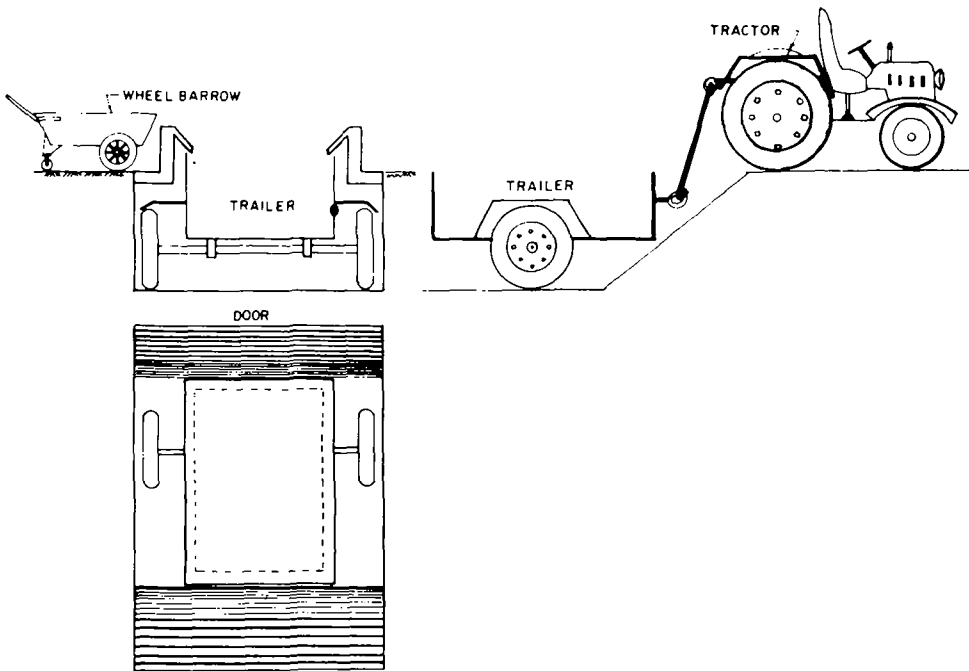
As a substitute for bullock carts for short haul, small capacity transport vehicles of a number of designs have recently been introduced. These are provided with a small (5-7.5 HP) diesel engine to carry 1-1.5 tonnes of material with low loading height (< 1.5 m), short turning radius (2.8-4.5 m) and fuel economy (8-12 km/litre). In one of these vehicles a simple tipping arrangement is provided in which the container held in position by a chain can be tilted by releasing the chain. In one type, the body is covered with space to seat a driver and 2 labourers. These vehicles due to their simple, robust constructions and economic operation should find increased usage (Fig. 9.3.1).



9.3.1 Toughrider

### 9.4 Tractor Trailer

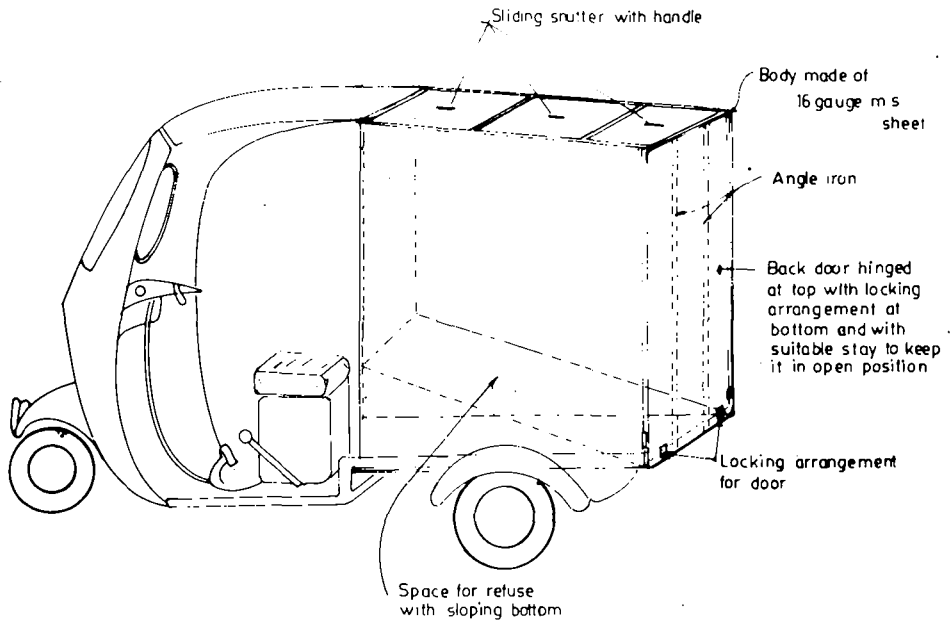
Tractor trailers due to low initial cost and ease of operation are used in medium sized towns and cities. NEERI studies[6] during 1971-73 indicated that 15 out of 33 cities used tractor trailers for transporting refuse. In



#### 9.4.1 Tractor trailer with stationary trailer

most of them, the tractor trailer was used as one unit while in a few cities, tractor was used to pull trailers parked at different locations. If a tractor is used to tow trailers parked at different locations (which serve also as collection bins), the operation would be economical. If the trailers can be tipped with a power take off unit, unloading will be quick. In such a case, a single tractor can serve 5-7 trailers and increase the number of trips in a shift. As the tractor has a small wheel base it has good manouvability enabling it to negotiate sharp turns in narrow streets and bylanes. In some of the trailers self closing loading shutters are provided which are spring actuated. While depositing waste in the trailer, the shutter is manually opened which closes automatically. In such cases, the waste is not exposed and hence is inaccessible to pickers, stray animals and rain. The tractors have the following drawbacks:

- i) They are designed for high torque and low speed which limit its operation at high speed and results in larger wear and tear.
- ii) The tyres of the tractors are designed for use on farms and are of mud grip type which wear out faster on city streets.
- iii) The breaking system is more efficient at low speed and when operated at higher speeds, it tends to lose road grip and skid.



9.5.1 Autorickshaw type refuse vehicle

- iv) There is no protection to the driver from rain and dust.

Where the tractors transport a number of trailers parked at fixed locations vandalism is common. A simple arrangement, as shown in Fig.9.4.1, can be used where the trailer is located below the ground in a chamber with ramps on either side. When the trailer is in position the gates can be closed. The sides will have small ramps over which the material can be tipped inside the trailer. This arrangement ensures transfer of material to the trailer without spillage.

### 9.5 Three Wheeler Autorickshaws

Such vehicles with closed body are in use (Fig.9.5.1) at some sites where the distance through which refuse has to be transported is not very large. These vehicles can ply in narrow lanes and bylanes and are quite popular in West-Asian countries. However, as these units are mostly petrol operated the cost of transportation will be high. There is no provision to seat a helper who can collect material from roadside. The low capacity and the small distance through which it can transport refuse are reasons which have prevented its widespread use in India.

### 9.6 Electric Vehicles

These are in use in some developed countries and can operate over short radius of about 2 kms. The battery has to be charged overnight. These

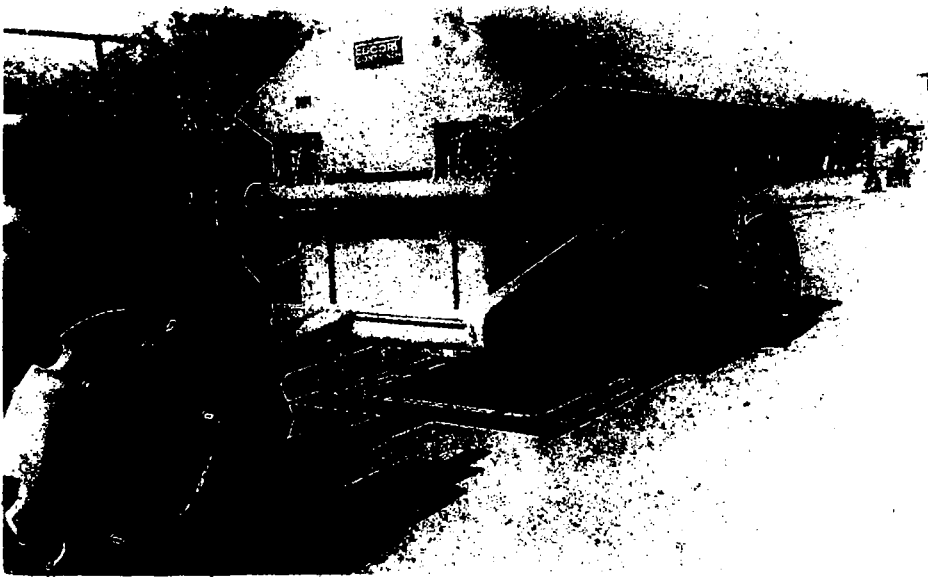
vehicles are available in India and some other developing countries only to a limited extent due to its high capital cost.

### 9.7 Dumper Placer

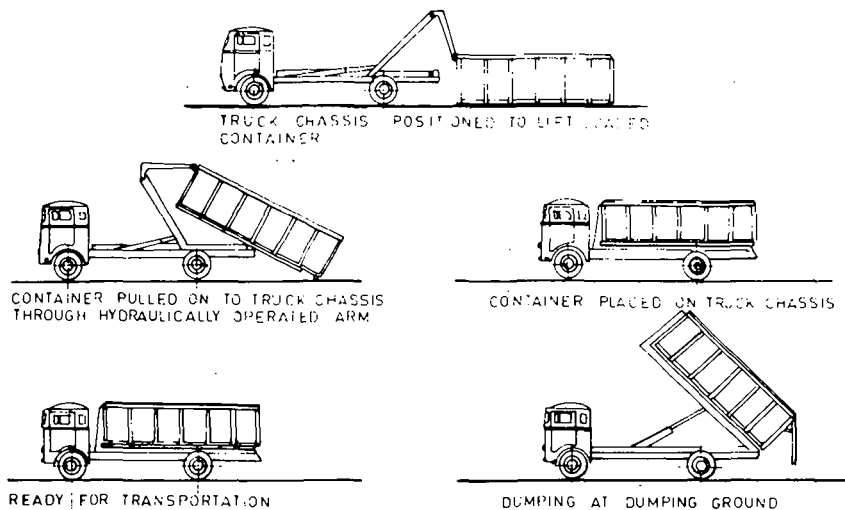
These units are used for lifting of heavy metal, etc. Large size containers are placed as collection bins. The vehicle is provided with a winch mechanism with the aid of which the bin is hoisted and placed on the body of the truck. A replacement can be simultaneously placed at the site or can be put later on. This type of unit is often used for transporting demolition waste. The unit has the disadvantage that only one unit can be put on the truck chassis and the carrying capacity of the truck is underutilised. One type called Fowlers dumping unit has the advantage that a number (upto 8) of collection bins called 'skip boxes' could be lifted and put on the truck chassis thus better utilising the truck capacity. These vehicles are no more in use in India now.

### 9.8 Container Carrier System

In this system, special types of containers are placed at collection points. When full, the containers are removed by a tractor prime mover to which a hydraulically powered frame chassis (carrier) is hitched. The tractor along with carrier comes to a specific site and the carrier hydraulically lifts the container and grips it firmly and for safe transportation (Fig. 9.8.1). At the



9.8.1 Container carrier system



### 9.9.1 *Special municipal vehicle*

processing/disposal site, the container is hydraulically tipped to discharge its load. This system suffers from some disadvantages such as low speed of tractor and low ground clearance of the container which causes problems in the case of uneven road surfaces.

## 9.9 Special Municipal Vehicle

It consists of a truck provided with special hydraulic arrangement for lifting, placing as well as unloading one 8-10 cubic meter container on a truck chassis. The container has low loading height with a number of flaps which are kept open for loading refuse. The container is kept at a specific site where it gets filled with refuse. The prime mover lifts and locks the container on the body for transportation to processing/disposal site (Figs. 9.9.1 & 9.9.2). As the prime mover is a truck it can move faster even on uneven surface than a tractor making more trips per day. It is claimed to make at least six trips per day.

## 9.10 Trucks

Various types of trucks (5 tonne, 7 tonne) have been commonly in use in most of the cities in India and other developing countries. These trucks make 2-4 trips/day covering about 20 kms per trip. Most of the civic authorities tend to use these vehicles when new for other municipal purposes and old ones are detailed for refuse transportation work. As the vehicles are old and the roads that have to be negotiated are rough it necessitates heavy repairs and maintenance resulting in high cost of operation. Refuse is a low density material with the result that a 5 tonne truck seldom carries more



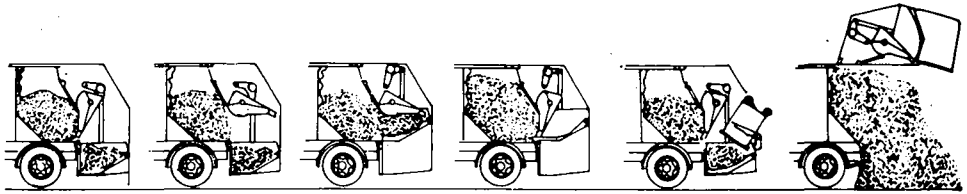
### *9.9.2 Container being loaded on chassis*

than 2-3 tonnes of refuse. The body design has to be modified to increase its carrying capacity. Due to the rough conditions under which these vehicles have to operate, it is desirable to use heavy duty diesel vehicles. Most civic authorities operate a mixed fleet of diesel and petrol vehicles of different makes adding to operation and maintenance problems. The vehicles should be provided with tipping gear (preferably having 2 hoists) for quick unloading and increasing the number of trips. In the case of vehicles equipped with tipping gear the sides should also be collapsible for manual unloading when the tipping gear does not work.

### **9.11 Compaction Vehicles**

In developed countries the compaction type of vehicles are in use which accept refuse having an initial density of  $150-200 \text{ kg/m}^3$  and compact it by nearly 2-4 times (i.e., to a density of about  $500 \text{ kg/m}^3$ ). In India and other developing countries, the refuse has an initial density of  $400-600 \text{ kg/m}^3$  which is more or less the same as the final compacted density in developed countries. Further, such vehicles are costly and hence will not be economically viable. Compactor vehicles are either of the hydraulically operated pressure plate type or mechanically driven screw impeller type. Refuse is dumped over the compression plate into the hopper (of an intermittent compression vehicle). When hopper is full the driver engages the





### 9.11.1 Different stages in working of a compaction vehicle

hydraulic pump by operating a lever and the compression plate moves forward (at about 2000 psi) pushing the refuse into the body. The plate automatically returns leaving an empty hopper. As the loading continues, refuse is compressed and pushed forward and upward into the body to obtain maximum load. Discharge is by hydraulic tipping gear when the compression plate rises to roof leaving a clear opening. In continuous compression vehicle, refuse is tipped into the hopper as in the previous case and the pressure plate packs the refuse forward and upward into the body. The double action compression ram of the unit keeps the hopper automatically clear (Fig. 9.11.1).

In the screw type continuous loaders, refuse loaded into the hopper falls on a powerful feed screw which moves the refuse forward inside the body. The screw (about 0.66 m dia) is made of special alloy steel with a wearing plate on the lead end. The pitch at the loading end is wide but narrows towards the body end which helps in crushing and compressing of the refuse. The screw tends to wear out quickly and has to be replaced often (within 6-8 months). When the body is hydraulically tipped, the rear mechanism opens to permit rapid discharge of the load.

## 9.12 Rail Transport

When the refuse has to be transported over large distances, as in some metropolitan cities, this form of transport can be used. The municipal vehicles collect refuse from various collection points and bring it to a transfer station where it is loaded into railway wagons for transmission to the disposal site. Rail transport is economical when large quantity is to be transported over long distance as in Bombay.

## 9.13 Maintenance of Refuse Transportation Vehicles

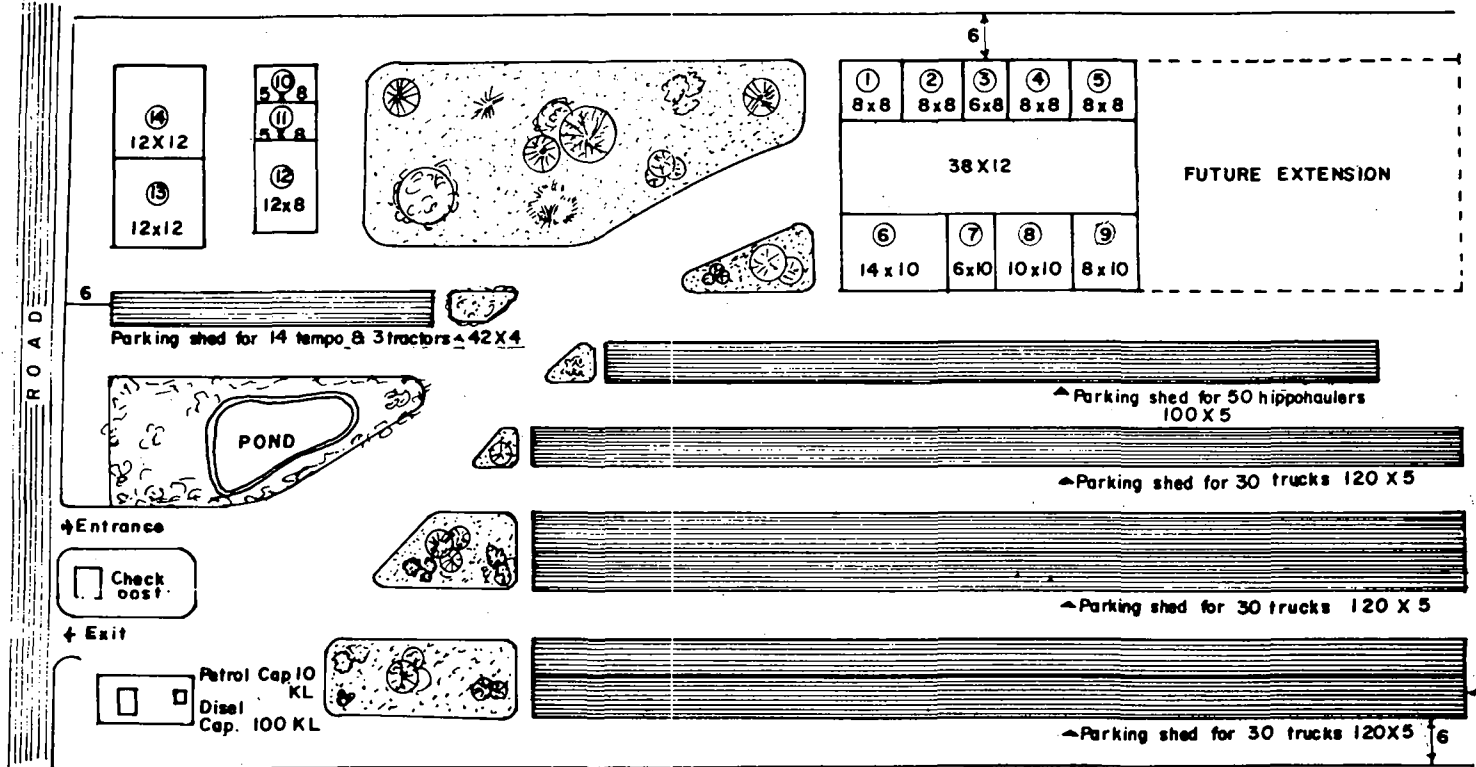
As the refuse transportation vehicles have to work under strenuous conditions it is desirable that a specific schedule of preventive maintenance be followed with proper garaging facilities. In spite of the preventive maintenance programme, the vehicles need frequent repairs. NEERI studies[6] during 1971-73 indicated that 12 out of the 33 cities provided only limited

workshop facilities; whereas 16 cities provided facilities for major maintenance also. It is desirable that in cities having more than 300,000 population, workshops be equipped for carrying out major as well as minor maintenance work. The equipment needed in a city having a population of 300,000 is listed in Table 9.13.1. A layout of a typical workshop and garage for a bigger city is also given in Fig.9.13.2 which can be modified to suit local conditions. It is necessary that the collection, transportation and workshop staff should all be under the overall supervision of one professional person (engineer) for proper co-ordination.

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*Table 9.13.1 - Major Equipment Needed for Workshop (1 each)*

- 1 6" lathe with necessary accessories
  - 2 Hydraulic jack of 5 tonne capacity
  - 3 Gas welding and cutting set with accessories
  - 4 Portable electric welding set with accessories
  - 5 Battery charger 6-12 V.
  6. Small bench lathe with accessories
  - 7 Heavy duty air compressor
  - 8 Car washing machine with accessories
  - 9 Bending machine
  - 10 Hand shear machine
  - 11 Reciprocating type Hacksaw machine
  - 12 Drilling machine 1" capacity
  - 13 Bench type grinder - double ended
  - 14 Flexible grinding machine
  - 15 Portable jib crane 1 tonne capacity
  - 16 Spray painting equipment
  - 17 Hot patching machine
  - 18 Pneumatic heavy duty grease gun
  - 19 Oil decanting pump
  20. Anvil, blower, work benches, press tools, etc.
  21. Water cooler
  - 22 Punching machine time recorder
-



9.13.2 Layout plan for a garage and workshop

## 9.14 Planning of Vehicle Routes

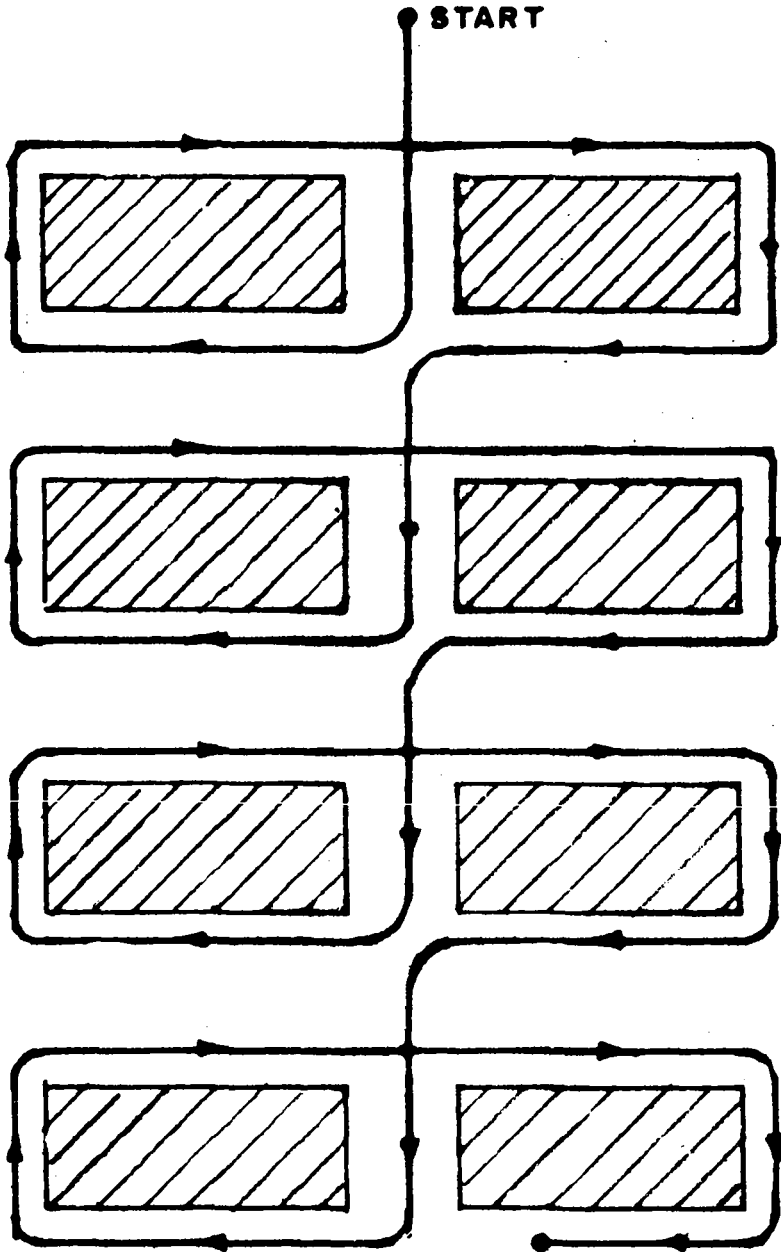
Presently in most of the cases, the routes of refuse vehicles are not properly designed but left to the vehicle operator or supervisor to use his discretion. If these routes are properly planned the expenditure can be reduced and better service provided.

In smaller towns where a single processing and/or disposal facility is in operation, planning of the routes is simple as it involves grouping of collection points into such routes which would require least transportation distance. In larger towns and cities, with more than one processing and disposal facility, rational allocation is necessary. The points can then be grouped together to obtain routes with least transportation distance. It might become difficult if each transfer station has to cater to more than one disposal site. The district balancing and route balancing have to be done to ensure a fair days work and to divide the collection areas into balanced routes so that all the crew have equal workloads. Micro routing involves careful analysis of routes in each service area and minimizing the transportation distance after carefully considering all the relevant factors. The problems can be solved by using the following approaches: a) Heuristic, b) Deterministic, and c) Deterministic-Heuristic. The heuristic approach uses a manual procedure by using certain guiding principles to arrive at a reasonable (not optimum) solution. This is a good tool for use by experienced personnel. In the deterministic approach, a mathematical model is developed and by providing all relevant input data, the model determines the optimum route. In the heuristic-deterministic approach, a computer programme is used to examine many possible alternatives, out of which the best possible is chosen.

## 9.15 Heuristic Method

The old system of assigning routes based on experience and intuition is systemised by formulation of some simple rules. However, their efficiency depends upon the experience of the user. The macro routing is to be done first followed by route balancing and micro routing. In the macro routing, collection areas are assigned to disposal facilities. A fair day's work has to be determined in terms of kms to be travelled, trips made and tonnage to be hauled per day. This helps in identifying blocks or areas that can be served by a vehicle and crew every day. Micro routing is then carried out by using heuristics when the originally identified blocks or areas and their configuration may get changed. The factors to be considered in micro routing are:

- i) Existing policies regarding collection and its frequency must be identified.



9.15.1 Recommended movement pattern for collection from one way street

- ii) Routes should not be fragmented or overlapping.
- iii) Collection and transport time should be reasonably constant for each route so as to equalise the workload.

- iv) The collection route should start as close to the garage as possible taking into consideration heavily travelled routes.
- v) Routes having heavy traffic should be served before or after rush hours only.
- vi) Sources where large waste quantities are generated should be serviced during the first part of the day.
- vii) Collection routes should be so arranged that the last bin emptied is nearest to the disposal site in that route.
- viii) In the case of one way streets, it is best to start the route near the upper end of the street working down it through the looping process (Fig. 9.15.1).

The general steps while using the above method are:

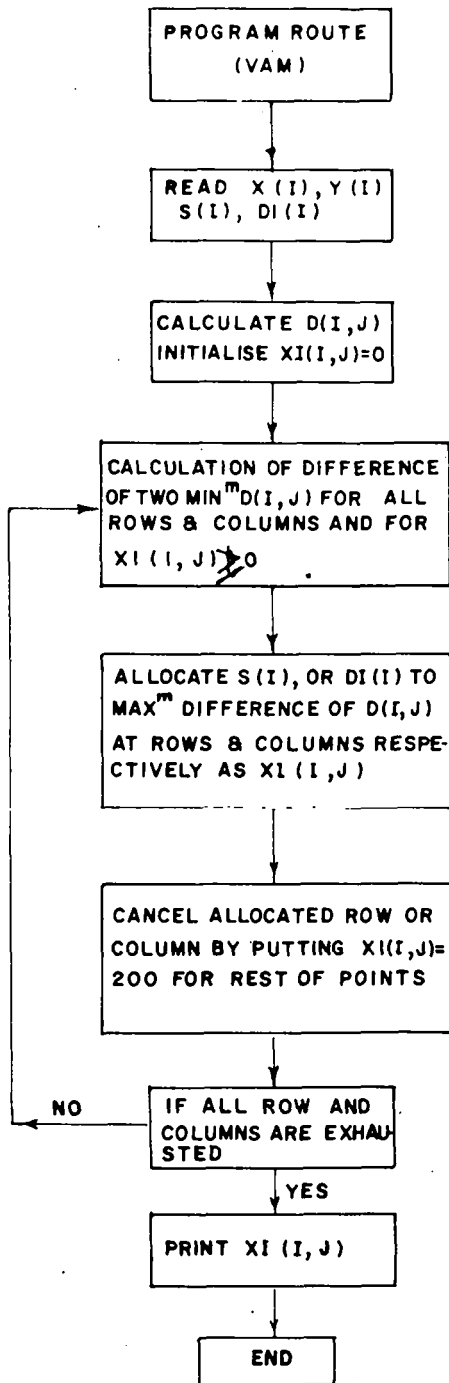
- i) Prepare a map showing sources and quantities of waste.
- ii) Analyse data and prepare summary tables.
- iii) Identify preliminary routes and then develop balanced routes by trial and error.

These methods have been extensively used in developed countries for house-to-house collection with encouraging results.

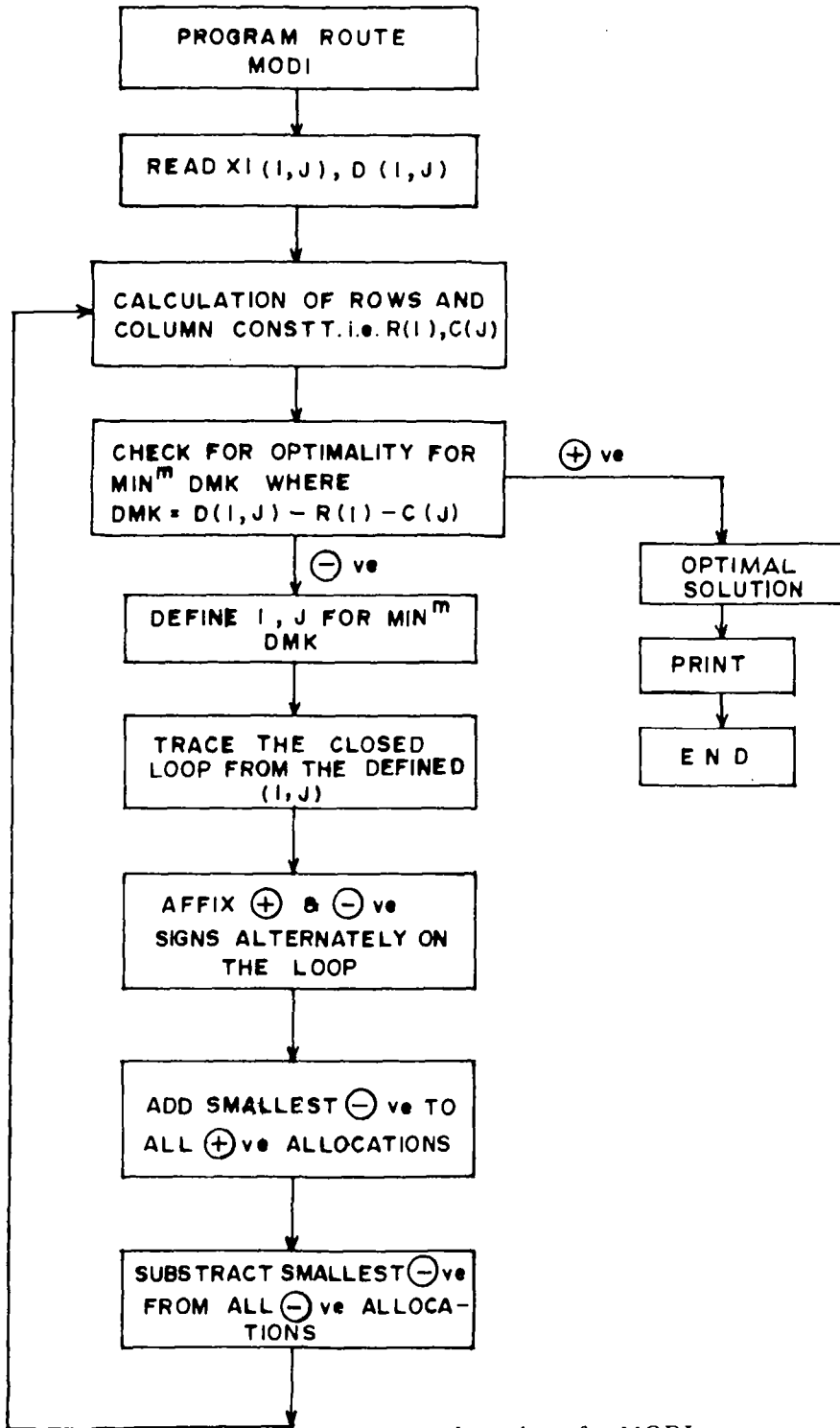
### 9.16 Deterministic Methods

These methods use advanced mathematical techniques. In the existing system, much of the information regarding location of collection bins, processing and disposal sites and quantities collected at individual collection bins would be available. In planning a new system, this data will have to be estimated for which simulation techniques have to be used. Macro-scale attempts to study and plan the system were made to evaluate alternate solutions to the entire solid waste problem involving generation, collection, treatment and economic planning of the whole system. Specific models have also been prepared for these cases. In the case of micro study, the location and allotment of different transfer stations to different processing and disposal sites and allocation of routes of collection vehicles is carried out [52, 53, 65].

Models are prepared for i) uniform and continuous generation of waste along the streets, ii) house-to-house collection of refuse and iii) use of transfer stations. As the conditions in developing countries are different, i.e., the waste collection along a street is not uniform and continuous, and



9.17.1 Flow chart for VAM



9.17.2 Flow chart for MODI



the vehicle has to collect the waste not from individual houses but from collection bins located at street corners, the collection is not from house-to-house but from community bins. Also transfer stations are rarely used and refuse vehicles proceed directly to processing/disposal facility. Hence the model used in developed countries cannot be directly used in developing countries.

### 9.17 Formulation of Model for Indian Conditions

The vehicle starts from the garage, proceeds to the starting point from where it travels successively to various points till it is completely filled. It then proceeds to the processing/disposal site before starting the next cycle of operation. As the quantity collected at different community bins is different and as these represent discrete points the 'Chinese Postman Problem' used in developed countries has to be modified, e.g., the quantity at discrete points need be converted to uniform quantity along converging roads. As many points have to be served more than once, simplifying assumptions have to be made which will depend upon the judgement of the user; the accuracy of the results will also vary.

NEERI prepared a suitable model[62] for Indian conditions, assuming that the cost of transportation is directly proportional to the route length and hence optimisation of length of routes was aimed at. No consideration was given to traffic conditions while preparing the model. It was also stipulated that every community bin is visited at least once and the quantity collected in a route should be equal to the capacity of the truck. It was found that it can be treated as "M salesman travelling salesman" problem. Modified Distribution Method (MODI) which is simple and fast has been used. By using Vogels Approximation Method, an initial solution is first obtained which reduces the number of steps (iterations) which would have been required had the problem been solved by using an initial solution obtained by inspection or by the use of 'North West Corner Rule'. As the number of collection points and vehicles are quite large in cities and towns, the above method can be used by preparing a computer programme which will help reduce the time requirement and give optimum result. Flowsheets for such programmes are given in Figs. 9.17.1 and 9.17.2.

## CHAPTER 10

### COMPOSTING

#### 10.1 Introduction

Decomposition and stabilisation of solid organic waste material has been taking place in nature ever since life appeared on this planet. With the progress of civilisation and advancement of scientific knowledge, efforts are being directed towards rationalising and controlling the process in such a way as to make it more effective and efficient. The processes that have evolved as a result are referred to as 'composting' and the final product called 'compost'. The composting methods may use either manual or mechanical means and are accordingly termed as manual and mechanical composting processes. Composting yields a product which contains plant nutrients (NPK) as well as micronutrients which can be utilised for the growth of plants. Prior to composting, some salvagable materials are removed, recycled and reused. Thus, a major portion of the input waste material is reused, resulting in conservation of natural resources. Composting is thus a useful method, especially in predominantly agricultural countries.

#### 10.2 Use of Compost

Compost is beneficial for crop production due to the following reasons:

- i) Compost prepared from municipal refuse contains about 1% each of NPK.
- ii) During composting, the plant nutrients are converted to such forms which get released gradually over a longer period and do not get leached away easily.
- iii) It is known to contain trace elements such as Mn, Cu, Bo, Mo, which are essential to the growth of plants.
- iv) It is a good soil conditioner and increases the texture of soil, particularly in light sandy soil.
- v) It improves the ion exchange and water retaining capacity of the soil.

- vi) The organic matter in soil in tropical climates gets depleted rapidly by microbial activity. Compost adds stabilised organic matter, thus improving the soil.
- vii) It increases the buffering capacity of the soil.

Hence compost application to soil is beneficial, but compost cannot be an alternate to chemical fertilizer; each of them has a specific role to play. It is desirable that compost is used in conjunction with chemical fertilizers to obtain optimum benefits. It has been successfully demonstrated that best results are obtained when the two are used together in certain proportions. The yield in such cases has been reported to be much higher than that obtained when they are used separately.

### 10.3 Principles of the Composting Process

The organic material present in the municipal wastes can be converted to a stable form either aerobically or anaerobically. During aerobic decomposition, aerobic microorganisms oxidise organic compounds to  $\text{CO}_2$ ,  $\text{NO}_2$  and  $\text{NO}_3$ . Carbon from organic compounds is used as a source of energy while nitrogen is recycled. Due to the exothermic reaction, temperature of the mass rises. Anaerobic microorganisms while metabolising nutrients, breakdown the organic compounds by a process of reduction. A very small amount of energy is released during the process, and temperature of the composting mass does not rise much. The gases evolved are mainly  $\text{CH}_4$  and  $\text{CO}_2$ . As anaerobic decomposition of organic matter is a reduction process, the final product is subject to some minor oxidation when applied to land.

### 10.4 Factors Affecting Composting Processes

#### 10.4.1 *Organisms*

Aerobic composting is a dynamic system in which bacteria, actinomycetes, fungi and other biological forms are actively involved. The relative preponderance of one species over another depends upon the constantly changing available food supply, temperature and substrate conditions. In this process, facultative and obligate aerobic forms of bacteria, actinomycetes and fungi are most active. Mesophilic forms are predominant in the initial stages which soon give way to thermophilic bacteria and fungi. Except in the final stages of composting when the temperature drops, actinomycetes and fungi are confined to 5 to 15 cm of outer surface layer. If the turning is not carried out frequently increased growth of actinomycetes and fungi in the outer layers imparts a typical greyish white colour. Thermophilic

actinomycetes and fungi are known to grow well in the range of 45-60°C.

Attempts have yet to be made to identify the role of different organisms in the breakdown of different materials. Thermophilic bacteria are mainly responsible for breakdown of proteins and other readily biodegradable organic matter. Fungi and actinomycetes play an important role in the decomposition of cellulose and lignins. Among the actinomycetes, *Streptomyces* sp. and *Micromonospora* sp. are common in compost, the latter being more prevalent. The common fungi in compost are *Thermomyces* sp., *Penicillium dupontii* and *Aspergillus fumigatus*.

The municipal solid waste contains most of the organisms responsible for composting. As compared to the aerobic process, little information is available regarding the organisms responsible for anaerobic composting. Though many of the organisms active in anaerobic decomposition of sewage sludge will be active here also, differences are expected due to the temperature and nutrients present.

#### 10.4.2 Use of Cultures

During the development of composting systems various innovators have come forward with inoculums, enzymes, etc. claimed to hasten the composting process. Investigations carried out by a number of workers have shown that they are unnecessary[41]. Required forms of bacteria, actinomycetes and fungi are indigenous to municipal refuse. When the environmental conditions are appropriate, indigenous bacteria, better adapted to municipal refuse than forms attenuated under laboratory conditions, rapidly multiply and carry out necessary decomposition. Since the process is dynamic and as any specific organism can survive over specific environmental range, as one group starts diminishing, another group of organisms starts flourishing. Thus, in such mixed system, bacteria develop and multiply to keep pace with available nutrients and environmental conditions. Hence, addition of similar and extraneous organisms such as an inoculum is superfluous. Such inoculums may, however, be important while composting some industrial and agricultural solid wastes which do not have the required indigenous bacterial population..

#### 10.4.3 Moisture

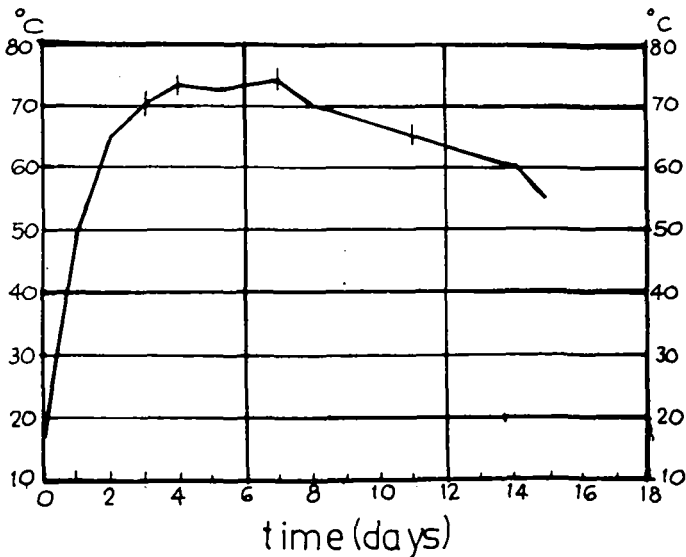
Moisture replaces air from the interspace between particles. Too low a moisture content reduces the metabolic activity of organisms; whereas anaerobic conditions would set in if the moisture content is too high. It has been shown that the optimum moisture content for composting is in the range of 50-60 per cent. Moisture required for satisfactory aerobic composting will depend on the materials used. High moisture content will be

required if straw and strong fibrous materials are present to soften the fibres and fill the interstices. Moisture content higher than 50-60 per cent can be used in mechanically aerated digesters. In anaerobic composting, the moisture required will depend upon method of storage and handling.

#### 10.4.4 Temperature

During anaerobic decomposition, 26 Kcal is released per gm mole of glucose as against 484-674 Kcal under aerobic conditions. As refuse has good insulation properties, the heat of the exothermic biological reaction accumulates resulting in increase of temperature of the decomposing mass. Loss of heat will occur from the surface and hence the larger the exposed surface area per unit weight of the composting mass, the larger will be the heat loss. When windrows are turned heat loss occurs resulting in drop in temperature but it rises during active decomposition to as high as 70°C. Addition of water to the composting mass results in drop in temperature. The temperature will tend to drop only when the conditions become anaerobic or the active period of decomposition is over (Fig.10.4.4.1). During anaerobic composting, a small amount of heat is released, much of which escapes by diffusion, conduction, etc. Thus the temperature rise will not be appreciable.

Table 10.4.4.2 gives the temperature and time of exposure for destruction of some common pathogens and parasites. According to Scott[74],



##### 10.4.4.1 Changes in temperature in a mass of aerobically composting mixed municipal refuse

Table 10.4.4.2 : Temperature and Time of Exposure Needed for Destruction of some Common Parasites and Pathogens

Organisms	Time and Temperature for Death
1. <i>S. typhosa</i>	No growth beyond 46°C, death in 30 minutes at 55-60°C and 20 minutes at 60°C, destroyed in a short time in compost environment.
2. <i>Salmonella sp.</i>	In 1 hour at 55°C and in 15-20 minutes at 60°C
3. <i>Shigella sp.</i>	In 1 hour at 55°C
4. <i>E. coli</i>	In 1 hour at 55°C and in 15-20 minutes at 60°C
5. <i>E. histolytica</i> cysts	In few minutes at 45°C and in a few seconds at 55°C
6. <i>Taenia saginata</i>	In a few minutes at 55°C
7. <i>Trichinella spiralis</i> larvae	Quickly killed at 55°C, instantly at 60°C
8. <i>Br. abortus</i> or <i>Br. suis</i>	In 3 minutes at 62-63°C and in 1 hour at 55°C
9. <i>Micrococcus pyogenes</i> var. <i>aureus</i>	In 10 minutes at 50°C
10. <i>Streptococcus pyogenes</i>	In 10 minutes at 54°C
11. <i>Mycobacterium tuberculosis</i> var. <i>hominis</i>	In 15-20 minutes at 66°C or after momentary heating at 67°C
12. <i>Corynebacterium diphtheriae</i>	In 45 minutes at 55°C
13. <i>Necator americanus</i>	In 50 minutes at 45°C
14. <i>A. lumbricoides</i> eggs	In 1 hour at 50°C

during aerobic composting when material is turned twice in 12 days, *E. histolytica* gets killed and when turned thrice in 36 days eggs of *A. lumbricoides* are also destroyed. NEERI studies[27] have shown that in the compost prepared anerobically from a number of Indian cities, *A. lumbricoides* and *T. trichuria* were present in samples in 33 per cent and 20 per cent of

the cities respectively. As shown by Knoll[50], the high temperature and long duration in aerobic composting along with the antibiotic effect results in the destruction of parasites and pathogens.

In anaerobic process, the destruction of parasites and pathogens occurs due to long detention time in an unsuitable environment, biological antagonism and natural die-away. The destruction of pathogens and parasites cannot be assured in anaerobic processes. It has been seen that activity of cellulase enzymes gets reduced above 70°C[12] and the optimum temperature range for nitrification lies in the range from 30° to 50°C, above which a large N<sub>2</sub> loss occurs. In the temperature range of 50°-60°C high nitrification and cellulose degradation occur and destruction of pathogens and parasites is also ensured.

#### 10.4.5 C/N Ratio

As explained in 10.3.1, the progress of decomposition in a composting mass is greatly influenced by C/N value. Since living organisms utilise about 30 parts of carbon for each part of nitrogen[41], an initial C/N of 30 would be most favourable for rapid composting. Research workers have reported optimum values ranging between 26 and 31 depending upon other conditions. C/N being the ratio of available carbon to available nitrogen, some forms resistant to biological attack may not be readily available. In cases where C/N is too low or high it can be blended with suitable material to keep the C/N at desirable levels. Straw, sawdust, paper, etc. are materials which can be used as carbon sources while blood, sludges, slaughterhouse waste serve as good sources of nitrogen.

#### 10.4.6 Addition of Sewage and Sewage Sludges

The municipal waste in developed countries has C/N values upto 80, to which sewage sludge (C/N of 5 to 8) is added to keep C/N ratio of mixture

Table 10.4.6.1 : Nitrogen Conservation in relation to C/N Ratio<sup>(41)</sup>

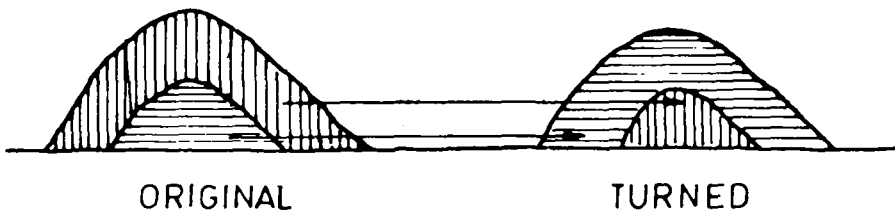
Initial C/N Ratio	Final % of nitrogen (dry weight basis)	% N <sub>2</sub> loss
20	1.44	38.8
20.5	1.04	48.1
22	1.63	14.8
30	1.21	0.5
35	1.32	0.5
76	0.86	-

at optimum levels. This partly solves the problem of treatment and disposal of sewage sludges which would otherwise require costly methods such as vacuum filters, filter press, etc. Municipal refuse in India and other developing countries has an initial C/N ratio of about 30 which does not need blending except in marginal cases. When initial C/N value is low, loss of nitrogen in the form of ammonia occurs (Table 10.4.6.1)[41]. Thus a large part of nitrogen will get lost.

Addition of sewage and sewage sludges will involve problems of smell and odour, handling and transportation costs. Even when sewage is used as a source of moisture in composting, bulk of the sewage will have to be treated otherwise. In view of this, addition of sewage and sewage sludge is not suitable in developing countries.

#### 10.4.7 Aeration

Aeration by natural process occurs in the superficial layers of the composting mass, while the inner layers tend to progressively turn anaerobic as the rate of oxygen replenishment cannot keep pace with utilisation. It is hence necessary to bring the inner layers in contact with oxygen which is accomplished by aeration by turning the material (Fig.10.4.7.1) or by supplying compressed air. In temperate regions, the composting mass is enclosed and air is supplied at the rate of  $1-2\text{m}^3$  of air/day/kg VS. In tropical regions where ambient temperatures are sufficiently high, composting is carried out in windrows which are turned periodically. Aerobic conditions can be maintained when the windrows are turned on alternate days[8]. NEERI studies[61] show that windrows of raw refuse remain aerobic (due to large void spaces) if turned after 5 days. The longer turning interval helps reduce the cost.



10.4.7.1 Arrangement of material during turning of windrows

### 10.5 Control of the Composting Process

The composting process needs to be regulated so as to ensure aerobic conditions and to stop it when completed. If the process is not regulated properly the final C/N may be either too low or too high. If C/N ratio of final product is high the excess carbon tends to utilise nitrogen in the soil to



build up cell protoplasm resulting in 'robbing' of nitrogen in the soil. When the final C/N ratio is too low the product does not help improve the structure of the soil. When night-soil or sludge is added to composting mass the parasites and pathogens may survive in the final product if high temperatures are not maintained for required period. Temperature and stability test[61] should be used together to test the stage and completion of the process.

## 10.6 Composting Systems

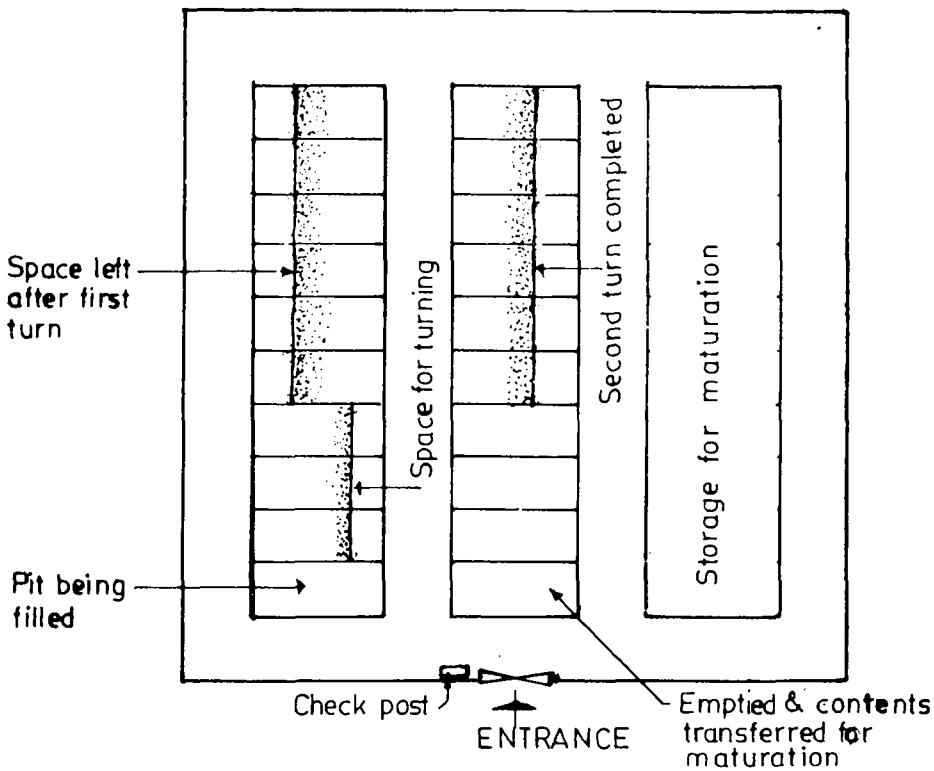
The composting systems can be broadly grouped as i) aerobic and ii) anaerobic. During the initial period of development of mechanical compost plants, a combination of anaerobic and aerobic methods were used (Beccari Method). Composting in pits used anaerobic process (Bangalore Method). Aerobic systems can be operated either manually or mechanically in open windrow, pits or in enclosed digesters. Open windrow system is preferred in tropical regions while in temperate regions closed digester system is used. The pit method of aerobic composting is also known as Indore Method.

### 10.6.1 Indore and Bangalore Methods of Composting

India can take credit for developing systematic manual composting when Howard and his associates as also Acharya and Subrahmanyam developed the Indore and Bangalore Methods of composting[41].

10.6.1.1 In the *Bangalore Method*, a layer of coarse refuse is first put at the bottom of a pit to a depth of 15-25 cm which is 7.5 cm deeper for a 25 cm width at the pit edges. Night-soil is poured to a thickness of 5 cm in the depressed portion and the elevated edges prevent its draining to the sides. On top of this, a second layer of refuse is spread which sandwiches the night-soil layer. Such alternate layers of refuse and night-soil are repeated till it reaches a height of 30 cms above the edge of the pit. The top layer of refuse should be at least 25-30 cms thick. The top of the mass is rounded to avoid rain water entering the pit. Sometimes a top layer of soil is given to prevent fly-breeding. It is allowed to decompose for 4-6 months; after which the compost can be taken out for use.

10.6.1.2 The *Indore Method* of composting in pits is similar to the above except that it is turned at specific intervals to help maintain aerobic conditions which will ensure high temperature, uniform decomposition as well as absence of flies and odour. While filling with refuse and night-soil, about 60 cm on the longitudinal side of the pit is kept vacant for starting the turning operations. The first turning is manually carried out after 4-7 days using long handled rakes and the second turning after 5-10 more days.

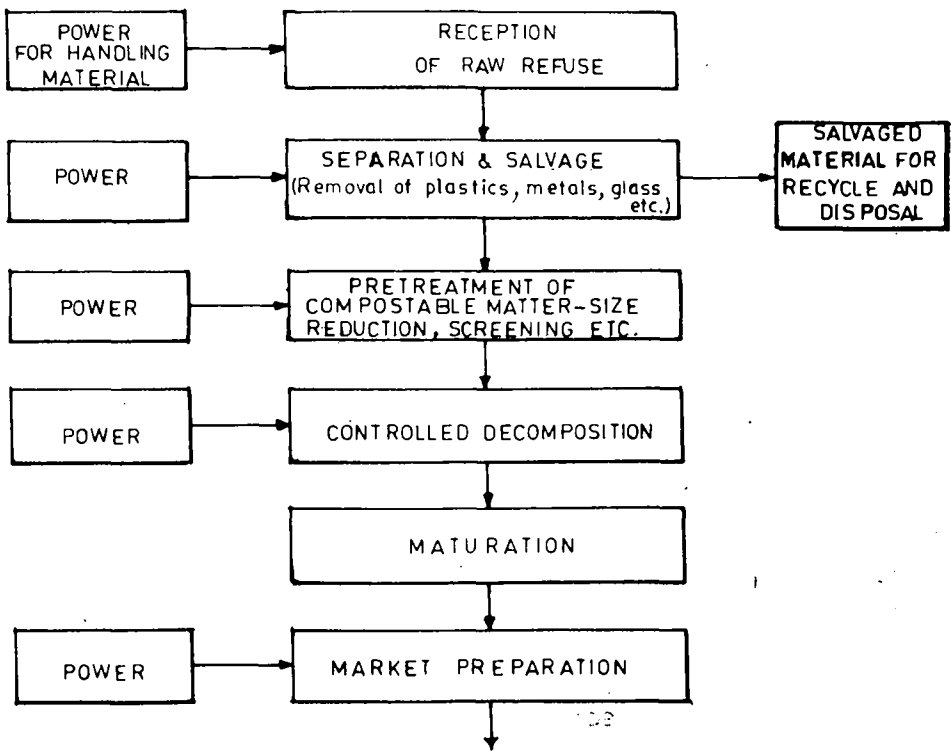


#### 10.6.1.1.1 A compost yard

Further turning is not necessary and composting will be complete in a period of 13-27 days (Fig. 10.6.1.1.1). Aerobic composting of refuse and night-soil in windrows can also be carried out using windrows of more or less same dimensions as the pit. Windrow method of aerobic composting is more popular for composting municipal refuse without night-soil.

### 10.7 Mechanical Methods

Though manual methods are popular in India due to high labour cost and limitations of space, mechanical processes are preferred in industrialised countries. In 1922, Becceri in Italy patented a process using a combination of aerobic and anaerobic decomposition in enclosed containers. The first full scale plant was established in 1932 in Netherlands by a non-profit utility company VAM using the Van Maanen process, in which raw refuse is composted in large windrows which are turned at intervals by mobile cranes moving on rails. The Dano process appeared in Denmark in 1930 and the Frazer Eweson process in USA in 1969. Several patented processes have since been developed using different methods of preparation of refuse or digestion. A mechanical compost plant is a combination of various unit operations meant to perform specific functions (Fig.10.7.0.1).

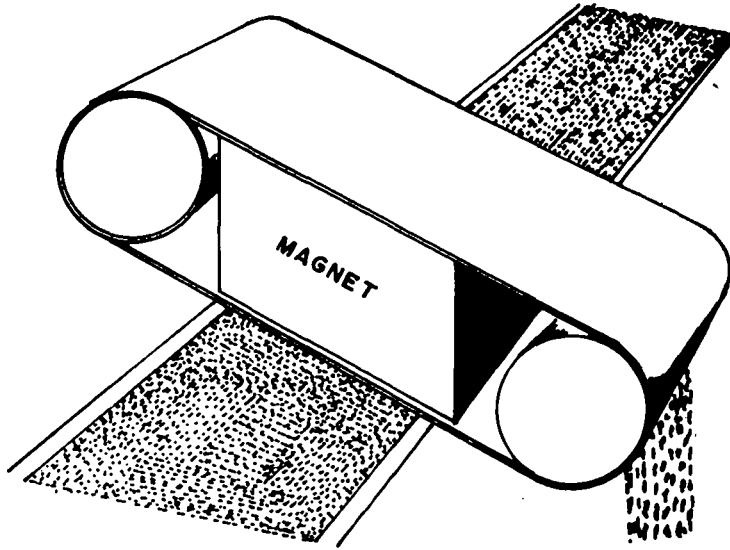


10.7.0.1 Flow chart for a mechanical compost plant

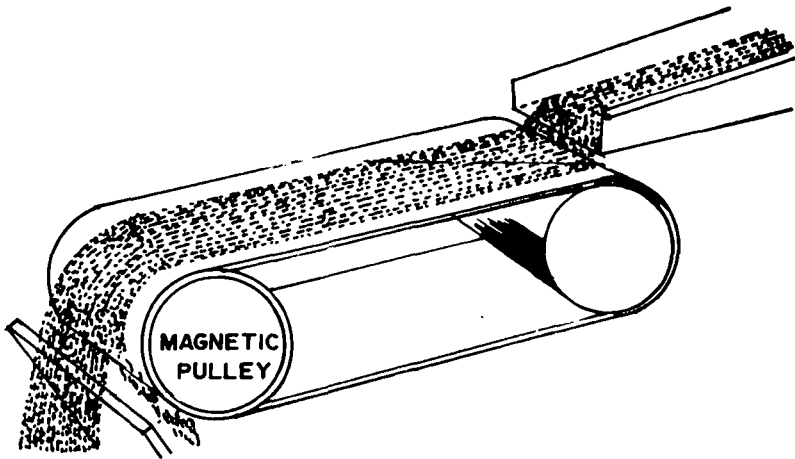
### 10.7.1 Unit Operations in Mechanical Composting Plants

Refuse collected from the feeder area of the city reaches the plant site at a variable rate depending upon the distance of collection points. The compost plant, however, has to operate at a uniform input rate. It is hence necessary to have a balancing storage to absorb the fluctuations in refuse input; for which a storage hopper is provided. The capacity of the hopper ranges from 8 to 24 hours storage. The exact capacity will depend upon the schedule of incoming trucks, the number of shifts and the number of days per week the plant and refuse cleansing system work.

The refuse is then fed to a slowly moving (5 m/mt) conveyor belt and the non-decomposable materials such as plastics, paper, glass are manually removed by labourers standing on either side of the conveyor belt. The thickness of material on the belt is kept below 15 cms to enable handpicking by labourers provided with hand gloves and other protective equipment. The removed materials are stored separately so that they can (if possible) be commercially exploited. The metals are removed by either suspended magnet system or a magnetic pulley system (Fig.10.7.1.1). In Indian refuse the metal content is low as most of it is reclaimed at the source itself. Metal remain-



**SUSPENDED - TYPE PERMANENT MAGNETIC SEPARATOR**

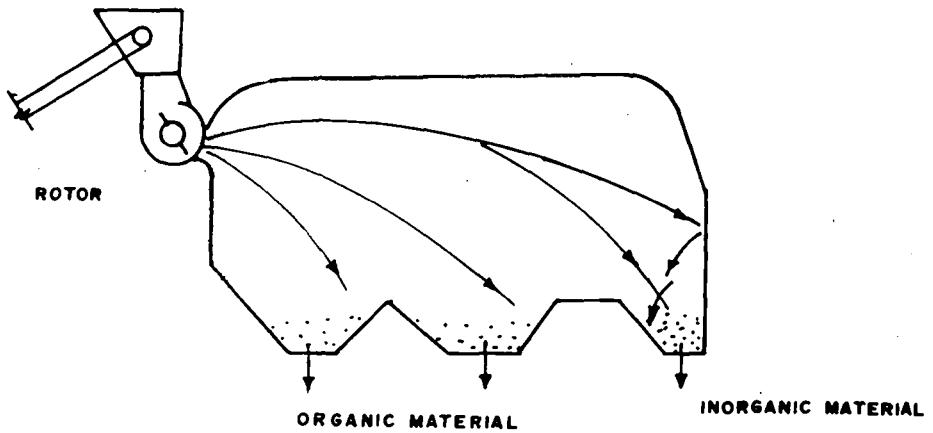


**PULLEY - TYPE PERMANENT MAGNETIC SEPARATOR**

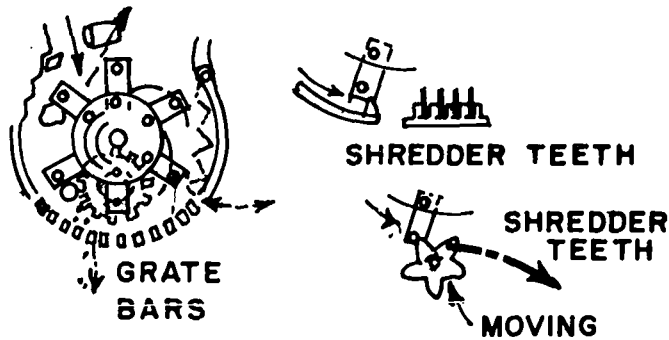
*10.7.1.1 Magnetic separator*

ing is either fine sized or in an irrecoverable form. Magnetic removal is not efficient for low metal content waste and hence not used in India.

Glass and metals are present in large proportions in the wastes from developed countries, for which ballistic separators are used. The materials are thrown with a force to take different trajectories depending on the den-



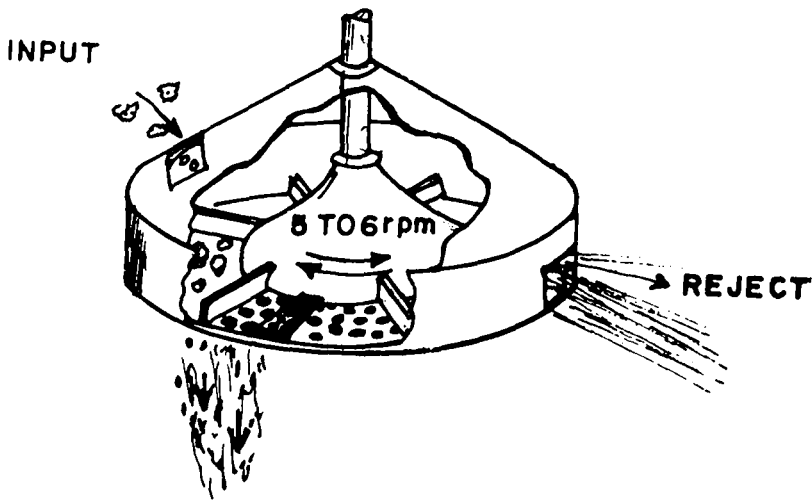
10.7.1.2 *Ballistic separator*



10.7.1.3 *Hammermill*

sity and get separated, but the operation is energy intensive (Fig.10.7.1.2). Glass and metals embedded in organic matter cannot be separated making the unit ineffective.

The material after removal of most of the non-compostable material is subject to size reduction when the surface area per unit weight is increased for faster biological decomposition. Size reduction also helps in reducing the possibility of fly-breeding in the composting mass. Two types of units are used for this purpose: i) Hammermills work at 600 to 1200 rpm and reduce the particle size by repeated hammer blows (Fig.10.7.1.3). These units are compact but consume more energy and ii) Rasp mills shear the material between a rotating arm moving at 4-6 rpm and a bottom plate with protruding pins (Fig. 10.7.1.4). The units are relatively large (about 7 m dia and 7 m high for 12 tonne/hr capacity) and heavy, but consume less energy per unit weight of material. The capital cost of a hammer mill is less but the operating cost is more than Rasp mill. Some explosions have been reported in hammermills due to the presence of aerosol cans in the waste.



#### 10.7.1.4 Rasp mill

The material is now subjected to controlled decomposition after adjusting the moisture content to 50-60% by spraying water. The composting is carried out in:

a) *Closed Containers with Forced Air Supply* : The container may be stationary (Earp Thomas) or may have a rotary motion (Dano System). Moisture, temperature and air supply are continuously monitored and controlled. Enclosing the composting mass in containers is adopted in temperate region due to low ambient temperature and to protect it from rain and snow. These conditions lower the temperature of decomposing mass and thus reduce the rate of reaction also.

b) *Windrow Composting* : In tropical regions with higher ambient temperature, composting in open windrows is to be preferred. The windrows have to be turned at suitable intervals to maintain the aerobic reactions. Compressed air supply will not be required in tropical regions. Turning of windrows can be carried out employing i) manual labour using buckets and shovels for smaller plants and ii) front end loaders having a bucket of 0.5-0.7 m<sup>3</sup> capacity and a 50 HP engine as in the case of earthmoving equipment. As the refuse is a light material its high power requirement will prove uneconomical. iii) Clamshell bucket which will lift the material, move over a gantry girder and then drop it at another location. Elaborate structural fabrication of the yard will be required adding to the capital cost. iv) Mobile jib cranes are fixed in position and rotated in a horizontal plane but will add to the cost as a number of such cranes will be required. v) Augers moving in opposite directions mounted in pairs on a suitable frame moving horizontally on pneumatic tyres. The horizontal and rotary motion is

provided with a suitable mechanism. vi) A machine with a rotating drum in the front to lift the material and pass it over a slat conveyor to the rear end of the machine. A beater mechanism breaks the lumps in the material before it is thrown back to reform the windrows.

The compost processed upto this stage is known as green or fresh compost, wherein the cellulose might not have been fully stabilised. The material is hence stored in large sized windrows for a further period of 1-2 months. Compost will be used by farmers two or three times a year depending upon the cropping pattern. Storage, either at plant or farmer's site has to be provided for. At the end of storage period, the material is known as 'ripe compost'. The ripe compost may further be processed for size reduction to suit kitchen garden and horticultural requirements in urban areas.

In industrially advanced countries, the wage rates are high which necessitate higher degree of mechanisation. Controlled decomposition in enclosed digesters is used in temperate climates, though at times windrows are also used. A typical layout of a Dano plant (Fig.10.7.2.1) as used in developed countries and two layouts (Fig.10.7.2.2 and Fig. 10.7.2.3) as adopted in India bring out the essential Indian differences. Plants based on these layouts have been proposed by NEERI for use at Jaipur and Hyderabad. The degree of mechanisation has been kept to the minimum, thereby reducing the capital cost to about 60% of plants of similar capacity used elsewhere.

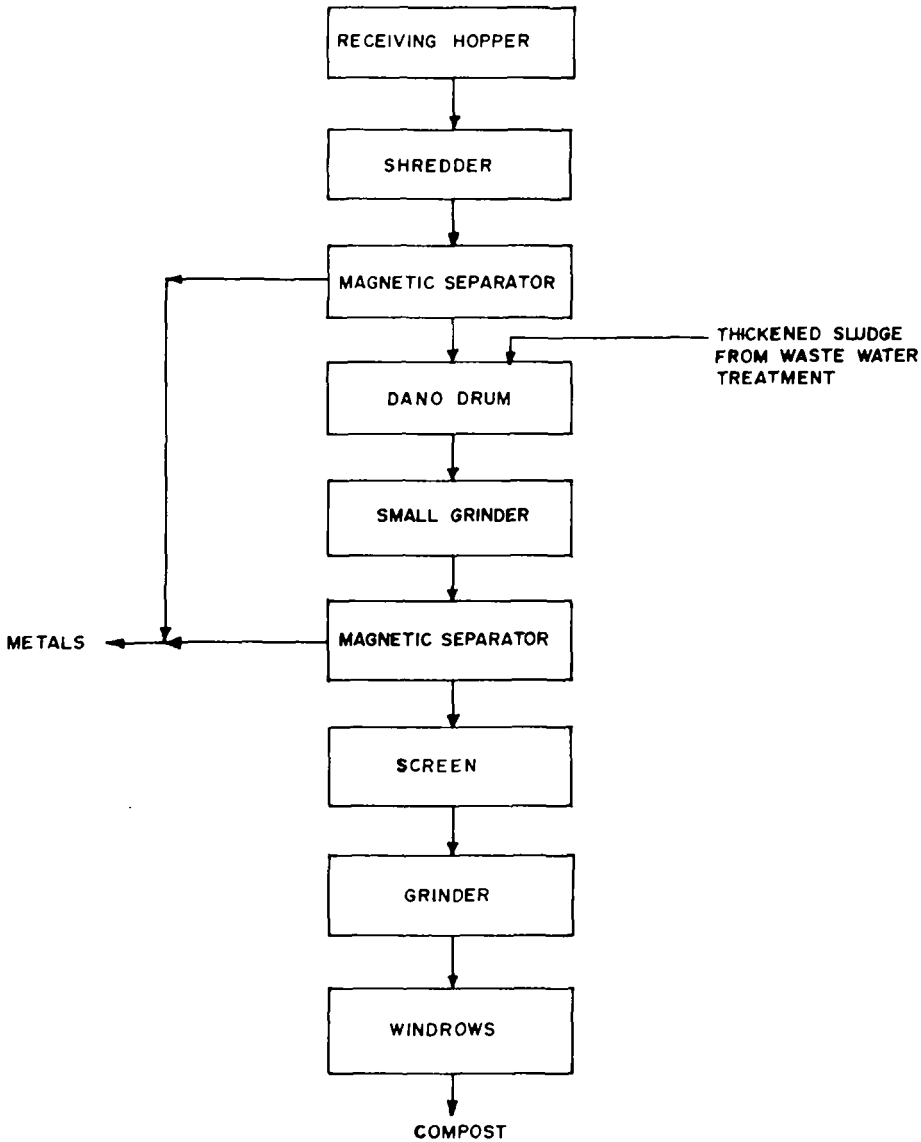
In addition to manual composting in India, about 100 mechanical plants were in use all over the world in 1969. The Netherlands was found to compost maximum percentage of its refuse (17%) while it was 1% in West Germany with 11 plants. About 20 plants of windrow type were in use in Czechoslovakia, 16 in Japan and 12 in Denmark of Dano type (Table 10.7.2.4).

### *10.7.2 Benefit - Cost Analysis*

The degree of mechanisation to be adopted will depend upon industrial and economic development, costs of labour and energy and socio-cultural attitudes of the community. A judicious combination of manual and mechanical methods will be required with due concern for public health aspects of the community as well as the workers and use of the product and acceptability by the farmers. Higher degree of mechanisation will demand high energy inputs which should be kept to the minimum. Reuse and recycling of valuable and available materials in the waste will recover part of the cost of production but not fully. Public health protection and an aesthetically clean environment are required for which the community has to bear the cost. Com-

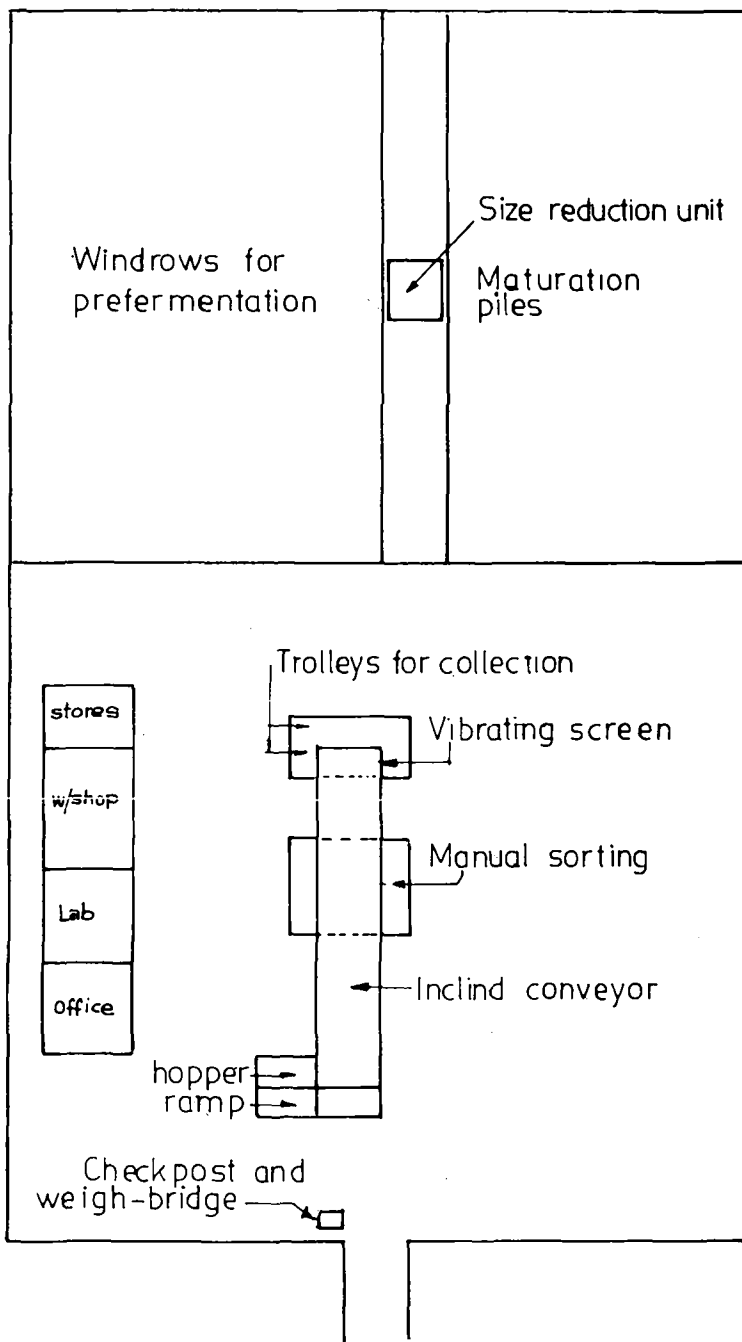
post production from community waste will need an element of social sharing of the cost.

It is difficult to compare the costs for two different locations due to variation in size, plant components, method of operation, labour, energy and land costs as well as final disposal method. Mechanical composting is not an inexpensive method, possibly due to lesser organic content in city refuse in industrialised countries. In Indian cities with more than 3000,000 popula-



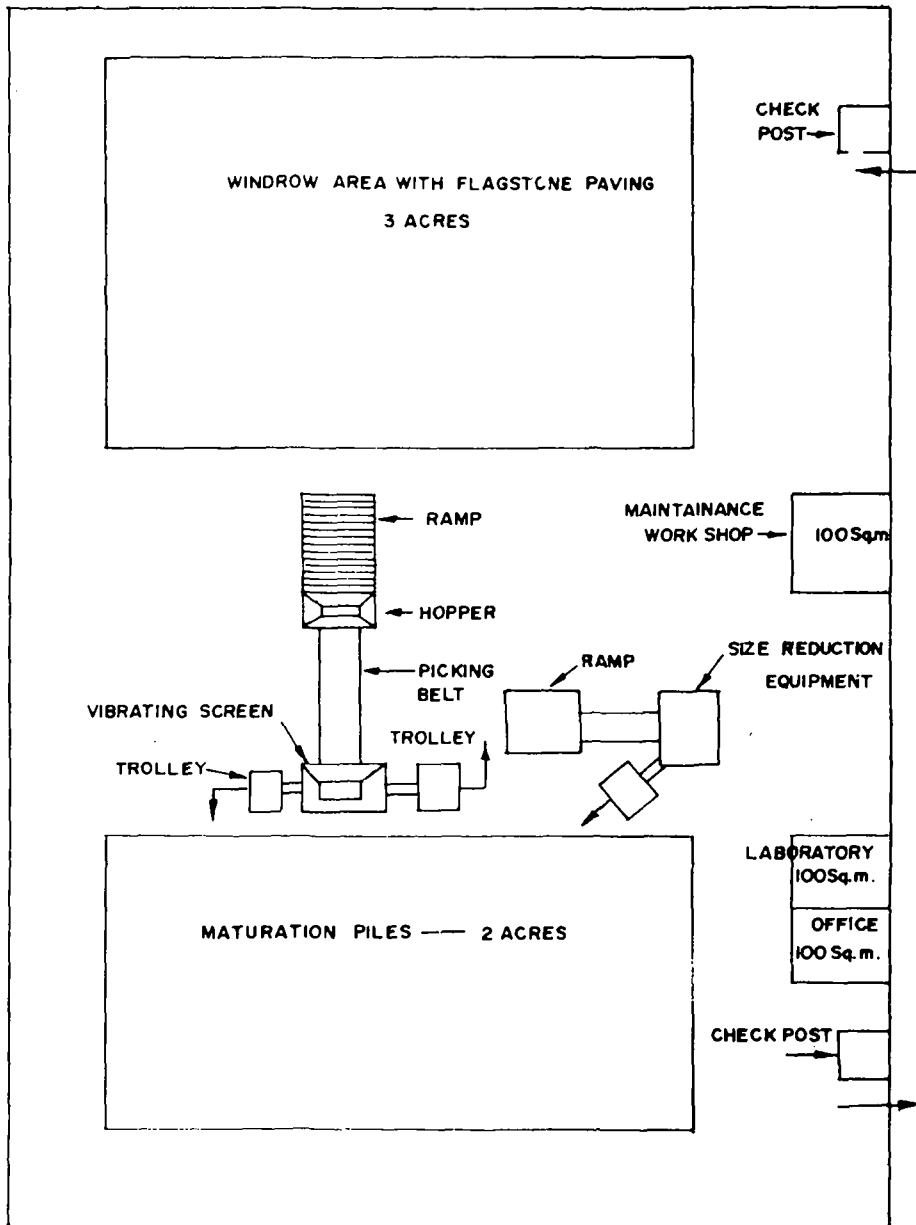
10.7.2.1 Flowsheet of a modern Dano plant





10.7.2.2 Flowsheet of Jaipur plant

tion, the capital cost varies from US \$ 0.33 to 1.33 million (Rs 3 million to 12 million), depending upon the degree of mechanisation involved. The production cost of compost varies from US \$ 2.65 to 8.88 (Rs 25 to Rs 80) per tonne.



**LAYOUT PLAN FOR MECH. COMP. PLANT**

*10.7.2.3 Flowsheet of Hyderabad plant*

Composting is a method for processing of waste for which the civic authorities collect taxes from citizens. The cost recovered from the sale of compost should go to discount the social costs of waste management system. It is imperative that compost should not be viewed as an industrial product for costing purposes and returns from sale of compost be treated as an

*Table 10.7.2.4 : Distribution of Mechanical Compost Plants in 1969*

Name of country	Dano	Windrow	Triga	Beccari	Others	Total
U.K.	2	-	-	-	2	4
France	1	-	3	-	-	4
Italy	2	-	-	-	2	4
Israel	2	1	-	-	-	3
Switzerland	6	1	-	1	1	9
W. Germany	2	3	-	-	6	11
U.S.S.R.	-	-	1	-	-	1

incidental benefit. Planners in the developing countries should clearly distinguish the compost (organic manure) and inorganic fertilizers for cost comparison.

In industrialised nations the savings in sludge treatment have not been accounted for when used with city refuse for composting. In the same manner, compost (organic manure) and chemical fertilizers (inorganic) should be complimentary. Farmers in India and other developing countries are well accustomed to use of green manure and composted farmyard wastes and would accept it. The transport cost of compost from urban centres to farms in hinterland may ultimately prove to be the critical issue. Location of compost plant to minimise transport cost to the farmers should not be overlooked.

#### *10.7.4 Pilot Study*

It is desirable to set up a pilot plant where a new compost plant is planned to assess the quantity and quality of wastes generated, conveyance pattern and ultimate usage of the compost. Acceptance by farmers, training of plant workers as well as the right combination of manual and mechanical operation could be chosen with the help of the pilot study. Community acceptance is best ensured by operating demonstration plots in selected areas so that farmers see the results to be convinced of the advantages. This is especially important as the price of compost that the farmers will have to pay will be much higher than the price to which they are accustomed. Compost is a bulky, low nutrient content material for which the transport costs should be kept to the minimum. It has been observed in India that the plant should be so located that the radial distance of the farms is less than 50 kms.

The processing method, unit operations and location of the composting plant should be such that the objective is achieved in full, viz., public health protection, reuse of nutrients, aesthetic environment and a sale of compost at a level acceptable to farmers.

### 10.8 Case studies (1980 Price level)

#### A. Mechanical composting plant

Capacity	=	200 tonnes per day (300 days/year)
Civil works	=	Rs 1.6 x 10 <sup>6</sup>
Land	=	Rs 0.15 x 10 <sup>6</sup>
Cost of plant and machinery	=	Rs 2.75 x 10 <sup>6</sup>
Total capital cost	=	Rs 4.5 x 10 <sup>6</sup> (US \$ 0.5 x 10 <sup>6</sup> )

#### Operating cost

Sr. No.	Items	Details	Cost/tonne
1.	Amortization	@ 8% of cost of civil work and 10% of cost of plant and machinery.	6.63
2.	Maintenance & repairs	@ 2% cost of civil work and 5% of cost of plant and machinery	2.68
3.	Land	Belongs to operator and hence 6% of cost is assumed as expenditure/year.	0.15
4.	Power and water charges	Connected HP-300 .	0.83
5.	Salaries	1 manager, 2 foremen, 4 operators & 4 mechanics, 1 electrician, 5 drivers, 15 helpers and 4 clerical staff.	2.91
6.	Disposal of non-compostable	About 80 tonnes/day of non-compostables will be disposed of by sanitary landfilling.	10.50
Total cost/tonne of input or cost/tonne of compost produced =		=	Rs 23/70 (US \$ 2.63) Rs 47/40 (US \$ 5.26)

B. *A semi-mechanised compost plant*

Plant capacity - 100 tonnes/day (300 days per year).

Refuse density - 500 kg/m<sup>3</sup>

The vehicles bringing refuse would discharge their contents directly in the windrow area to form windrows of size 3 m x 1.6 m 40 m long forming a fresh windrow every day. The material in the windrows would be turned on 5th, 10th, 15th day for aeration. On 20th day, the material will be screened using a mobile screening unit. The fine material will be transferred to maturation yard, where it will be held for about a month or two before despatch for sale. The over-size organics will be composted with fresh incoming refuse while inorganics will be landfilled. It will be a labour intensive plant using minimum mechanical equipment.

Civil works = Rs 4.0 x 10<sup>5</sup>

Land = Rs 2.6 x 10<sup>5</sup>

Machinery = Rs 2.9 x 10<sup>5</sup>

Total capital cost = Rs 9.5 x 10<sup>5</sup>

*Operating Cost*

Sr. No.	Item	Details	Cost/tonne
1.	Amortization	@ 8% of cost of civil works and 10% of cost of machinery.	1.01
2.	Maintenance and repairs	@ 2% of cost of civil works and 5% of cost of machinery.	0.38
3.	Land	Belongs to operator and hence 6% of cost is assumed as expenditure/year.	0.26
4.	Power and water charges		0.35
5.	Salaries	1 superintendent, 3 electricians, 3 operators, 2 drivers, 50 unskilled labourers and 3 clerical staff.	6.66
6.	Disposal of non-Compostables	About 50 tonnes per day will have to be disposed of by sanitary landfilling (manual) in an adjacent site.	5.25

Cost/tonne of input = Rs 13.91 (US \$ 1.54)

or cost/tonne of compost produced = Rs 27.82 (US \$ 3.07)

## CHAPTER 11

### INCINERATION

#### 11.1 Introduction

Burning of refuse has been practised in the past by individuals in urban as well as rural areas. Defence establishments have been using it as a standard method of disposal of refuse in single cell incinerators. In several Indian cities, incineration was practised but abandoned and no reliable data is available on their performance. Incineration can be defined as a controlled combustion process for burning solid, liquid and gaseous combustible wastes to gases and residue containing non-combustible material. During combustion, moisture is vaporised whereas the combustible portion is vaporised and oxidised. Carbon dioxide, water vapour, ash and non-combustibles are the end-products.

#### 11.2 Self Sustained combustion Reaction

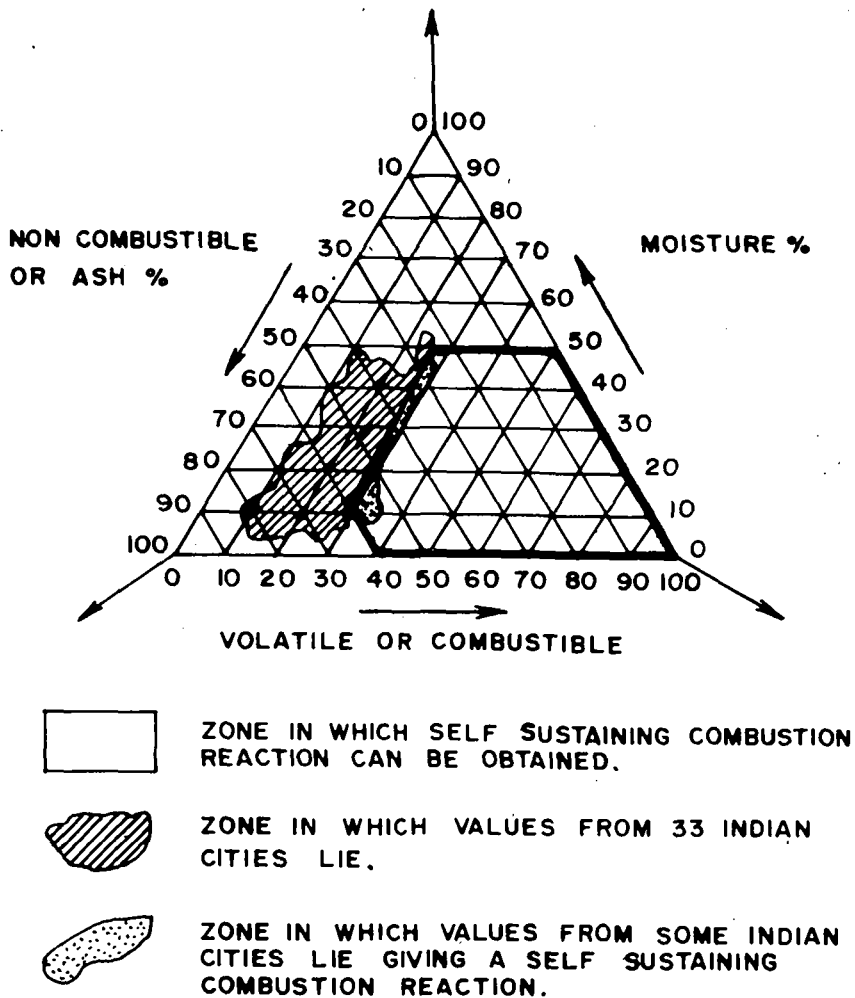
Calorific value, ash and moisture content, in addition to other parameters would indicate whether the waste can sustain combustion on its own without the addition of auxiliary fuels. Table 11.2.1 gives the calorific values of some constituents of municipal solid wastes.

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*Table 11.2.1 : Calorific Values of some Common Constituents of Municipal Solid Wastes*

Component	Kcal/kg
Paper	2700 - 4500
Plastics	6500 - 9000
Rags	3600 - 4500
Rubber	5000 - 6500
Leather	3500 - 5000
Garden waste	500 - 4500
Wood	4000 - 4600

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### 11.2.2 Three component diagram

The 'Three Component Diagram' (Fig. 11.2.2) is plotted for the waste which would indicate its self sustaining combustion capacity. When the point plotted using per cent ash, moisture and combustible matter lies in the hatched portion, self sustained combustion reaction can be obtained; otherwise auxiliary fuel has to be added. The data collected from 33 Indian cities[11] indicates that in most of the cases, the points lie outside the zone of self sustained combustion.

In other developing countries incineration has not been widely used due to low calorific values of the wastes. In Singapore and Hongkong, incinerators are being used mainly due to the higher calorific value of the wastes[78].

### 11.3 Air for Combustion

Air is required in the combustion process, for which it can be supplied beneath the grates (underfire air) or over the fuel bed (overfire air) to provide turbulence. In order to effect complete combustion and promote turbulence, at least 50% excess air should be provided in incinerators. However, too large an excess air would lower furnace temperature. Refractory furnaces require 150 - 200% excess air; whereas water tube wall furnaces require about 50-100% excess air. The total air required for municipal incinerators is split into overfire (70%) underfire (10%) and secondary (20%) for good performance.

Time, temperature and turbulence are called the three T's of combustion. When solid waste is exposed for a sufficient time to a turbulent hot atmosphere, the waste will be satisfactorily incinerated. To facilitate drying, some furnace designs use preheated air or incorporate reflecting arches to radiate heat stored from the burning of previously charged material. The first part of the grate system is also referred as drying grate. Ignition takes place as the solid waste is dried and continues through the furnace. The portion of the grates where ignition first occurs is called the ignition grate.

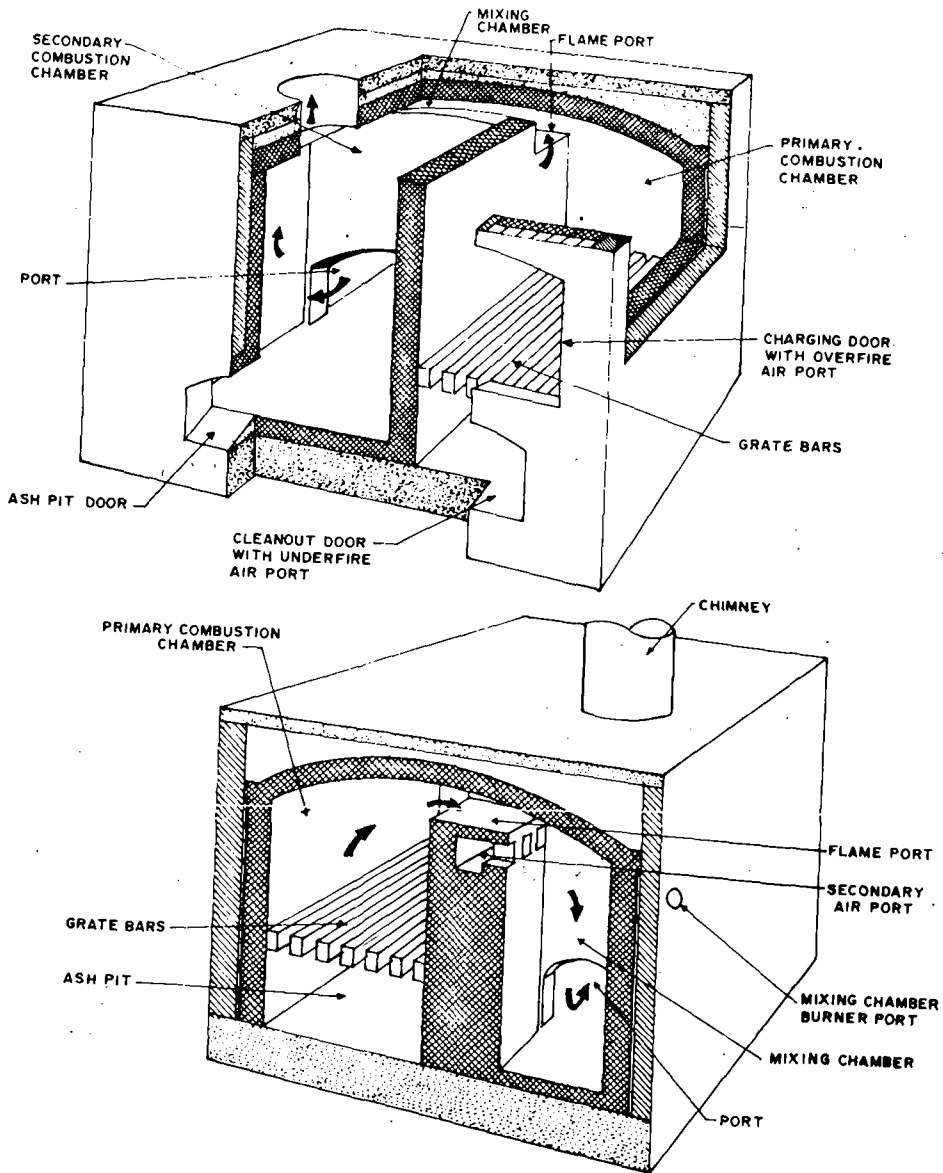
Turbulence ensures mixing of each volume of gas with sufficient air for complete burning of volatile combustible matter and suspended particulates. It must be intense and persist long enough for the mixing to be completed while the temperature is still high enough to ensure complete burning.

### 11.4 Types of Incinerators

#### 11.4.1 *Multiple Chamber Incinerators*

The simplest types are the multiple chamber incinerators. Combustion in these units proceeds in two stages, primary or solid fuel combustion in the ignition chamber followed by secondary or gaseous phase combustion in secondary combustion chamber. In the ignition chamber, drying, ignition and combustion of waste occurs. The moisture and volatile components of the waste are vaporised and partially oxidised while passing from the ignition chamber through the flame port connecting the ignition chamber with the mixing chamber. The volatile components of refuse and the products of combustion flow from the flame port to mixing chamber in which secondary air is introduced. Secondary combustion achieves combustion of unburnt furnace gases and carbon suspended in the gases and elimination of odours. The combination of adequate temperature and additional air, along with secondary burners if necessary, help initiate the secondary

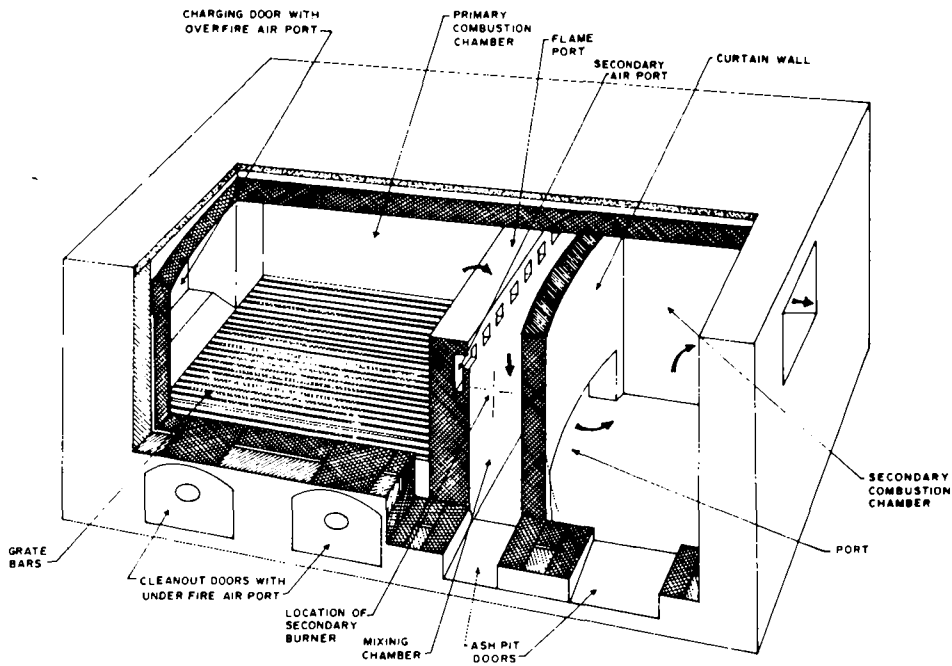




*11.4.0.1 Sectional view of a retort multi-chamber incinerator*

combustion process. Turbulent mixing occurring as a result of restricted flow areas and abrupt changes in flow directions both in horizontal and vertical plane furthers the gaseous phase reaction. Due to the abrupt changes in directions and expansions, the particulate matter is removed by wall impingement and simple settling. The gases finally escape through a stack or a combination of gas cooler and induced draft system.

Multiple chamber incinerators are of two types: i) Retort, and ii) In-line. Retort type (Fig.11.4.0.1) is preferred when the quantity of waste



#### 11.4.0.2 Sectional view of in-line multi-chamber incinerator

to be burnt is less than 340 kg/hr (750 lbs/hr) while Inline type is used for higher capacities (Fig.11.4.0.2). The specific features of the two types are:

##### *Retort type*

- i) The arrangement of chambers is such that gases change direction by  $90^{\circ}$  both in lateral and vertical directions.
- ii) Due to return flow of gases, a common wall is used between primary and secondary combustion stages.
- iii) Mixing chambers, flame ports and curtain wall ports have length to width ratios of 1:1 to 2.4:1.
- iv) The thickness of bridge wall under the flame port is a function of dimensional requirements in the mixing and combustion chambers which become unwieldy above 225 kg/day (500 lbs/day).

##### *Inline type*

- i) The gases take  $90^{\circ}$  turn only in vertical direction.
- ii) All ports and chambers extend across the full width of the incinerator.

- iii) Mixing chamber, flame port and curtain wall port have length to width ratios of 2:1 to 5:1.

Section 11.19 deals with the design of a simple multiple chamber incinerator.

#### 11.4.2 Municipal Incinerators

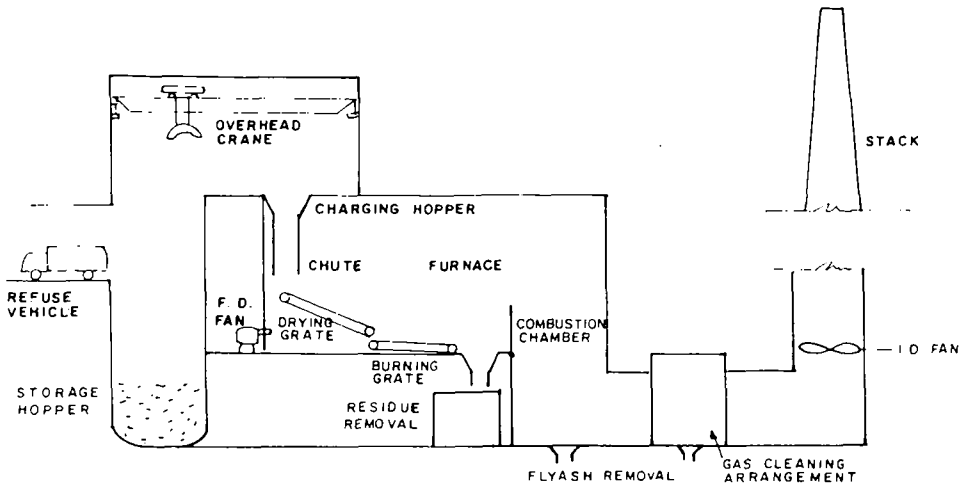
Municipal incinerators are constructed and operated for large capacities. In general, such installations have the following components:

i) *Reception and Storage* : Refuse is weighed on a weighbridge provided with one unit upto 1000 tonnes/day. The refuse is dumped in a storage pit (Fig. 11.4.2.1) having a capacity of 16 to 36 hours of refuse intake, depending upon the schedule of arrival of vehicles at the site, reliability of maintenance and availability of alternate site, etc. The refuse from the pits is transported to charging hopper with a monorail crane. The capacity of the crane depends on the rate of feeding and cycle time (1.5-3 minutes) of bucket operation. A second crane is provided when the size of the plant exceeds 300 tonnes/day.

ii) *Charging Hopper and Chute* : The refuse is dumped by the crane into a charging hopper (1.25 m x 1.25 m to 1.25 m x 2.5 m) which is deep enough to take a bucketful of solid wastes without spilling over. The refuse from the charging hopper goes to the furnace through a charging chute with a smooth inside surface, increasing cross-section and protected from the extreme heat of the furnace by water jackets. Continuous feed minimises irregularities in the combustion system. Batch feeding causes fluctuations in the thermal process due to non-uniform rate of feeding and intermittent introduction of large quantities of cool air.

iii) *Furnace* : Furnaces used for the incineration of municipal solid waste are vertical circular furnace, multicell rectangular and rotary kiln. Although these furnaces vary in configuration, total space required is based on a heat release rate of about 160,000 Kcal/m<sup>3</sup>(18000 BTU/cft) of furnace volume/hour, although heat release rates varying from 110,000 to 220,000 Kcal/m<sup>3</sup>/hr (12,500 to 25,000 BTU/cft/hr) have been used.

In vertical circular furnace with suitable refractory linings, the solid waste is charged through a door or lid in the upper part (usually the ceiling) dropping on central cone grate. The surrounding circular grate underfire forced air is the primary combustion air which also serves to cool the grates. As the cone and arms rotate slowly the fuel bed is agitated and the residue moves to the sides where it is discharged manually or mechanically through a dumping grate on the periphery of the stationary circular grate. Stoking



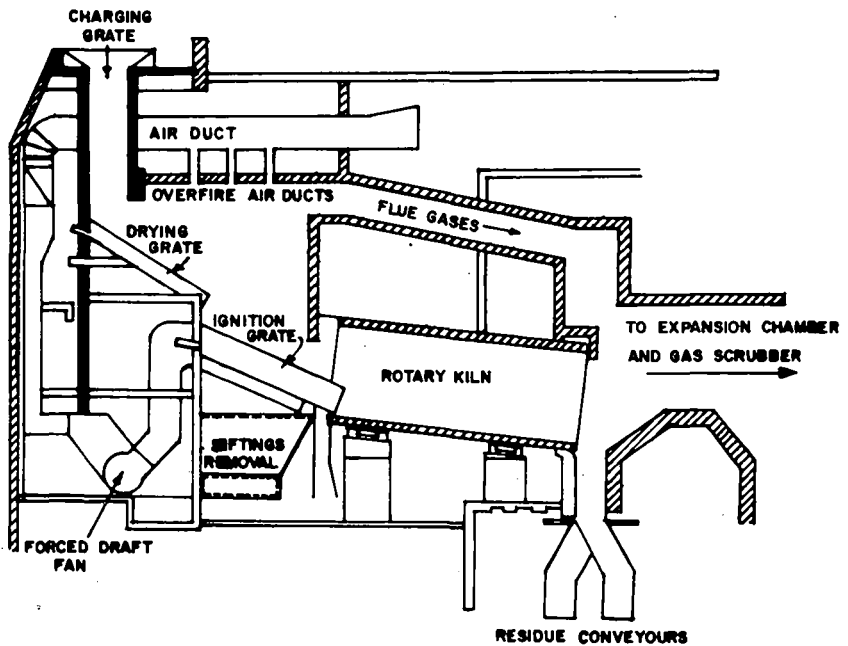
#### 11.4.2.1 Section through a non-heat utilization type incinerator

doors are provided for manual agitation and assistance in residue dumping, if required. Overfire air is introduced to the upper portion of the circular chamber. A secondary combustion chamber is located adjacent to the circular chamber.

The multicell rectangular type also called the mutual assistance furnace, may be refractory lined or water cooled. It contains two or more cells set side by side, each cell having a rectangular grate. Solid waste is charged through a door at the top of each cell which has a common secondary combustion chamber and share a residue disposal hopper. The rectangular is the most common form in recently constructed municipal incinerators. Several grate systems are adaptable to this form. Two or more grates are arranged in tiers so that the moving solid waste is agitated as it drops from one level to next. Each furnace has only one charging chute and secondary combustion is frequently provided.

A rotary kiln furnace (Fig. 11.4.2.2) consists of a slowly revolving inclined kiln that follows a rectangular furnace where drying and partial burning occurs. The partially burned waste is fed by the grates into the kiln where the cascading action exposes unburned material for combustion. Final combustion of the gases and suspended particulates occurs in the mixing chamber beyond the kiln discharge. The residue falls from the end of the kiln into a quenching tank.

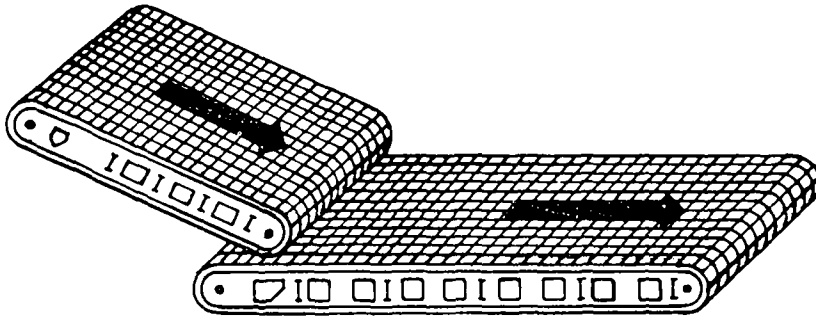
*iv) Grates and Stoking:* The grate system transports the solid waste and residue through the furnace and at the same time, promotes combustion by adequate agitation and passage of underfire air. The degree and method of agitation on the grates are important. The abrupt tumbling



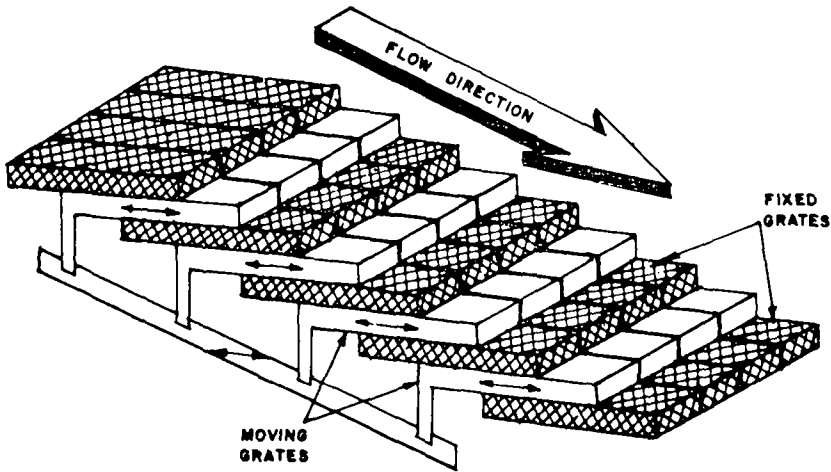
#### 11.4.2.2 Rotary kiln furnace

encountered, when the burning waste drops from one tier to another, will promote combustion, but may contribute to entrainment of excessive amounts of particulate matter in the gas stream. Continuous gentle agitation promotes combustion and limits particulate entrainment. Combustion is largely achieved by air passing through the waste bed from under the grate, but excessive amounts of underfire air contribute to particle entrainment. Inert materials, such as glass bottles and metal cans aid combustion by increasing porosity of the fuel bed. Conversely, inert materials may also inhibit combustion by clogging the grate openings. Mechanical grate systems should withstand high temperatures, thermal shock, abrasion, wedging, clogging and heavy loads. Such severe operating conditions can result in misalignment of moving parts, warping or cracking of castings.

Grate loading rate varies from 220 to 320 kg/m<sup>2</sup>/hr (50 to 70 lbs/cft/hr) which is also expressed in Kcal/m<sup>2</sup>/hr (BTU/cft/hr). An average rating of 750.00 Kcal/m<sup>2</sup>/hr (3000.00 BTU/sft of grate/hr) is used as a design parameter. Grate system can also be classified by function, such as drying grate, ignition grate and combustion grate. Grates for incineration of solid wastes can also be grouped as travelling, reciprocating, rocking, rotary kiln, circular, vibrating, oscillating and reverse reciprocating grates, multiple rotating drums, rotating cones with arms and variations or combinations of these types. In the United States, travelling, reciprocating, rocking, rotary kiln and circular grates are widely used. Travelling grates (Fig.



11.4.2.3 Travelling grates



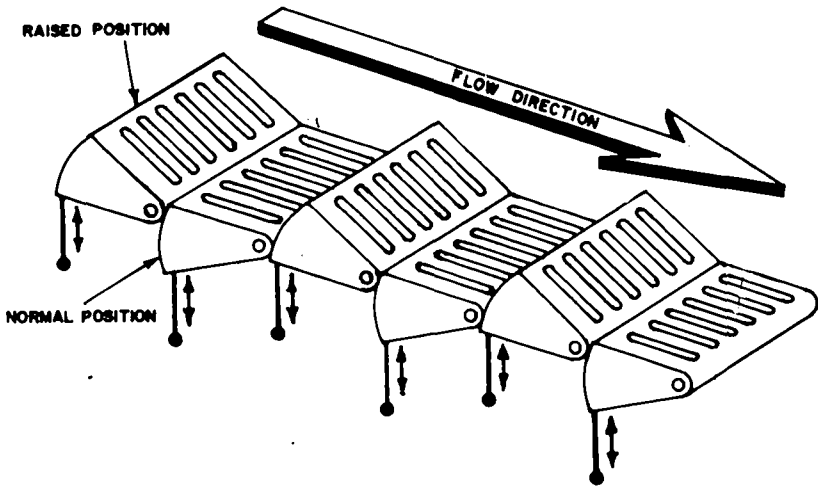
11.4.2.4 Reciprocating grates

11.4.2.3) are belt like conveyors operating continuously. A single travelling grate does not promote agitation. Two or more grates at different elevations provide some agitation as the material drops from one level to next.

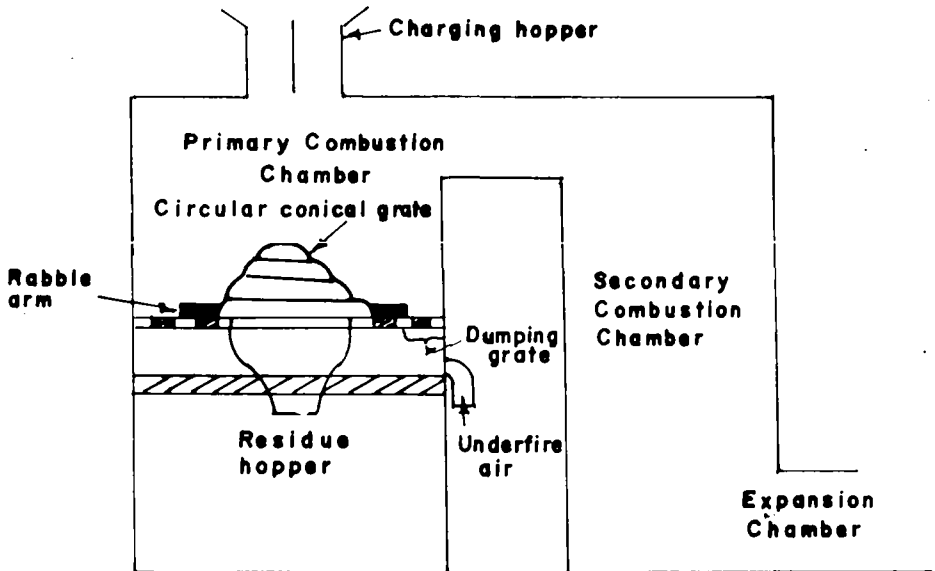
In reciprocating grate systems (Fig.11.4.2.4) the grate sections are stacked like overlapping roof shingles. Alternate grate sections slide back and forth while adjacent grate sections remain fixed like travelling grates. Reciprocating grates may be arranged in multiple level series providing additional agitation as the material drops from one grate to the next.

Rocking grates (Fig.11.4.2.5) are arranged in a row across the width of the furnace, at right angles to solid waste flow. Alternate rows are mechanically pivoted or rocked to produce an upward and forward motion, thus advancing and agitating the solid waste. Rocking grates have also been arranged in series.

The rotary kiln (Fig.11.4.2.2) has a solid refractory surface and is preceded by a reciprocating grate. The slow rotation of the kiln, which



11.4.2.5 Rocking grates



11.4.2.6 Circular conical grate

is inclined, causes the solid waste to move in a slowly cascading and forward motion. The circular grate (Fig.11.4.2.6) in the vertical circular furnace is used in combination with a central rotating cone grate with extended rabble arms that agitate the fuel bed.

### 11.4.3 Other Services

The incinerators require a large amount of water for quenching of the clinker, for the removal of fly ash in the water scrubbers and in the boilers.

The amount of water required varies from 1500 to 9000 litres/tonne (350 to 2000 gallons per tonne) of refuse burnt depending on the design. Energy consumption by various units in the incinerator varies from 30-50 KWH/tonne of refuse burnt depending on the type of unit.

### 11.5 Auxiliary Fuels

Auxiliary fuels will be required in the following cases:

- i) Furnace starting and warming up.
- ii) Promotion of primary combustion when the solid waste is wet or does not have adequate calorific values.
- iii) Completion of secondary combustion to ensure odour and smoke control.
- iv) Additional heat is required for heat recovery units.

When the refuse has a low calorific value with lower content, auxiliary fuel will be required.

### 11.6 Recovery of Heat

Recovery of heat has been practised extensively in European installations but to a limited extent in USA. The heat recovered can be used for supplying hot water, generating electricity and to heat the plant during winter. Heat is recovered by adopting suitable systems such as

- i) waste heat boiler system with tubes located beyond conventionally built combustion chambers;
- ii) water tube wall combustion chambers;
- iii) combination of the above; and
- iv) integrally constructed boiler and water tube wall combination.

Excess air needed will depend upon the system adopted. Low excess air increases the amount of heat recovered and reduces the capacity of air pollution equipment. The theoretical efficiency of the recovery process can be as high as 70% depending on the type of equipment used. The amount of steam produced varies from 1 to 3.5 kg per kg of solid waste.

### 11.7 Use of Refuse as Supplementary Fuel

In USA, upto a few years back, the effort was towards installation of incinerators burning refuse alone and having heat recovery facilities. These faced a number of problems due to variable composition of refuse having



different calorific value which resulted in variable output. The European countries, on the other hand, were using separated and shredded waste as a supplementary fuel in existing thermal power plants using coal or gas as the principal fuel. Such plants did not suffer due to variable calorific value of refuse. Further, by burning solid waste in a utility power plant, the process took advantage of an existing system. The trend now in USA has been towards adoption of this system as exemplified by the installation of a plant in St. Louis<sup>(55)</sup> which uses 650 tpd of refuse in a 125 Mw tangentially suspension fired boilers that burn pulverised coal. Some more similar plants are now being constructed.

## **11.8 Products of Incineration**

### *11.8.1 Siftings*

Siftings are the fine materials that fall from the fuel bed through the grate openings during the drying, ignition and burning processes. Siftings consist of ash, small fragments of metals, glass and ceramics and unburned or burned organic substances which are collected in troughs and conveyed continuously by sluicing or mechanical means to a residue collection area.

### *11.8.2 Residue*

Residue contains all solid materials remaining after burning including ash, clinkers, tin cans, glass, rock and unburned organic substances. Residue removal can either be a continuous or batch process. In a continuous feed furnace, the greatest volume of residue comes off the end of the burning grate; the remainder comes from siftings and fly ash. The residue from the grate must be quenched and removed from the plant. Batch operated furnaces usually have ash collection and storage hoppers beneath the grates. Periodically, the residue is removed, quenched, accumulated in a residue hopper and discharged from the bottom by opening a watertight gate.

In continuous feed operations, residue is discharged continuously into troughs connected to all furnaces. A slow moving drag conveyor, submerged in the water filled trough, continuously removes the residue. The discharge end of the conveyor is inclined to allow drainage of quench water from residue before loading into a holding hopper or directly into trucks.

### *11.8.3 Clinker and Flyash*

The clinker from grates of the incinerator essentially consists of fused ashes, metal and other non-combustibles which may be about 10% of refuse input. This material can be crushed and utilised as additives to cement, concrete or in road building. The flyash from the gas scrubbing units can be utilised as additive to cement, cellular concrete, manufacture of bricks or

road making. The quantity of flyash may be about 12-15 kg/tonne (30-40 lbs/tonne) of refuse.

#### 11.8.4 Suspended Particulates

Control equipment will be required to remove the entrained particles from flue gases before they are released into the atmosphere. The types of equipment are described in Table 11.8.4.1.

Table 11.8.4.1 - Equipment for Particulate Removal

Sl No	Characteristics Equipment	% efficiency Particulate removal	Pressure drop (Water gauge)	Miscellaneous
1)	Wetted baffle spray	10-53	0.75-1.5 cm	Water needed—2-9 litres/mt/tonnes
2)	Settling chamber	10-30	-	-
3)	Cyclones	60-65	6-10 cm	-
4)	Wet scrubbers	94-96.5	12-16 cm	Water requirement 8-24 litres of water/m <sup>3</sup> of gas treated.
5)	Electrostatic precipitators	96-99.5	1 cm	Energy consumption 7-14 KW/mt/m <sup>3</sup> of gas treated.
6)	Fabric filter	99.6	10-16 cm	-

#### 11.8.5 Waste Gas

Incinerator stacks provide natural draft and dispersion for gases and particulate matter. Accordingly, the height and diameter of stack depends upon the amount of draft required, the topography and meteorological conditions. The theoretical draft requirement of a stack is calculated by using<sup>(40)</sup> .:

$$P = 0.09806 H P_a T_a \left( \frac{1}{T_a} - \frac{1}{T_g} \right)$$

where P = pressure differential in millibars  
H = height of chimney above inlet (m)

- $P_a$  = density of air at ambient temp. ( $\text{kg/m}^3$ )  
 $T_a$  = absolute value of ambient temperature ( $^{\circ}\text{K}$ )  
 $T_g$  = absolute value of flue gas temperature ( $^{\circ}\text{K}$ )

The draft produced should be sufficient to overcome frictional losses and provide a negative pressure of 1 to 2 mm of water. The range of total available stack draft varies from 3 mm water column for a 22 kg/hr (50 lbs/hr) unit to 7 mm water column for 910 kg/hr (2000 lbs/hr) unit. Air pollution control requirements may need higher stack height than necessary for creating sufficient draft. Guillotine type dampers, provided to regulate the draft need constant adjustment, especially during light off period. A barometric damper in the stack or stack breeching regulates draft at proper level. Dampers are provided in stacks having induced draft fans operating at constant speed. Adjustable speed, induced draft fans are also used to control draft. Table 11.11.1 gives the design factors for multiple chamber incinerators<sup>(33)</sup>.

### 11.9 Air Pollution and Control

Incineration leads to release of waste gas which may cause air pollution for which suitable precautions should be taken. Sulphur dioxide emissions are low due to low sulphur levels in the waste. Oxides of nitrogen ( $\text{NO}_x$ ) are not likely to be high, as revealed from the experience in European and US plants. Suspended particulates released through the stacks may be high, for which suitable control devices would be required.

A comparison of emissions from different sources is shown in Table 11.9.1 which indicates that they are not likely to be high. However, location of an incinerator in an area already having high levels of emissions may further add to the problem.

*Table 11.9.1 : Comparison of Total Emissions in West Germany with those from Existing Incinerators<sup>(66)</sup>*

Pollutant	West Germany (Tonnes/Year)	Incinerators (Tonnes/Year)
$\text{SO}_2$	$4 \times 10^6$	12000
$\text{N}_2\text{O}_3$	$2 \times 10^6$	5000
HCl	Unknown	8000
HF	--	50
Dust	$4 \times 10^6$	2000

## 11.10 Incineration of Plastics

Plastics found in wastes may be thermoplastics which soften, deform and melt when heated or thermosettings which are stable. Plastics are based on polymers generally containing C, H & O which at normal incineration temperature of 600°C and above get converted to CO<sub>2</sub> and H<sub>2</sub>O. At temperatures above 600°C, nitrogen oxides may be formed if it contains nitrogen as in the case of nylon polyurathans, polyamides and nitriles. Fumes of PVC, HCl and HF may be released in some wastes. Specially designed incinerators are available for burning waste PVC and recovery of HCl.

## 11.11 Design Aspects

Based on experience of existing installation, different design values have been given by various authorities. Table 11.11.1 gives the mean values of various parameters. As the characteristics of wastes fluctuate it is necessary to indicate permissible variations from optimum values and hence, the range is indicated.

*Table 11.11.1 : Design Factors for Multiple-chamber Incinerator*

Item and Symbol	Recommended Value
<i>Primary combustion zone</i>	
Grate loading, L <sub>G</sub>	220-320 kg/m <sup>2</sup> hr
Grate area, A <sub>G</sub>	$R_C \frac{O}{O} L_G : m^2$ where R <sub>C</sub> is refuse combustion rate in kg/hr.
Average arch height, H <sub>A</sub>	0.9643 (A <sub>G</sub> ) <sup>4/11</sup> : m
Length-to-width ratio (approx.)	Retort : Upto 200 kg/hr. 2 : 1; over 200 kg/hr. 1.75 : 1
Inline	Diminishing from about 1.7:1 for 340 kg/hr to about 1:2 for 900 kg/hr capacity. Over-square acceptable in units of more than 3 m ignition chamber length.

### *Secondary combustion zone*

Gas velocities :

Flame port at 540°C, V <sub>FP</sub>	15-20 m/sec
Mixing chamber at 540°C, V <sub>MC</sub>	6-10 m/sec

Curtain wall port at 510°C, $V_{CWP}$	About 0.7 of mixing chamber velocity
Combustion chamber at 480°C, $V_{CC}$	1.5-3 m/sec : always less than 3 m/sec.
Mixing chamber downpass length, $L_{MC}$ from top of ignition chamber arch to top of curtain wall port	Average arch height, m
Length-to-width ratios of flow cross sections : Retort, mixing chamber and combustion chamber	Range - 1.3 : 1 to 1.5 : 1
In-line	Fixed by gas velocities due to constant incinerator width.

*Combustion air :*

Air requirement: batch-charging operation. Basis : 300% excess air, 50% air requirement admitted through adjustable ports; 50% air requirement met by open charge door and leakage.

Air distribution :

Overfire air ports	70% of total air required
Underfire air ports	10% of total air required
Mixing chamber air ports	20% of total air required
Port sizing, nominal inlet velocity pressure.	2.5 mm water gage

Air inlet ports oversize factors :

Primary air inlet	1.2
Underfire air inlet	1.5 for over 200 kg/hr to 2.5 for 20 kg/hr
Secondary air inlet	2.0 for over 200 kg/hr to 5.0 for 20 kg/hr

*Furnace temperature :*

Average temperature, combustion products	550-600°C
--	-----------

*Auxiliary burners :*

Normal duty requirements

Primary burner	1600 to 5550	Kcal/kg of moisture in
Secondary burner	2200 to 6600	the refuse

---

*Draft requirements :*

Theoretical stack draft,  $D_T$       3 to 6 mm water gage

Available primary air  
induction draft,  $D_A$               2 mm water gage

(Assume equivalent to inlet  
velocity pressure)

Natural draft stack  
velocity, vs.                          Less than 10 m/sec at 480°C

---

*Design* - an incinerator to burn 150 kg/hr of office waste comprising mostly of paper having a calorific value of 4200 Kcal/kg. Moisture content of the waste is 15%.

I. Dry combustibles              =  $0.85 \times 150$       =      127.5 kg/hr  
Moisture                              =  $0.15 \times 150$       =      22.5 kg/hr

II. Calorific value of              = 4200 Kcal/kg  
of paper

Total heat                              =  $4200 \times 127.5$   
    = 535500 Kcal

III. Heat loss : When 1 kg of paper is burnt, 0.56 kg of water is formed.

i) Heat loss in evaporation of contained  
moisture  
=  $22.5 \times 588.3$                       =                      13236.75 Kcal

ii) Heat loss in evaporation of water formed  
during combustion  
=  $0.56 \times 127.5 \times 588.3$               =                      42004.62 Kcal

iii) If radiation losses are taken as 20%  
Heat lost by radiation  
=  $0.2 \times 535500$  =                      107100 Kcal  
Total heat loss =                              162341.37 Kcal

IV. Net available heat =  $535500 - 162341.37 = 373158.63$  Kcal.

- V. When 300% excess air is supplied, 21.7 Kgs of combustion products are formed per kg of paper.

Therefore Total combustion products

$$\begin{aligned}
 &= 21.7 \times 127.5 \\
 &= 2766.75 \text{ kg} \\
 \text{water} &= 22.5 \text{ Kg.} \\
 \text{Total products} &= 2789.25 \text{ kg/hr.}
 \end{aligned}$$

- VI. Average gas temperature:

$$\begin{aligned}
 T &= \frac{Q}{CPM} = \frac{373158}{0.26 \times 2789.25} \\
 &= 514.4^\circ\text{C}
 \end{aligned}$$

$$\begin{aligned}
 \text{Therefore } T &= 514.4 + 20^\circ\text{C (ambient temp.)} \\
 &= 534.4^\circ\text{C}
 \end{aligned}$$

- VII. Combustion air requirement:

4.24 m<sup>3</sup> of air is needed to burn 1 kg of dry paper.

As 200% excess air has to be supplied,

$$\begin{aligned}
 \text{Air} &= 4.24 \times 2 \times 127.5 \\
 &= 1081.2 \text{ m}^3/\text{hr} = 18.02 \text{ m}^3/\text{mt.}
 \end{aligned}$$

- VIII. Airport requirement: at 2.55 mm water gage, the air velocity is 384.56 m/mt.

$$\begin{aligned}
 \text{Total} &= \frac{18.02 \times 10^4}{384.56} \\
 &= 468.58 \text{ cm}^2
 \end{aligned}$$

$$\text{Area of overfire air port} = 0.7 \times 468.58 = 326.18 \text{ cm}^2$$

$$\text{Area of underfire air port} = 0.1 \times 468.58 = 46.8 \text{ cm}^2$$

$$\text{Area of secondary air port} = 0.2 \times 468.58 = 93.6 \text{ cm}^2$$

- IX. Volume of products of combustion :

17.65 m<sup>3</sup> of products of combustion are formed from the combustion of 1 kg of paper with 300% excess air.

$$\text{Therefore } 17.65 \times 127.5 = 2251.3 \text{ m}^3/\text{hr.}$$

$$\text{Water} = \frac{22.5 \times 2.2}{35.3} \times \frac{379}{18} = 29.5 \text{ m}^3/\text{hr}$$

$$\begin{aligned}
 \text{Therefore Total} &= 2251.3 \times 29.5 \\
 &= 2280.8 \text{ m}^3/\text{hr}
 \end{aligned}$$

X. Volume of products of combustion through flame port.  
 = Total volume - volume of secondary air  
 = 2280.8 - 1001.2 × 0.2  
 = 2064.56 m<sup>3</sup>/hr.

XI. *Flame port area* : Assuming that temperature in flame port is 610°C and that velocity is 17.0 m/sec.

$$\text{Area} = \frac{2064.56}{3600 \times 17} \times 100 \times 100 \times \frac{883}{293} = 1016 \text{ cm}^2$$

XII. *Mixing chamber area* : Assuming the velocity as 7.5 m/sec and temp. in mixing chamber as 555°C,

$$\text{area} = \frac{2280.8}{60 \times 60 \times 7.5} \times \frac{828}{293} = 0.2387 \text{ m}^2$$

XIII. *Curtain wall port area*: Assuming velocity as 6.00 m/sec and temp. in curtain wall port as 525°C,

$$\text{Area} = \frac{2280.8}{60 \times 60 \times 6.00} \times \frac{798}{293} = 0.287 \text{ m}^2$$

XIV. *Combustion chamber area*: Assuming velocity to be 2 m/sec and the temp. in combustion as 500°C,

$$\text{Area} = \frac{2080.8}{60 \times 60 \times 2} \times \frac{773}{293} = 0.835 \text{ m}^2$$

XV. *Stack area*: Velocity should be less than 9 m/sec. Let it be 8 m/sec.,

$$\text{Therefore Area} = \frac{2280.8}{60 \times 60 \times 8} \times \frac{773}{293} = 0.21 \text{ m}^2$$

XVI. *Grate area*: The grate loading can be between 60-110 kg/m<sup>2</sup>/hr. If the average grate loading is taken as 80 kg/m<sup>2</sup>/hr,  
 Grate area = 150/80 = 1.875 m<sup>2</sup>

XVII. Average arch height = 0.9643 (Grate area)<sup>4/11</sup>  
 = 0.9643 (1.875)<sup>4/11</sup>  
 = 1.211 m



$$P = 0.09806 H P_a T_a \left( \frac{1}{T_a} - \frac{1}{T_g} \right)$$

$$P = 0.5 P_a = 1.134 \text{ kg/m}^3 \text{ at } 30^\circ\text{C and normal pressure}$$

$$T_a = 273 + 30 = 303$$

$$T_g = 500 + 273 = 773$$

$$0.5 = 0.09806 H \times 1.134 \times 303 \left( \frac{1}{303} - \frac{1}{773} \right)$$

Therefore  $H = 7.396$  metres

Say 7.4 metres.

### 11.12 Cost

The initial cost of an incinerator to burn 200 tpd of waste is likely to be in the range of Rs.10 to 20 million (US \$ 1.11 to 2.22 million), depending upon the degree of sophistication and equipment used. The running cost of these units will be about Rs.50/- per tonne (\$ 5.55 per tonne) excluding the cost of auxiliary fuel.

The incinerators, however, can be located in urban centres if proper air pollution control equipment is used. But the transport vehicles bringing refuse would be objectionable in the vicinity of hospital or school buildings. When other conditions are favourable saving in transportation cost will make this system competitive as compared to other methods.

#### A. Cost Analysis (at 1980 price level)

Incineration without heat utilisation to burn 200 tonnes/day of solid waste (300 days/year)

Civil works	=	Rs. $3 \times 10^6$
Mechanical equipment	=	Rs. $7 \times 10^6$
Total capital cost	=	Rs. $10 \times 10^6$ (US \$ $1.11 \times 10^6$ )
Furnace volume needed	=	$140 \text{ m}^3$
Land required	=	1.6 ha.

*Operating Cost*

Sr. No	Item	Details	Cost/tonne Rs.
1	Amortization	@ 8% cost of civil works and 10% of cost for mechanical equipment	15.5
2	Maintenance & repairs	@ 2% of cost of civil works and 5% of cost of mechanical equipment	6.83
3	Land	Land cost @ Rs.0.5 x 10 <sup>6</sup> /ha. Six per cent of this taken as operating cost	0.8
4	Electricity	@ 40 KWH/tonne, costing Rs 0.25/KWH	10.00
5	Water	@ 800 litres/tonne	0.20
6	Salaries	1 Manager, 2 Foremen, 4 Crane operators, 6 Mechanics, 3 Electricians, 3 Weighbridge attendants, 10 Labourers to be employed	3.42
7	Auxiliary fuel	To supply 500 Kcal/kg of refuse, furnace oil having calorific value of 9600 Kcal/Litre and costing Rs.2/litre to be used	104.3

Total cost/tonne = 141.03  
(US \$ 15.67)

In case, a self sustained combustion reaction is obtained, auxiliary fuel will not be needed and then the operating cost will be Rs 36/75 (US \$ 4.08). The net cost of incineration will also require consideration of saving in transportation cost when it is located within the city limits and the additional expenditure on maintenance of surrounding roads. Air pollution control equipment, if required, will add to the cost.

B. Incinerator with heat utilisation to burn 200 tonnes/day of solid wastes (300 days/year)

Cost of civil works = Rs.  $5 \times 10^6$

Mechanical equipment = Rs.  $15 \times 10^6$

Capital cost = Rs.  $20 \times 10^6$

Land required = 2 ha

Plant will work 300 days/year

Operating cost :

*Operating Cost :*

Sr No	Item	Details	Cost/tonne Rs
1	Amortization	@ 8% of cost of civil works and 10% of cost of mechanical equipment	31.66
2	Maintenance and repairs	@ 2% of cost of civil works and 5% of cost of mechanical equipment	14.16
3	Land	Land cost @ Rs $0.5 \times 10^6$ /ha. Six per cent on this to be taken as operating cost	1.0
4	Electricity	@ 40 KWH/tonne. To be taken from power generated by the plant	-
5	Water	@ 2000 litres/tonne	0.50
6	Salaries	1 Manager, 6 Shift engineers, 4 each foremen & crane operators, 3 weighbridge attendants and 12 each of mechanics, electricians & labourers	7.72
7	Auxiliary fuel	To supply 500 Kcal/kg of refuse. Furnace oil having a calorific values of 9600 Kcal/litre & costing Rs 2/litre to be used.	104.30

Total cost/tonne = 159.34

(US \$ 17.15)

If the refuse characteristics are such as to give a self sustained combustion reaction, auxiliary fuel will not be required. In such a case, operating cost will be Rs 55/04 per tonne (US \$ 6.11). Air pollution control equipment, if required, will add to the cost.

#### *Less*

The net cost of incineration will be obtained after deduction of

- 1) returns from sale of  $(2.3 - 0.8) = 1.5$  mw of power generated;
- 2) savings in transportation cost when it is located within city limit after deduction of additional expenditure needed for maintenance of surrounding roads; and
- 3) returns from sale of clinker and flyash.

### **11.13 Incineration Vis-a-Vis Other Methods**

Incineration should be considered after a complete economic and environmental impact analysis in comparison with other processing methods which will depend upon local conditions.

#### *Merits*

- i) The residue from the process is low (about 10-15%) which comprises of flyash and clinker.
- ii) Land requirement is low.
- iii) Location within city limits reduces transportation cost.
- iv) Modern incinerators can burn any type of refuse as long as it has the desired calorific value.
- v) The process as well as residues are acceptable from sanitary considerations.

#### *Demerits*

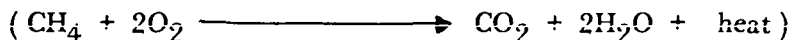
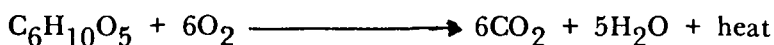
- i) The capital and operating costs are high.
- ii) In densely built urban areas, it may add to air pollution problems.
- iii) Skilled personnel will be required.

## CHAPTER 12

### PROCESSING METHODS FOR THE FUTURE

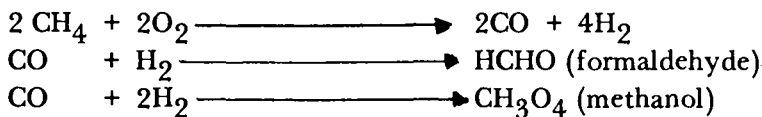
#### 12.1 Pyrolysis

Pyrolysis is an irreversible chemical change brought about by the action of heat in an atmosphere devoid of oxygen. Synonymous terms are thermal decomposition, destructive distillation and carbonisation. In partial combustion, oxygen is present in insufficient quantities to cause complete combustion (i.e., less than SOR). Normal combustion, as in conventional incineration requires the presence of sufficient amount of oxygen which will ensure complete oxidation of organic matter. Using cellulose ( $C_6H_{10}O_5$ ) to represent organic matter, the reaction is



In order to ensure complete combustion and to remove the heat produced during the reaction, excess air is supplied which leads to air pollution problems.

In the case of partial combustion, the reaction would be



Thus even the simplest of hydrocarbons will yield a variety of products under conditions of partial combustion. As the complexity of fuel increase the variety of possible products also increases. Pyrolysis, unlike incineration is an endothermic reaction and heat must be applied to the waste to distil off volatile components.

When the waste is predominantly cellulose under slow heating at a moderate temperature, the destruction of bonds is selective (the weakest breaking first) and the products are primarily a non-combustible gas and a

non-reactive char. On the other hand, when the waste is rapidly heated to a high temperature, complete destruction of the molecule is likely to take place. Under intermediate conditions, the system would yield more liquid of complex chemical composition. Normally these two processes are referred to as *low temperature and high temperature pyrolysis* respectively. Pyrolysis is carried out at temperatures between 500 and 1000°C to produce three component streams.

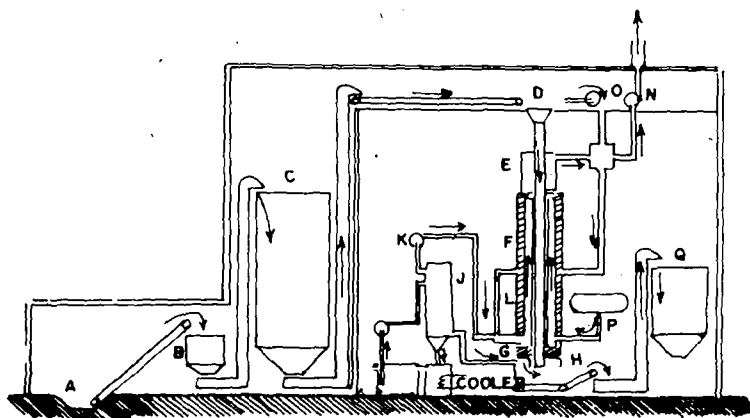
- i) *Gas* : It is a mixture of combustible gases such as hydrogen, carbon monoxide, methane, carbon dioxide and some hydrocarbons.
- ii) *Liquid* : It contains tar, pitch, light oil and low boiling organic chemicals like acetic acid, acetone, methanol, etc.
- iii) *Char* : It consists of elemental carbon along with the inert materials in the waste feed.

The char, liquids and gas have a large calorific value. This calorific value should be utilised by combustion. Part of this heat obtained by combustion of either char or gas is often used as process heat for the endothermic pyrolysis reaction. It has been observed that even after supplying the heat necessary for pyrolysis, certain amount of excess heat still remains which can be commercially exploited. Though a number of investigations have been made, only a few have led to full scale plants.

### 12.1.1 *Destrugas System*

It is high temperature pyrolysis process (1000°C) in which mainly fuel gas is obtained. Raw solid waste is first subjected to size reduction in an enclosed shed. The air from this shed is taken up as intake air in the plant so as to avoid odour problems (Fig.12.1.1.1). The crushed refuse is fed to the retorts through which it sinks under gravity. The retort is heated indirectly by burning the gas in a chamber enveloping it. The produced gas is washed and partly (85%) used for heating (heat value = 220 Kcal/kg of refuse input) in the burners and the remaining 15% is sold<sup>(64)</sup>. The slag mostly consists of char and some glass as well as the metals are salvaged earlier (Table 12.1.1.2).

It is indicated that 5 tonnes per day retort size is the optimum. In a typical installation, a battery of six such retorts of 5 tonnes/day could be provided for 30 tonnes per day. A number of such batteries would normally be provided to give the required capacity of the plant.



- A RECEIVING PIT      E PREHEATER      J SCRUBBER      N SUCTION APPARATUS FOR HOT GAS  
 B DISINTEGRATOR      F RETORT      K GAS PUMP      O COMPRESSOR  
 C SILO      G GAS OUTLET FROM RETORT      L GAS BURNERS      P GAS TANK FOR START-UP  
 D CHARGING      H SLAG CONVEYOR      M HEAT EXCHANGER      Q SLAG SLO

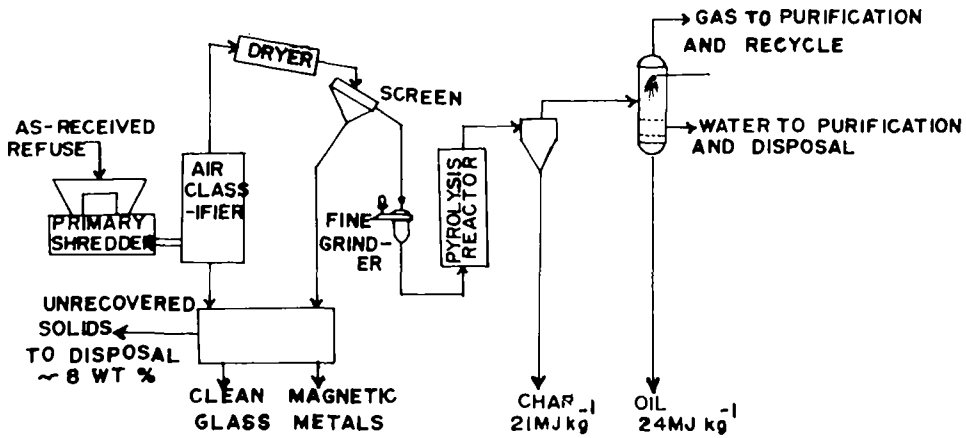
### 12.1.1.1 Kalundborg process

Table 12.1.1.2 : Mass Balance for Destrugas Process<sup>(64)</sup>

Input	Output
1.000 kg refuse	0.285 kg dry slag
	0.285 kg water
	0.350 kg (0.5 m <sup>3</sup> ) gas
	0.040 kg scrap
	0.040 kg losses
Total 1.000 kg	1.000 kg

### 12.1.2 Garretts Flash Pyrolysis Process

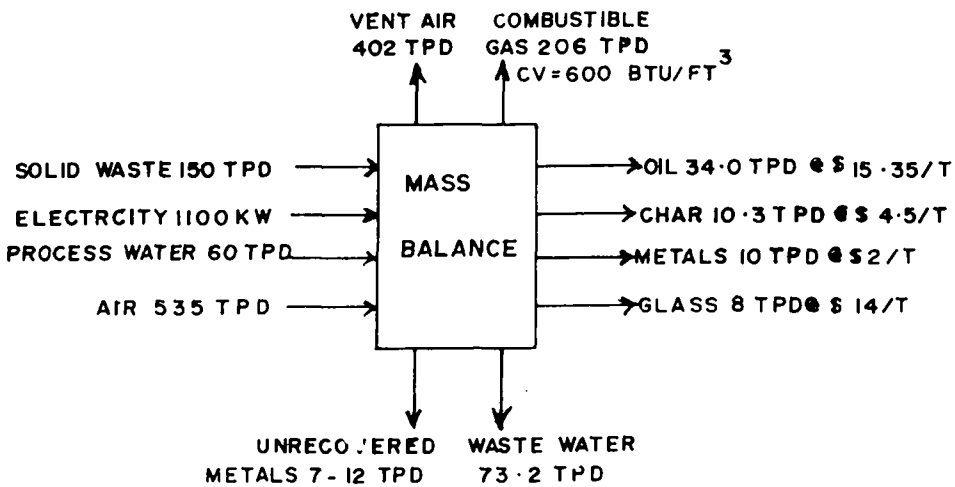
This low temperature pyrolysis process yields fuel oil. Garrett Research and Development Company has been operating a 4 tonne per day pyrolysis plant at La Varne, California<sup>(56)</sup>. In this plant refuse is initially coarse shredded to less than 50 mm size, air classified to separate organics and dried in an air drier. The organic portion is then screened, passed through a hammer mill to reduce the particle size to less than 3 mm and then pyrolysed in a reactor at atmospheric pressure. The proprietary heat exchange system enables pyrolytic conversion of the solid waste to a viscous oil at 500°C. Fig. 12.1.2.1 indicates the oil recovery system and the method of separating glass and



12.1.2.1 Garrett process

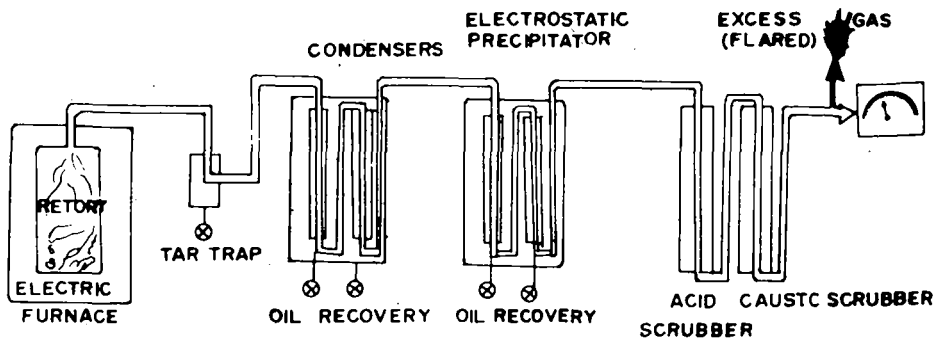
Table 12.1.2.3 : Energy Calculations

Energy input/tonne of refuse	=	135 KWH + 2.26 kgs of oil + 56 kgs of fuel gas
	=	725356 Kcal
Energy output	=	136 litres of oil
	=	1033452 Kcal
Net gain	=	1033452 - 725356
	=	308096 Kcal
% gain	=	$\frac{308096}{725356} = 42.47\%$



12.1.2.2 Mass balance-Garrett process





12.1.3.1 Bureau of Mines Pyrolysis unit

Table 12.1.3.2 : Mass Balance of Bureau of Mines Process<sup>(51)</sup>

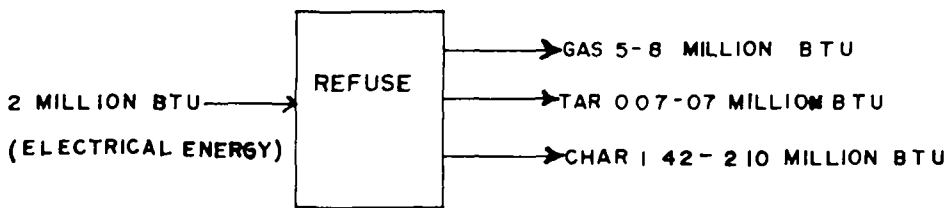
Input	Output
1 tonne of refuse	Char : 70 - 100 kg
	Tar + pitch : 2 - 20 litres
	Light oil : 6 litres
	Liquor : 160 - 260 litres
	Ammonium sulphate : 9 - 11 kg
	Gas : 300 - 500 m <sup>3</sup>

metal from the inorganics. Fig.12.1.2.2 gives the mass balance and Table 12.1.2.3 the energy calculations.

The manufacturers indicate that for U.S. conditions a 2000 tonnes per day plant is expected to show profit.

### 12.1.3 Energy Research Centre of Bureau of Mines, Pittsburg

It is a proprietary high temperature pyrolysis process which has been investigated mainly on laboratory scale<sup>(51)</sup>. The waste charge is heated in a furnace with nickel chromium resistors to the desired temperature. The produced gases are cooled in an air trap where tar and heavy oil condense out. Uncondensed vapours pass through a series of water cooled condensers where additional oil and aqueous liquors are condensed. The gases are then scrubbed in an electrostatic precipitator before further use. The arrangement of units is shown in Fig.12.1.3.1. It is claimed that one tonne of dried refuse produces 300 - 500 m<sup>3</sup> of gas (Table 12.1.3.2 and Fig. 12.1.3.3) but the process has yet to be tested on full scale.



### 12.1.3.3 Energy Balance - Bureau of Mines process

In all the above processes, a net gain in energy occurs, besides ensuring proper destruction of the solid waste. Being a closed system, air pollution problems are not encountered. The products are easy to store and handle and hence this process is being increasingly favoured in place of incineration.

Studies to assess the feasibility of adopting the process for a specific office waste in India have been undertaken at NEERI and a process outlined. It will have a potential use for such specific waste which have a higher paper content.

## 12.2 Biogas from Solid Wastes

When solid wastes with a large proportion of organic matter is subjected to anaerobic decomposition a gaseous mixture ( $\text{CH}_4$  &  $\text{CO}_2$ ) known as biogas could be produced under favourable conditions. Extensive laboratory and small scale field studies<sup>(63)</sup> have been undertaken at NEERI which have yielded interesting results. The organic fraction of refuse (OFR) can be subjected to anaerobic decomposition to yield biogas. The process is quite stable and upsets do not easily occur. The gas production ranges from  $0.29 \text{ m}^3/\text{kg}$  of VS added/day to  $0.13 \text{ m}^3/\text{kg}$  of VS added/day in different seasons. (Table 12.2.1). The pH of the digesting mixture remains around  $6.8 \pm 0.20$ . The volatile solids destruction ranges from 40 to 55%. The sludge has good manurial value (NPK :: 1.6 : 0.85 : 0.93) and was observed to drain easily. The process was found to give a good performance with a detention time of 25 days. Preliminary tests show promise for its adoption in developing countries but further pilot plant studies will be required to assess :

- i) size to which the refuse particles need to be shredded;
- ii) method of mixing digester contents; and
- iii) method of mixing and separating organics from the original refuse mass.

## 12.3 Treatment for Recovery of Useful Products

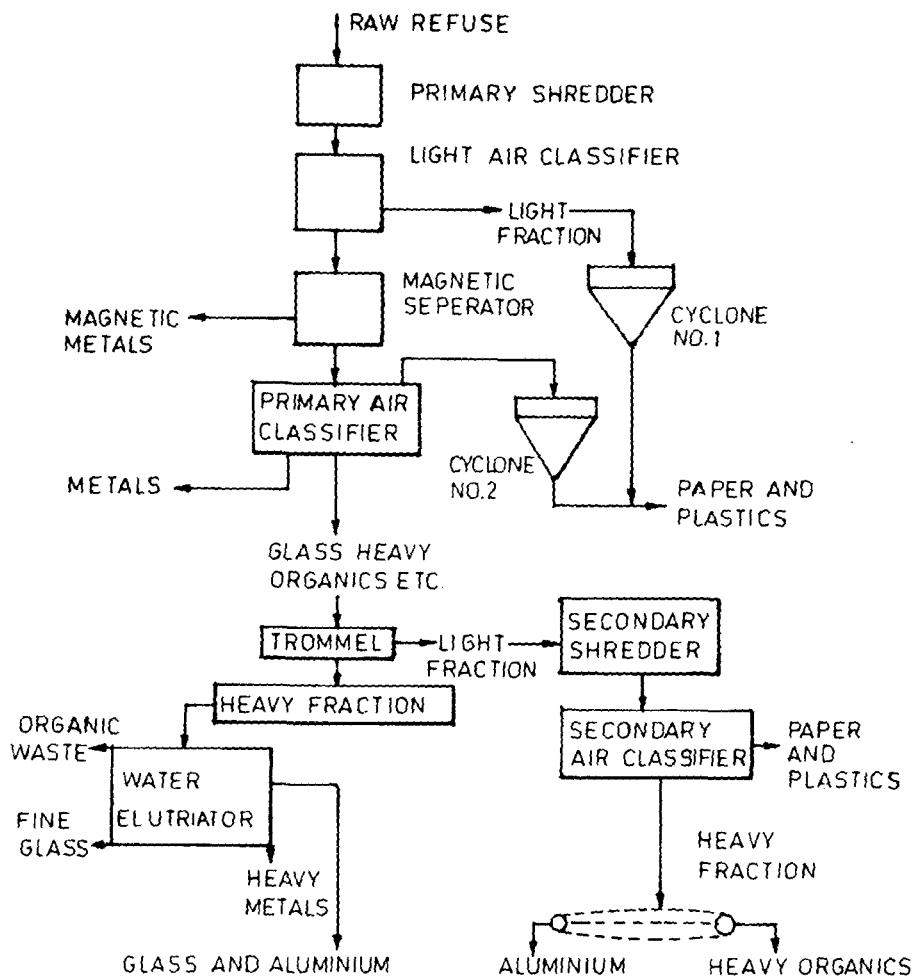
Refuse is a heterogenous mixture which contains various ingredients, some of which have a large resale/reuse potential. Refuse in developed countries

*Table 12.2.1: Biogas Produced and Volatile Solids Destruction in different Months in a Field Unit*

Month	Gas produced m <sup>3</sup> /kg VS added/day	%reduction in VS
November	0.110	43.5
December	0.100	40.2
January	0.125	43.5
February	0.130	44.8
March	0.250	50.0
April	0.305	54.5
May	0.330	56.2
June	0.275	53.4
July	0.150	48.0
August	0.150	47.3
September	0.150	46.7
October	0.165	48.7

contains glass and ferrous as well as non-ferrous metals in large proportion. The energy required and the pollution caused to obtain a product from virgin material is more than that required for obtaining it from secondary sources as from refuse. Hence research efforts have been concentrated in this area. In India much of the useful constituents seldom reach the waste stream, though in industrial and commercial areas and in high income group areas such conditions may be encountered. The pattern is similar in other developing countries. Before any reusable components can be removed from refuse, size reduction is necessary to make it amenable for handling. It can then be subjected to either incineration and pyrolysis followed by separation of useable constituents from the processed waste or to a detailed physical separation process.

Residue after incineration is smaller in volume, relatively pollution free and innocuous. However, it alters the form of many constituents which cannot be easily reused. Glass tends to melt to an intractable, contaminated lump. Most of the plastics burn away and some of them (like PVC) while burning release halides resulting in chemical reactions that impair metal recovery. Metals may melt, get oxidised or converted to halide compounds and get lost in the gaseous effluents. Thus the recovered metals from incinerator residue will not be of very good quality. During pyrolysis, on the other hand, oxidation of metal components does not occur. The final pro-



12.3.1 Raw refuse separation flowsheet

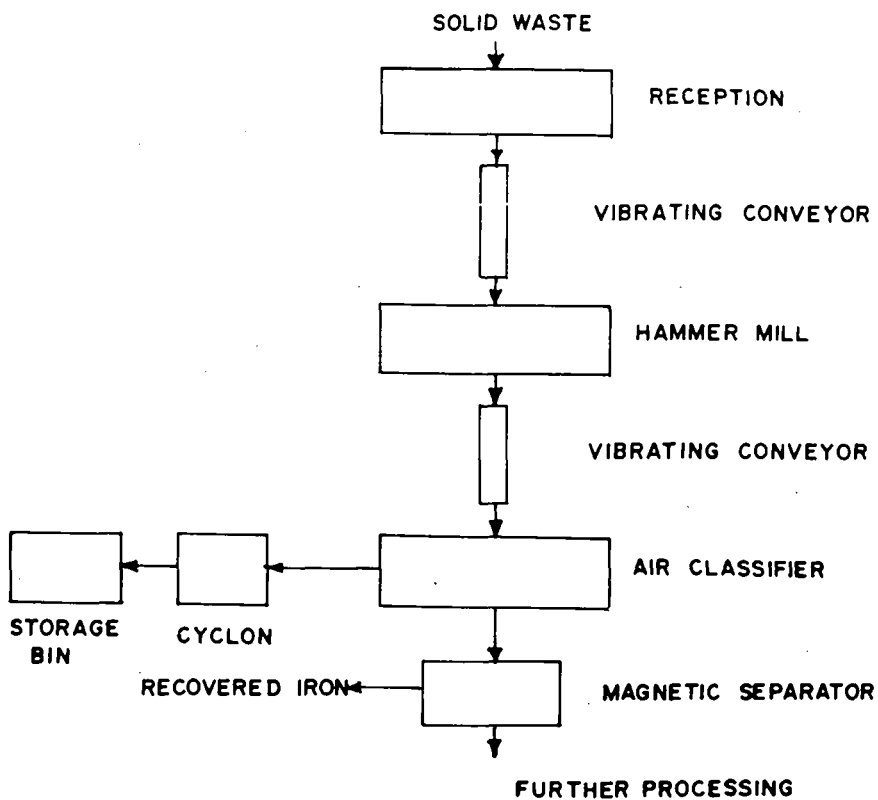
duct is in the form of a friable char which unlike incinerator residue does not require crushing to release values.

Shredded raw refuse can also be regarded as a multivaluable ore and treated by mineral engineering methods into products which can serve as a potentially useful material. A number of organisations have come forward with flow sheets for recovery of various ingredients like glass, metals, etc. such as the one by U.S. Bureau of Mines<sup>(76)</sup> (Fig.12.3.1). In this process, the material is initially subjected to coarse shredding in a machine which breaks plastic and paper bags and boxes without damaging metal objects. Glass is broken into pieces but not in fines. The material then passes under a magnetic separator where it is subjected to a vertical air classifier when the heavy objects fall through the vertical air stream while the lighter objects (paper, plastics, etc.) are carried away to a cyclone separator. The

heavier particles are passed through a trommel screen of 57 mm (2.25") size. The fines are subjected to elutriation by water which helps separate glass from organic waste containing soil and glass. Oversize is processed by an optical color sorter into white and colored glass and oversize from the trommel is subjected to further shredding to 25-75 mm (1-3") followed by secondary air classification and water elutriation. Light material (paper and plastics) from the secondary cyclone is separated by the use of high tension electro-dynamic technique when paper is drawn to the electrode while plastic sticks to the drum and gets separated. The heavies from the secondary water elutriator mainly comprise of organic wastes and metallic aluminium. A similar flow-sheet has been developed by Warren Springs Laboratory, UK.

#### 12.4 Refuse Derived Fuel

As the solid waste from developed countries contains a large paper fraction, it was felt that it could be used as a good fuel. In 1972, a plant was set up in St. Louis<sup>(55)</sup>, USA wherein a refuse quantity of 295 tonnes was to be



12.4.1 Flowsheet of plant for production of RDF at St. Louis

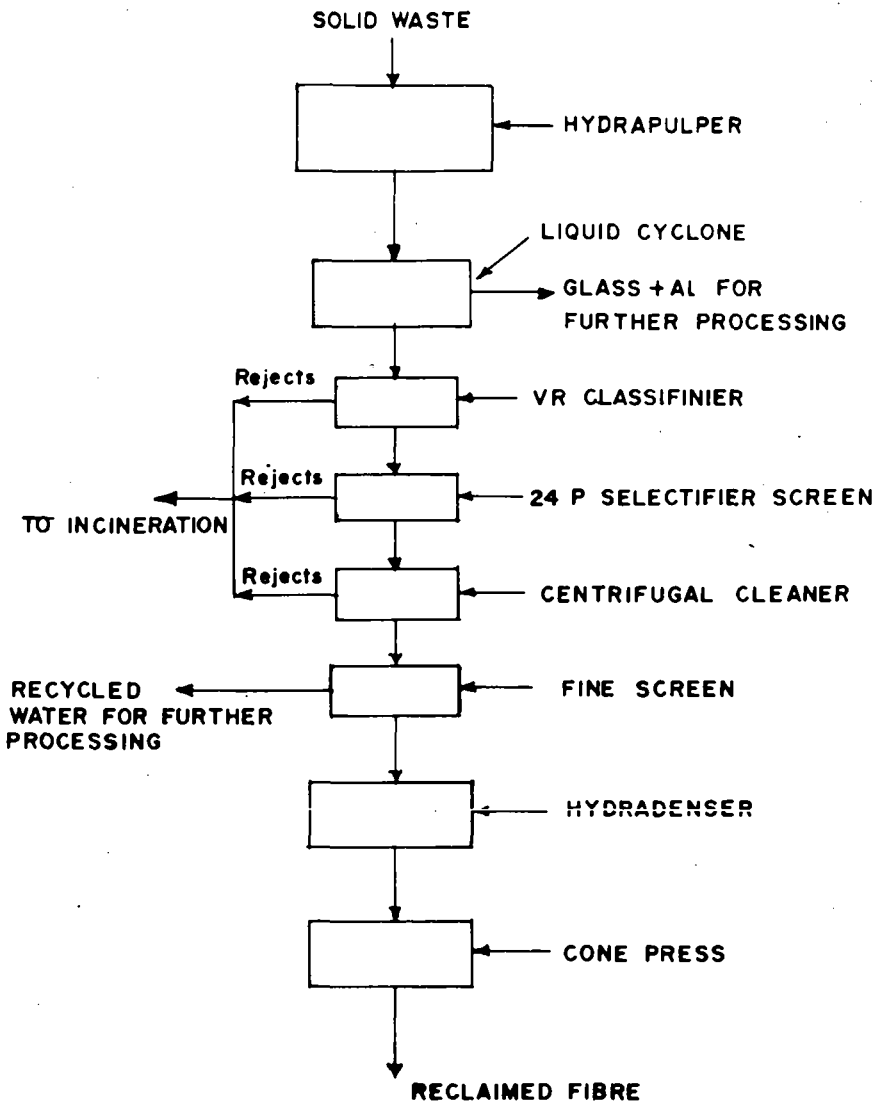
processed every 8 hours. In the plant the incoming refuse is first subjected to size reduction after which the magnetic metals are removed by a magnetic separator. The remaining material is then passed through a vertical flow air separator where paper is removed (Fig.12.4.1). The material is further subjected to size reduction and burnt in a boiler of a 125 MW plant. The suspension fired boilers are provided with clusters of 5 jets, 4 out of which use coal and the fifth uses refuse derived fuel (RDF). The sulphur content of refuse is much less (0.2 - 0.3%) as compared to (2 - 3%) in coal and no problems have been encountered upto now in its operation. Due to the encouraging performance of this plant, RDF is being used at a number of other thermal power plants also. This method, besides reducing the sulphurous emissions, ensures a ready market for the energy produced. Also minor fluctuations in calorific value of refuse do not cause problems in the operation of the plant as coal is being simultaneously used. Thus the problems faced in using refuse alone for incineration with power generation are avoided.

### 12.5 Conversion of Solid Wastes to Protein

Laboratory investigations<sup>(19)</sup> conducted at Louisiana State University, USA showed that under aerobic conditions, it is possible to convert the insoluble cellulose contained in municipal waste by a cellulolytic bacteria. The bacteria are then harvested from the media for use as protein. Studies were conducted using waste bagasse as the sole carbon source. The process involves size reduction followed by a mild alkaline oxidation treatment before aerobic oxidation. The bagasse is slurried in water, mixed with simple nutrient salts mixture and then fed to the reactor from where it is harvested. The single cell protein produced has a crude protein content of 50 to 60%. It has a good amino acid pattern and has been successfully tested on animals. The process has yet to be tested on a full scale basis, but shows promise, especially due to its high efficiency of protein production. It has been shown that a 450 kg bullock can synthesise 0.4 kg of protein in every 24 hrs; whereas 450 kg of soyabean synthesises 36 kgs of protein in 24 hrs and 450 kg of yeast can synthesise more than 50 tonnes of protein in 24 hrs.

### 12.6 Other Methods

Due to high paper content in the waste from developed countries, a method has been developed to hydropulp the waste and recover paper fibre from refuse. The method is being used in a full scale plant of 150 tpd capacity operating at Franklin, Ohio (Fig.12.6.1).



12.6.1 Flowsheet of Black Clawson plant for fibre recovery

## CHAPTER 13

### DISPOSAL ON LAND

#### 13.1 Introduction

Disposal of solid wastes by dumping in low-lying areas has been practised since early times. Such sites often do not have any proper system of operation and are found to attract a large number of ragpickers, who during their search for reclaimable materials spread the waste around spoiling the appearance of the site. As proper controls are not exercised hot ashes and combustible wastes are often dumped at such sites causing fire and smoke problems. The decomposable wastes are exposed leading to rodent and fly nuisance. Paper tends to spread around and litters the landscape, which becomes aesthetically objectionable and hygienically undesirable. Further, the decomposition causes a lot of nuisance and the site cannot be put to suitable use early. Such sites are often located in low-lying areas where they tend to pollute surface and ground waters. The method was systematised and mechanised in USA during 1930's and termed as 'Sanitary Landfilling' to overcome the various defects encountered.

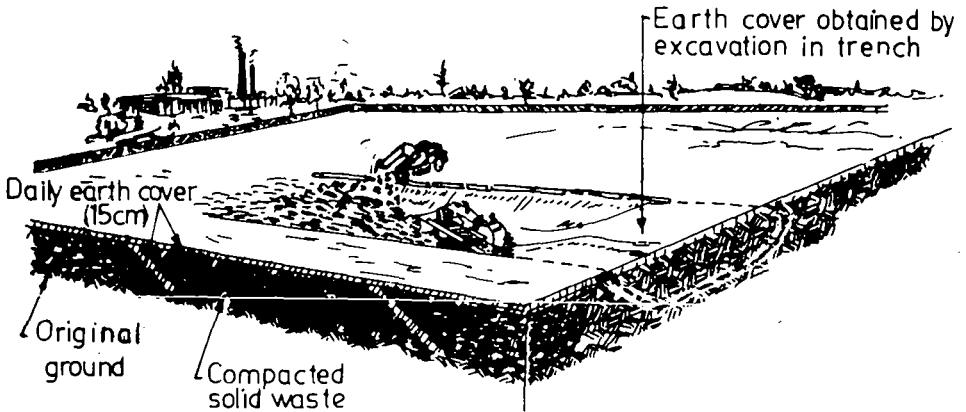
Sanitary landfilling has been defined<sup>(20)</sup> as a "method of disposing of refuse on land without creating nuisance or hazards to public health or safety, by utilising the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary". Thus the method essentially consists of laying the material systematically followed by its compaction to smallest practical volume with least exposed area and then covering it with soil. As it is compacted, further decrease in volume will not be very large. As the exposed surface area will be the smallest the amount of soil cover needed will be small which is an important consideration, especially when the soil cover has to be brought from outside. Covering of the waste with soil or other inorganic material makes it inaccessible to flies and rodents and the heat released during decomposition is conserved, increasing the chances of destruction of fly larva and pathogenic organisms.



## 13.2 Types

Sanitary landfilling can be practised for all types of site conditions. To suit different site conditions, the basic process is modified in 3 distinct ways which are known as i) trench method, ii) area method and iii) ramp method.

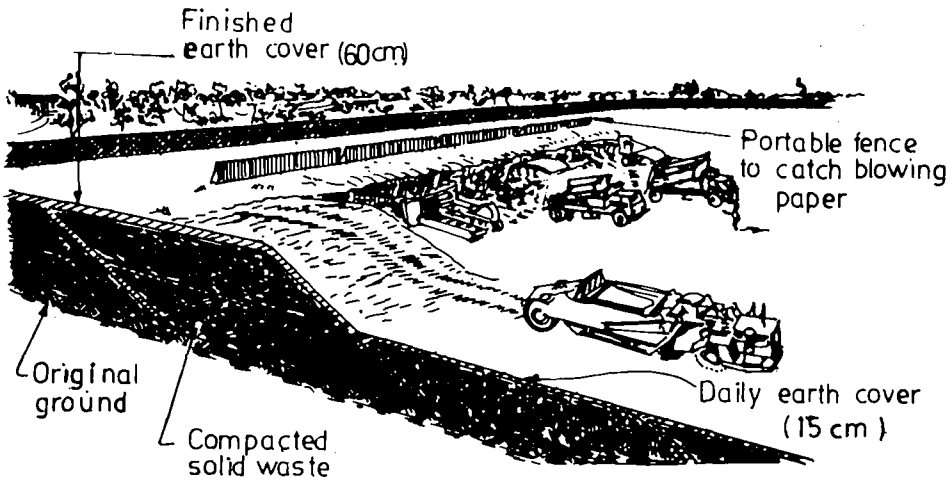
i) *Trench Method:* This method is best suited for flat land where excavation can be carried out easily and where the ground water table is sufficiently low. A trench - 2 m deep and 2 to 5 m wide (i.e., 1 to 2.5 times the width of a tractor which permits easy movement across the trench) is cut. The length of the trench depends on site conditions, number of trucks likely to arrive simultaneously and is such that it takes a day's refuse quantity. The excavated soil is placed on the sides of the trench and after the refuse has been put in layers and compacted and the trench filled, is used to give the soil cover (Fig.13.2.1).



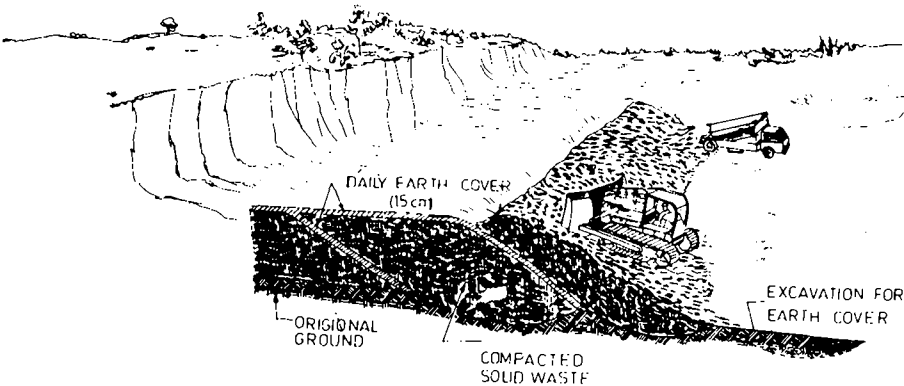
13.2.1 Trench method

ii) *Area Method:* This method is best used in areas where natural depressions exist as in quarries, ravines and valleys. The waste is put in the natural depressions and compacted. A layer of earth is given on top and compacted. The process is repeated till the depression is filled up (Fig. 13.2.2). The earth cover has to be excavated from borrow-pits at the site itself or imported from elsewhere.

iii) *Ramp Method:* This is a modified form of area and trench method and used in flat as well as gently rolling areas. A ramp about 15 metres wide, 30 m long and of a suitable height is created. By using a bullclam or similar equipment, a shallow cut is taken at the foot of the ramp. A valley like trench is cut so that the tractor can operate transversely across its width for ease in manouvability. Trucks come to the top of the ramp and discharge their contents inside the trench. Due to the size of the ramp, a



13.2.2 Area method

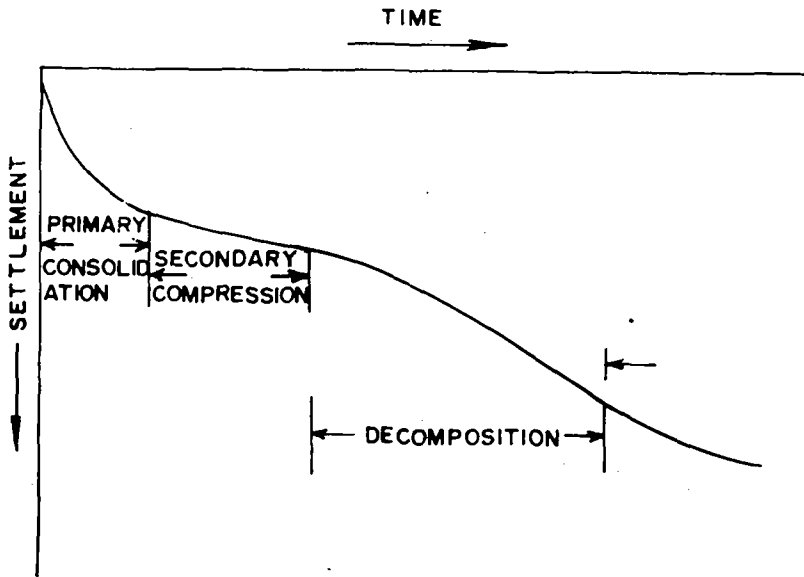


13.2.3 Ramp method

number of trucks are able to dump their contents simultaneously inside the trench. At the end of the operation, the refuse is compacted by the tractor which also pushes earth on it and compacts it. Thus it becomes a part of the ramp on the top of which vehicles can operate on the next day (Fig. 13.2.3).

### 13.3 Thickness of Fill

The thickness to which a layer can be laid and compacted before giving the soil cover depends mainly on the ease of operation of mechanical equipment. Also as the newly laid layers are not completely consolidated the risk increases with the thickness of layer. The thickness of layer is hence restricted to 2 m.



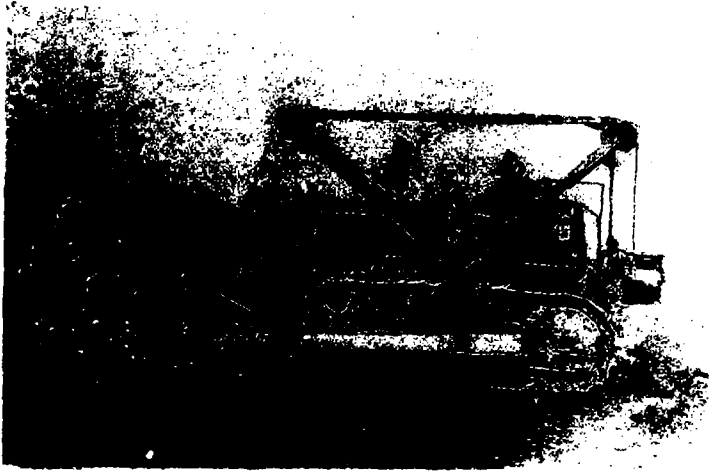
13.4.1 Settlement curve for a refuse mass

### 13.4 Compaction and Settlement

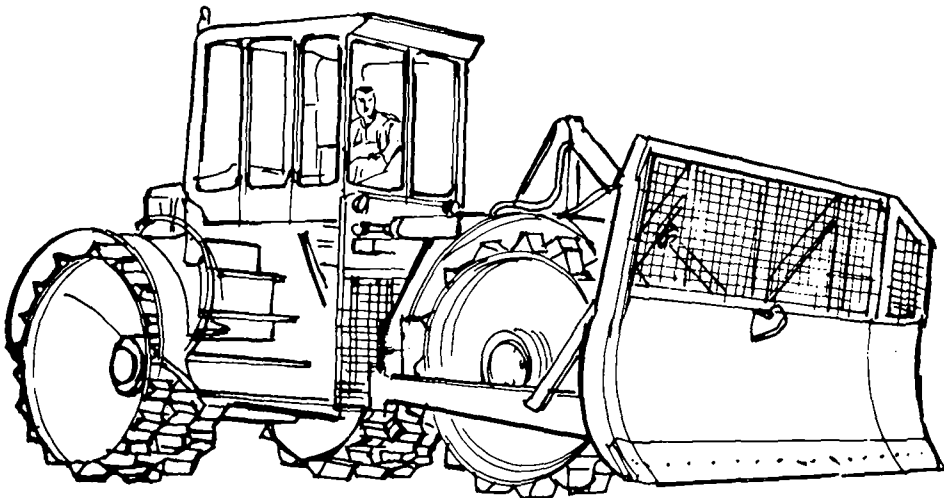
The total settlement consists of i) primary consolidation, ii) secondary compression and creep, and iii) decomposition. In the first stage, a large proportion of total settlement occurs in a short duration and is also known as 'short term shear deformation'. This stage extends upto the point where the curve changes its trend (Fig.13.4.1). The second stage proceeds slowly and the factors affecting it are the same as in the first stage. As the organic matter after decomposition is converted to stable end-products, resultant increase in density is reflected by further settlement as shown in the third stage. Out of the 3 stages, the second and third stages are slow and cannot be mechanically hastened. Primary consolidation depends on weight, composition and arrangement of particles, depth of fill and moisture penetration. Out of these factors, for a given case, only unit weight of fill material can be changed. This increase is achieved by using heavy equipment which due to large static compactive force and dynamic forces (impact causes fragmentation and vibration causes rearranging of particles) results in better arrangement of particles and voids to give a higher density<sup>(9)</sup>.

### 13.5 Mechanical Equipment

The mechanical equipment needed at such sites serves following purposes: i) Levelling of waste, ii) Compaction, and iii) Excavation and conveyance of soil for cover. The normal practice is to use 2 sets of equipment, one of



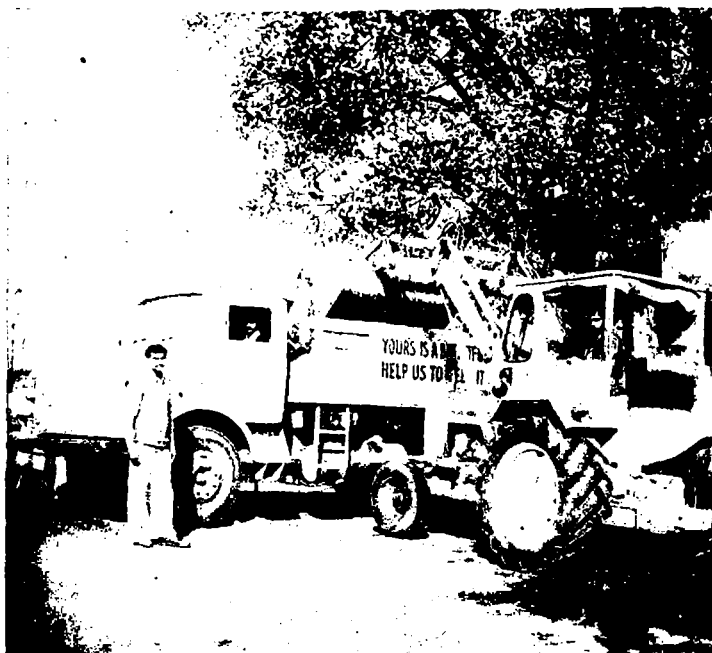
13.5.1 *Bulldozer at landfill site*



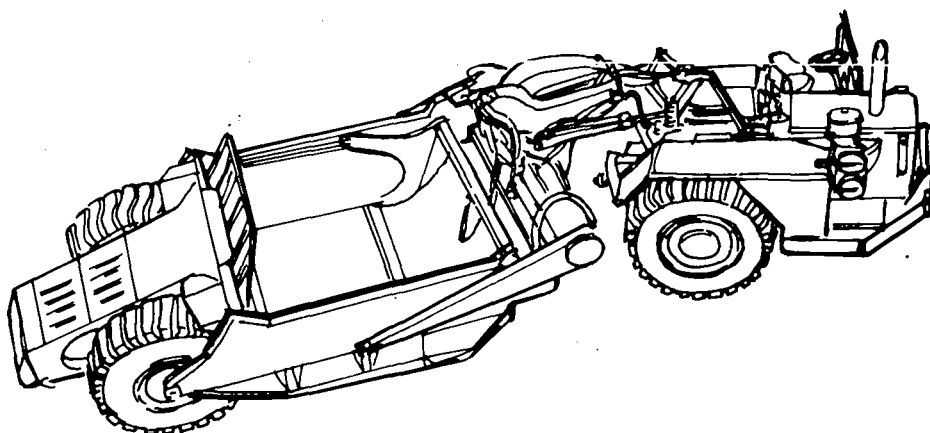
13.5.2 *Steel wheeled compactor*

which performs two functions. A track type bulldozer of the low ground pressure type can level the material as well as provide compaction (Fig. 13.5.1). Due to its slow speed, it can operate economically over short distances upto 100 metres. A caterpillar D4 type bulldozer can handle about 200 tonnes of refuse in 8 hours operation. The useful life of such an equipment is about 10,000 working hours. It is desirable to use landfill blade on such bulldozers. The track type unit distributes its load over larger area and hence is more stable than a wheel type unit (Fig.13.5.2).

Front end loaders (Fig.13.5.3) which have a hydraulically operated bucket of 0.5 - 3 cum. capacity can be used for levelling of deposited solid



*13.5.3 Front end loader*



*13.5.4 Scraper*

waste and also for transferring soil from borrow pit to the working face. When provided with wheels it can travel over longer distances but the wheels are likely to get punctured often unless provided with a protective steel device.

The scraper (Fig.13.5.4) can be self propelled or towed by a tractor and has a cutting edge which removes a thin soil layer which is stored in its body. Storage capacity of scrapers manufactured in India ranges between

10 to 12 cum. Their economical range of operation is upto 300 m. Drag-line consists of a track mounted unit which is kept stationary and by a cable operated bucket carried on a boom, the material is excavated, lifted and transported to another location within the radius of operation of the boom.

### 13.6 Units Needed

In the case of smaller capacities a wheel type front end loader can alone serve the job as it can excavate light soil, transport it, push solid waste and compact it. Obviously it cannot give the same efficiency as that of specialised equipment, but can give a reasonably satisfactory performance. In larger sites a bulldozer will be required for short distance pushing, grading and compaction. For providing soil cover, a scraper or dragline or a front end loader will be needed depending upon site conditions.

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Table 13.6.1: *Equipment Needed (8 hrs operation) for different Population Ranges*

Population range	Bulldozer D <sub>4</sub> type	Scraper (10-12 cu.m.)
< 0.5 million	1	1
0.5 to 1.0 million	2	2
1 to 2 million	4	4

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### 13.7 Densities in Landfills

As a result of natural and artificial rearrangement of particles the densities of landfill sites increase. The final 'insitu' densities that can be attained depend on the characteristics of the solid waste. In USA, the 'in situ' densities have been reported to be in the range of 475 - 600 kg/m<sup>3</sup>, while in UK, values upto 700 kg/m<sup>3</sup> have been reported. On the other hand, NEERI found, during their studies in Calcutta, that the original densities of 518-573 kg/m<sup>3</sup> increased to 1128 kg/m<sup>3</sup> within six months without the use of any artificial compaction equipment<sup>(24)</sup>. The increase was due to natural rearrangement and subsidence and due to movement of vehicle over the site.

The 'in situ' densities can be measured by various methods such as Auger method, Backhoe method, etc. The *Backhoe method* is quite simple and consists of excavating a sufficiently large trench (say 1m x 1m x 1m),

Table 13.7.1: Increase in Densities of Indian City Refuse<sup>(24,26)</sup>

Density/site	Belgachia,Howrah	Kadapra,Calcutta	Dhapa, Calcutta
Original density	671 kg/m <sup>3</sup>	518-573 kg/m <sup>3</sup>	518-573 kg/m <sup>3</sup>
Ave.density after 4-6 months	1527 kg/m <sup>3</sup>	1117 kg/m <sup>3</sup>	1137 kg/m <sup>3</sup>

weighing all the waste removed and measuring exact volume of excavation to get the density value. As compared to the *Auger method* in which a core of the material is removed and weighed, this method enables visual observation of the excavation. Also as the excavation is quite large as compared to that of Auger, boundary effects due to rough sides and loosened material on sides can be neglected. It is desirable to measure the density values at a number of sites and adopt the mean value.

### 13.8 Manual Method

As the literature in this field is mainly based on western experience, where mechanisation is preferred, it appears that mechanisation is essential for sanitary landfilling. Mechanisation was preferred in developed countries because:

- i) the bulky wastes containing furniture, boxes, had to be broken down for more orderly placement;
- ii) the initial low density would have required too large a volume;
- iii) high wage rate and low cost of mechanisation; and
- iv) excavation of soil for earth cover can be easily done, using mechanical equipment.

NEERI observed that bulky wastes such as furniture, etc. are absent in Indian solid wastes, which will be true in other developing countries as well. The initial density of city refuse in these countries is observed to be in the range of 300-600 kg/m<sup>3</sup> as compared to 125-200 kg/m<sup>3</sup> in developed countries. The use of manual labour should prove economical, provided health safeguards are ensured. Further, the 'in situ' density of waste in landfill sites in India which did not use any mechanical equipment was quite high and was in fact higher than that observed at landfill sites using mechanical equipment in developed countries (Ref.Art.13.7). Manual operation can reduce the cost and yet provide satisfactory results. For manual landfilling the following steps are suggested:

- i) Selection of site should be made using the same criteria as for mechanised method.

- ii) Provide an all weather access road from existing main road to the point at which filling is to commence. Such a road can be prepared from the construction and demolition waste, ash, clinker and a small stock of this material should be kept for day-to-day repairs.
- iii) To help guide vehicles to the spot, provide flags or pegs on the location. To indicate height to which filling has to be done, 'sight rails' should be provided.
- iv) The filling should start from a point nearest to road with vehicles approaching the point after reversing. Tipping vehicles can unload faster and assure a quicker out-turn. The dumped material can be spread and levelled manually using rakes having a number of teeth. By using ramp method, the filling will move progressively inside the site.
- v) To indicate the point where vehicle should stop for unloading, a strong heavy wooden bumper bar can be provided.
- vi) To avoid the rear wheels of vehicles from sinking in the newly deposited mass, cover the area near working face with steel or wooden sleepers.
- vii) Cover the waste at the end of a day's operation.

This method would need about 50-60 workers/million population with a minimum requirement of 2 persons.

### 13.9 Selection of site

While selecting a site, a number of points need be considered:

i) *Land Requirement:* The volume of fill required depends upon density, degree of compaction, depth of fill and life for which the site is to be used. The volume required will change in different cases. At a waste generation rate of 0.33 kg/capita/day and final 'in situ' density of 1000 kg/m<sup>3</sup>, about 150,000 m<sup>3</sup> will be needed per million population for one year's operation.

ii) *Land Use Restrictions:* The town planning authorities should be consulted before selecting a particular site so that it is compatible with their plans.

iii) *Approach:* The site should be easily accessible for vehicles throughout the year. It is desirable that narrow bridges, steep grades and roads that are likely to be submerged during some periods are avoided. Such sites receive additional loads from other processing and disposal site (which may not be working) in which case alternate approach roads will



be needed. Such sites should not be too close to residential and commercial localities.

iv) *Haul Distance:* Provided all the other conditions are satisfied, the site should be as near the area to be served as possible. Larger the haul distance to the site, the larger will be the recurring transportation cost.

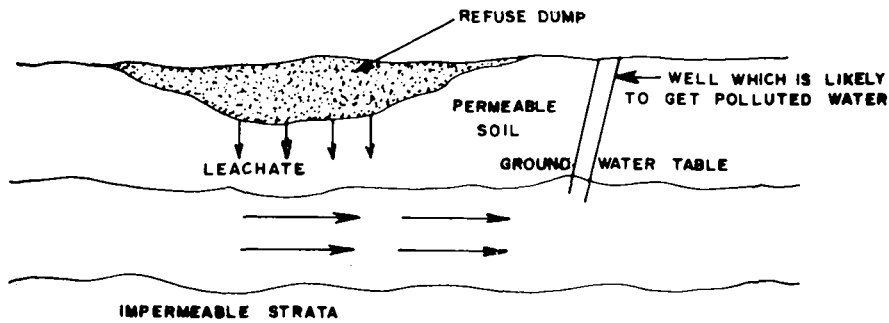
v) *Cover Material:* If the required soil cover is available at the site itself, no additional expenditure need be incurred on transporting it to the landfill site. A soil analysis along with the depth to which it is available is also necessary.

vi) *Hydrogeological Investigations:* The rainwater percolating through the solid waste tends to carry large amount of pollutants to the groundwater if the underlying strata is pervious or fissured. NEERI studies<sup>(10)</sup> have shown that the leachate coming out is highly polluting (15 to 20 times more concentrated than the domestic wastewater).

*Table 13.9.1: Pollution of Groundwater in kg/tonne of Refuse*

Pollution parameter	Indian city refuse <sup>(10)</sup> (1972)	Swiss refuse <sup>(75)</sup> (1968)
SO <sub>4</sub>	0.12	0.54
Cl	1.76	0.232
NO <sub>2</sub>	0.00032	0.00002
NO <sub>3</sub>	0.00347	0.034
NH <sub>3</sub>	0.30	0.0001
PV	0.288	0.078
BOD <sub>5</sub>	17.56	0.011

Table 13.9.1 gives pollution load contributed by such leachates. As the pollution introduced is high, unless proper precautions are taken it is likely to cause problems by getting drawn up through a dug well or other sources of water (Fig.13.9.2). To avoid leachate contamination of groundwater, an impermeable barrier in the form of a puddled clay blanket should be provided. A thin plastic membrane could be provided and the leachate collected taken out through specific points, treated and then let out to meet water pollution control regulations.



### 13.9.2 Pollution of ground water by leachate

vii) *Surface Water Pollution:* Surface water during its flow over the deposited waste may carry along some pollutants. Water courses flowing across the site should be diverted, and the surface water due to precipitation prevented from reaching the water course by an impermeable barrier.

## 13.10 Maintenance

Maintaining the site in proper working condition needs careful considerations as below:

i) *Operation in Monsoon:* During monsoon, the soil may become slushy, slippery and dangerous to the mechanical equipment. It is necessary to provide all weather access roads with proper drainage and also stock of demolition waste, concrete rubble, stones for urgent repairs at the site. When using trench method, water may fill up the trenches for which dewatering equipment will be required.

ii) *Fire Protection:* Hot ashes and combustible material get deposited at site which can start fires. Soil can be used to extinguish it, but it is best to provide fire fighting equipment which will be useful in the case of bigger fires.

iii) *Air-borne Dust and Litter:* Air-borne litter is a common problem due to the larger paper content. Such problems may come up only in some specific cases when paper can be arrested by self-supporting movable screen of chicken wire mesh. Dust poses problems during dry weather which can be minimised by spraying water over the deposited wastes.

iv) *Drainage:* Excessive ponding of water on landfill site may result in water seeping inside causing attendant problems. Adequate surface drainage coupled with precautions already discussed should help avoid this problem.

v) *Rodents:* Rodents may be attracted to the site from neighbouring areas or may be delivered to site along with the waste. If proper covering

is provided the problem could be minimised or the rodents killed best by using anticoagulant poison.

*vi) Birds:* Birds are attracted to site due to availability of food material. Prompt covering of waste should help reduce it. If such sites are near an airport they pose danger to aircraft. Sites near an airport or which are so located that birds going from the site to water course cross aircraft path should be avoided.

*vii) Insects:* If proper sanitary measures are adopted at the site, fly and mosquito breeding is not expected to occur. Eggs of flies might be originally present in the waste delivered at site leading to their breeding. Insecticides (say Malathion @ 675 gms/ha) can be sprayed at the site.

*viii) Salvage:* If the site is properly operated the ragpickers can be prevented from working at the site as they, during their work, tend to spread the waste around. In sanitary landfilling sites, wastes only from the working face are exposed and hence by proper precautions, nuisance of ragpickers can be avoided.

*ix) Gases:* The organic matter in the waste undergoes anaerobic decomposition producing  $\text{CH}_4$  and  $\text{H}_2\text{S}$ .  $\text{H}_2\text{S}$  is in very small concentrations and causes corrosion and odour problems.  $\text{CH}_4$  diffuses slowly and if the site is used before completion of decomposition it may accumulate and pose fire or explosion hazards. During landfilling, a web of gravel drains is laid which due to its lesser resistance collects the gases and takes it to a specific site where it can then be burnt or safely let out. As this precaution was not taken fire hazard was noticed at one such site in Delhi. At some sites in USA, efforts are made to use the gas. Proper precautions must be taken before using such sites for locating closed structures.

*x) Facilities for Staff and Equipment:* Heavy equipment at the site must be protected by keeping them in garages and by providing routine maintenance. The records can be maintained in an office where the weight (as obtained from weighbridge at entrance to site) and other details of the vehicles are kept.

*xi)* A checkpost at the entrance of the site along with a weighbridge must be available.

Specific wastes which are not to be accepted should be clearly indicated. If the site is away from the main highway directional signs should be provided.

### 13.11 Use of Reclaimed Land

Due to the decomposed organic material lying within the fill, the site after reclamation can be conveniently used to locate parks with trees and lawns, and used as playgrounds. In some cases, shops and other light construction

have been made as in Bombay, Calcutta, Surat and few other cities<sup>(27)</sup>. Before using such sites to build closed residential structures, it should be ensured that gas production has ceased and arrangements exist for safely venting out any gas that may be produced.

### 13.12 Hazardous Wastes

Normal practice is to reject toxic and hazardous wastes and only accept municipal wastes and known industrial and commercial wastes which are not likely to pose problems. Toxic and hazardous wastes require special precautions in their handling and must be disposed of at separate special disposal sites.

### 13.13 Cost

i) *Capital Cost:* Civil works at site consists of check post, garages, offices, roads inside the site, water supply for drinking and fire fighting. Mechanical equipment consists of bulldozers, scrapers, front end loaders, workshop equipment for maintenance and weighbridge. The exact cost of these items will vary from site to site. Land cost will vary depending upon the location and ownership. When land belongs to operating agency the yearly land cost is taken as equal to the annual interest that would accrue to the operating agency, when an investment equal to cost of land is made in Government bonds or securities.

ii) *Operating Cost:* Operating cost will mainly consist of repayment of loan for incurring capital expenditure. It will also involve POL (Petrol, Oil and Lubrication) of mechanical equipment as well as expenses on its maintenance and repairs. The expenditure on salaries of staff, water charges, maintenance of civil works and expenditure on transportation of waste and soil cover within the site should also be accounted for.

The cost of disposal while using mechanical equipment works out to Rs.15/- to Rs.30/- per tonne (US \$ 1.6 to 3.3) depending upon quantity of waste being disposed, and degree of mechanisation(Art.13.13.1).If manual sanitary landfilling is practised the cost will be about Rs.2/- to Rs.8/- per tonne depending upon quantity of waste handled and availability of soil.

Table 13.13.1 Cost of Sanitary Landfilling (1980 price level)

		<i>Area of site</i> : 700 ha.	
		<i>Refuse disposed/day</i> : 900 tonnes	
Sr. No.	Item	Details	Cost Rs tonne
1	Transportation	Additional transportation for 5 kms @ Rs.1.6/km/tonne	8.00
2	Unloading of refuse	Labour charges	1.50
3	Equipment	4 bulldozers & 1 scraper. Expenditure on amortization, fuel, M&R and salary of crew	8.57
4	Land	Land belongs to operator. Consider 6% of cost of land as yearly expenditure on this account	7.76
5	Roads	Provision and maintenance of internal roads	0.60
6	Salaries	Six clerks, 2 office superintendents & 8 security guards	0.28
7	Civil works	Construction and maintenance of garages and office buildings	0.05
8	Weighbridge	Weighment of incoming vehicles	0.07
9	Water	Drinking, fire fighting and washing of equipment	0.19
Total cost per tonne			= 27.02 (US \$ 3.0)

## CHAPTER 14

### LEGISLATION AND BYELAWS IN SOLID WASTE MANAGEMENT

#### 14.1 Introduction

Satisfactory performance of any public utility depends on i) institutional infrastructure with required manpower and equipment, ii) adequate financial inputs, iii) legislative powers, and iv) public response.

According to the Indian constitution, public health and sanitation falls within the purview of the State laws. Collection and disposal of solid waste is of local nature and is entrusted to local civic authorities. The municipal laws lay down detailed lists of obligatory and discretionary duties. Public health and sanitation is listed among obligatory duties and hence the civic authorities are required to make adequate provision.

Local civic authorities in Indian States like U.P., Punjab, Bihar, Tamilnadu, West Bengal, are governed by old Statutes passed in 1916, 1911, 1922, 1920 & 1932 respectively which deal with collection and carting away of the waste. Developments taking place in other areas as well as urban complexes do not get reflected in the laws to satisfy modern urban living conditions. Similar situation exists in many other developing countries. Annexures IV and V give recent provisions of laws applicable to the cities of Bombay<sup>(16)</sup> and Calcutta<sup>(18)</sup>. Annexures VI & VII give extracts from relevant Act and its provisions as applicable in Sri Lanka<sup>(29)</sup> and Colombo<sup>(21)</sup>.

The old regulations suffer from the defect that the various categories of wastes for which they would be applicable are not covered in sufficient details and are made applicable for domestic and to some extent trade wastes. They do not provide sufficient powers to the civic authorities for prosecution of offenders with the result that the enforcement has become ineffective. Unless the regulations are made specific backed with regulatory powers, enforcement will be difficult.

Most of the municipal byelaws deal with administrative aspects (primarily because Municipal Acts were framed for regulating functions of local authorities) and the processing and disposal aspects are seldom dealt with.

Citizens should play a greater role in ensuring proper environmental standards. Legal provisions should be made only to safeguard against violation of the rules.

#### **14.2 General Provisions of the Law**

The law should specify and define the terms used. The law should also specify the categories of wastes which should be collected and carted away by civic authorities and those for which the producer should be responsible. The manner in which collection and transportation will be carried out and the organisation necessary for it should be clearly identified. The responsibilities of the executing agency officials should be clearly specified. Detailed provisions should be made regarding the industries and the types of wastes which can be accepted by civic authorities and the manner of its collection and processing laid down. Existing regulations do not cover upkeep and maintenance of such sites. The laws should also lay down charges to be levied and recovered from individual households, industries, market places, etc. The penalties to be imposed in case of violations of the regulations and the method of recovery of such dues should also be laid down. A comprehensive law is required to bring about an improvement in the civic environment. Republic of Singapore achieved the present state due to the comprehensive provisions in the Public Health Act (Annexure VIII).

#### **14.3 Toxic and Hazardous Wastes**

The civic authorities take care of domestic and commercial solid wastes. The industrial and toxic solid wastes may be collected and disposed of separately by the civic or other competent authorities or the producer may, with the approval of the authority, arrange for its disposal on his own site or on a privately operated site. In all these cases, the site and the method of disposal should be first approved by the competent authority.

The law should lay down that the producer of such industrial and toxic waste shall be responsible for its safe storage, collection and disposal including equipment and containers to be used in the storage of the waste on the premises. Standard specifications of vehicles and precautions to be taken while transporting the wastes to the disposal site should be laid down. Only licensed contractors, if waste is being transported privately, be allowed to operate such services. Industry, irrespective of whether disposal of its waste is to be carried out on its own site or on a private site or a public site should be required to obtain a permit from the competent authority. The authority should have the right to sample the waste and get it analysed. A list of toxic solid wastes and precautions to be taken during their disposal

need be maintained. The authority should also have its own testing facility to analyse such wastes and arrive at suitable methods for its disposal. Periodic checks should be made to ensure that the disposal is done in the manner stipulated. In case of violation, the authority should have powers to revoke the permit and levy fines.



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## GLOSSARY OF TERMS

Some of the words used and their connotations are reproduced below from IS 9569-1980. 'Glossary of Terms relating to Solid Wastes'.<sup>(44)</sup>

*Aerobic* - Able to live and grow only in the presence of free oxygen.

*Afterburner* - A device used to burn or oxidize the combustible constituents remaining in effluent gases.

*Air* - The mixture of gases comprising the earth's atmosphere.

*Air, Stoichiometric* - See Combustion Air, Theoretical.

*Air, Underfire* - Air that may be forced or induced in a controlled quantity and direction and is supplied below a grate and passes through a fuel bed.

*Air Pollutant* - A substance which when present in adequate amount adversely affects the environment.

*Air Pollution* - The presence in ambient atmosphere of substances, generally resulting from the activity of man, in sufficient concentration, present for a sufficient time and under circumstances to interfere significantly with comfort, health or welfare of persons or with full use or enjoyment of property.

*Air Quality* - The composition of air with respect to quantities of pollutants therein.

*Air Quality Standards* - The maximum acceptable pollutant concentration in the outside air that cannot be exceeded during a specified time in a specified area.

*Alley Collection* - Removal of solid wastes from containers placed adjacent to an alley.

*Analysis, Proximate* - Analysis of a solid fuel to determine its moisture, volatile matter, fixed carbon and ash content. Usually the fuel's heat value is also determined.

*Analysis, Ultimate* - The chemical analysis of a solid, liquid or gaseous fuel. In the case of solid fuel, the amount of carbon, hydrogen, sulphur, nitrogen, oxygen and ash are determined.

*Biodegradable* - A substance that can be broken down by microorganisms.

*Burner, Refuse* - A device for central or on-site burning of refuse. It is very simple in construction and all the factors of combustion are not controlled.

*Burner, Secondary* - A burner installed in the secondary combustion chamber to maintain a specified minimum temperature and complete combustion of incompletely burnt gases.

*Burning Rate* - The quantity of solid waste incinerated (expressed as  $\text{kg/m}^2\text{h}$ ) or the amount of heat released (expressed as  $\text{cal/m}^2\text{h}$ ) during incineration.

*Calorific Value* - Number of heat units obtained by complete combustion of unit mass of a fuel.

*Clinker* - Hard, sintered or fused pieces of residue formed in a fire by agglomeration of ash, metals, glass and ceramics.

*Combustion Air, Excess* - Air that is supplied in excess of theoretical air. It is normally expressed as a percentage of theoretical air.

*Combustion Air, Primary* - Air that is added to combustion system at the point where fuel is first oxidized.

*Combustion Air, Secondary* - Air introduced above or beyond a fuel bed by natural, induced or forced draft. It is generally referred to as overfire, air, if supplied above the fuel bed through the side walls or the bridge wall of primary chamber.

*Combustion Air, Theoretical* - The amount of air required to completely burn the waste. The amount is calculated from the chemical composition of the waste and is also known as stoichiometric air.

*Damper* - A manually or mechanically controlled valve or plate fixed in a breeching, duct or stack that is used to regulate a draft or rate of flow of air or other gases.

*Electrostatic Precipitator* - A device for collecting particulates by placing an electric charge on them and then attracting them to a collecting electrode.

*Emissions* - The sum of total substances discharged into air from a stack, vent or any other discrete source. It is generally applicable to harmful and injurious substances.

*Emission Standard* - A rule or measurement established to regulate or control the amount of a given pollutant which may be discharged into the atmosphere from the source.



*Facultative* - Able to live and grow with or without free oxygen.

*Flue* - A passage designed to carry combustion gasses and entrained particles.

*Fluidized Bed Technique* - A combustion process in which heat is transferred from finely divided particles such as sand to combustible materials when kept in a fluidized state in a combustion chamber.

*Fly Ash* - The finely divided particles of ash entrained in flue gases arising from the combustion of fuel. The particles of ash may contain incompletely burned fuel. The term has been applied predominantly to gas-borne ash from boilers with spreader stoker, underfeed stoker, and pulverized fuel (coal) firing. The particles fall to the ground close to the point of release.

*Garbage* - Waste food material originally intended for or associated with food for human consumption.

*Garchey System* - A patented system in which refuse is first stored in a water filled flushing device under a sink from where it is conveyed through tubes to a central holding tank.

*Grate* - A device which supports solid fuel or solid waste during drying, ignition and combustion and the openings in it permit air to pass through it.

*Heat Release Rate* - The amount of heat released during complete combustion. Generally it is expressed as  $\text{kcal/m}^3$  (of internal volume of furnace) h.

*Heat Value, High* - The amount of heat, expressed in kilocalories liberated when a kilogram of solid waste is completely burnt and the products of combustion are cooled to initial temperature of solid waste as in a calorimeter.

*Heat Value, Low* - The high heat value minus the latent heat of vaporization of water formed by burning the hydrogen in fuel.

*Ignition Temperature* - Lowest temperature at which a fuel can be burnt by a self-sustaining combustion reaction.

*Leachate* - Liquid that has travelled through solid waste or other medium and has extracted, dissolved or suspended material from it.

*Odour Threshold* - The lowest concentration of a substance in air at which its odour is perceptible.

*Pathogen* - An organism capable of producing disease.

*Pollution* - Presence in the environment of some substances of such type and quantity that the quality of the environment is impaired or rendered offensive to life.

*Putrefaction* - Microbial decomposition of organic matter accompanied by odours.

*Recycling* - The process by which waste materials are transformed into new products in such a manner that the original products lose their identity.

*Refuse* - It includes all kinds of wastes in solid state, excepting excreta, coming from residential, commercial and industrial areas.

*Reuse* - The reintroduction of a commodity into the economic stream without any change.

*Salvaging* - Controlled removal of waste material for utilization.

*Satellite Vehicle* - A small vehicle which discharges its contents into an accompanying large vehicle.

*Slag* - A substance formed by chemical action and fusion at furnace operating temperatures.

*Street Refuse* - Refuse collected from streets when they are cleaned either manually or mechanically.

*Transfer Station* - A site at which solid waste is transferred from one set of vehicles to another directly or after compaction.

*Vector, Disease* - A carrier capable of transmitting a pathogen from one vector to another.

## COLLECTION AND ANALYSIS OF REFUSE SAMPLES

Various countries and organisations use different methods for analysis of solid waste samples. Indian Standards Institution has prepared standards for i) physical analysis of samples, ii) preparation of sample for chemical and microbiological analysis and iii) chemical analysis of solid waste samples as given below:

### METHOD FOR PHYSICAL ANALYSIS AND DETERMINATION OF MOISTURE IN SOLID WASTES (EXCLUDING INDUSTRIAL SOLID WASTES) — IS : 9235 — 1979

#### 1. SCOPE

1.1 This standard prescribes a method for physical analysis and determination of moisture in solid wastes excluding industrial wastes.

#### 2. GENERAL REQUIREMENTS OF SAMPLING

2.0 It is of utmost importance for all analysis that the samples be representative. cursory samplings reveal very little about the true composition of the material and may lead to erroneous conclusions.

##### 2.1 *Refuse*

2.1.1 A mobile hammermill shall be used to take a crude sample of refuse so that the refuse to be examined may be ground and homogenized on the spot.

2.1.2 Crude refuse 100 to 200 kg may be taken as the basic unit for a sample which may be taken at variable intervals depending on the amount of waste. In accordance with the purpose of the analysis, 2 to 4 individual samples may be ground together in order to reduce the number of samples during more lengthy tests.

2.1.3 The ground refuse has to be mixed intensively. During mixing, about 10 to 20 small individual portions are taken and filled into airtight plastic bags in quantities of 1 to 2 kg, to be stored as samples. This heterogeneous mixture is the crude sample.

2.2 *Compost — Grab* samples (1 to 2 kg) shall be taken from as many parts of the windrow as possible and well mixed. It shall be ensured that equal amounts are taken from all parts. The actual sample of 1 to 2 kg shall be taken from this mixture. In the same way compost samples shall

be taken from the test material in plastic baskets and small windrows. The mixture obtained in this way is the crude sample.

**2.3 Sewage Sludge** — Before a sample is taken, the sewage sludge shall be well homogenized. However, too intensive mixing with a high speed agitator should be avoided if the sample is to be used in dehydration tests (flocculation and filtration tests). The sewage sludge obtained in this way is the crude sample.

#### **2.4 Residue After Incineration**

2.4.1 The crude sample shall be taken directly from the conveying system under examination if possible. Fly ash and riddlings shall be taken from the corresponding areas.

2.4.2 The size of the sample shall depend on the kind of information sought and the structure of the material. In the case of single samplings (which may have a random composition) a large quantity should be taken and prepared. For longer examination periods, in which several single samples are taken at smaller intervals, the quantity may be fixed at 100 kg. per sampling. Considerable deviations may occur with smaller quantities.

2.4.3 Depending on the information sought 2 to 4 single samplings may be ground and mixed in order to limit the number of samplings for lengthier tests.

### **3. PREPARATION OF SAMPLE**

3.1 Crude samples are not ready for examination. They should be ground and homogenized further after drying. The moisture content of the crude sample is determined during drying. It is essential that this moisture content of sample is measured as soon as possible after the sample is collected.

NOTE—If any moisture is found condensed on the walls of the container, it should be reabsorbed in the sample.

### **4. DETERMINATION OF MOISTURE**

4.1 *Procedure* — In order to determine the moisture content, weigh the entire crude sample. Spread it thinly and dry in a drying oven till its mass becomes constant. Drying may be generally done at 105°C but in case of combustibles the temperature shall be 70 to 75°C. However, if microbiological tests are also to be conducted, drying shall be done at 40 to 50°C. The dried crude samples are somewhat hygroscopic. They

shall be left to cool in a turned off drying oven and weighed immediately afterwards.

#### 4.2 Calculation

$$DS + W = 100 \text{ (NS)}$$

$$c = a - b$$

$$e = d - b$$

$$W = \frac{c - e}{c} \times 100$$

$$BS = (e/c) \times 100$$

Where

DS = dry substance of the crude sample, percent by mass;

W = moisture content of the crude sample, percent by mass;

NS = non-dried substance of the crude sample;

c = net mass, wet;

a = gross mass, wet;

b = mass of receptacle (tare)

d = gross mass, dried and

e = net mass, dried.

## 5. SEGREGATION AND GRINDING

5.1 Waste material may contain glass, ferrous and non-ferrous metals, plastics, etc. Glass and ceramics may be separated by judicious sieving, plastics and non-ferrous metals may be hand-picked and ferrous metals may be removed by a strong magnet.

5.2 The remaining material may be ground with an appropriate pulverizing equipment (crushing mill, hammermill, ball mill, knife mill) until it becomes a farinaceous, homogeneous powder which is sifted through a 0.5 mm screen. The screening residue should be ground thoroughly to particles of the smallest size possible. The material in the form of sample is now ready for analysis.

5.3 The separated material may further be segregated into organic and inorganic portion. The organic portion consists mainly of paper, rubber, plastics, wood, textiles and cork. A part of these materials may be pulverized even further with a knife mill and mixed with the sample. This is of importance if it is desired to determine the carbon content of fermentable organic substance and volatile substance. The mass of the remaining material shall be determined and expressed as a percentage of the dry substance and referred to as the organic screening residue.

5.4 The inorganic screening residue consists almost exclusively of metals. They shall be cleaned with air pressure and their mass determined and expressed as a percentage of the dry substance.

5.5 The screening residue should be taken into account when calculating the results of analysis of the crude sample. The inorganic screening residue shall be considered inert while calculating the calorific value. An approximate value shall be used for the organic part, if necessary.

## 6. RESULTS OF ANALYSIS

6.0 The moisture content of the crude sample is closely linked with the place and method by which it was taken and whether it was immediately mixed and filled into containers or only after some time.

6.1 To facilitate comparison of results, the data of analysis shall be normally calculated on the basis of dry substance.

6.2 When a single crude sample is drawn and analysed in order to obtain information about the quantity of a sample unaffected by a process or to determine its state, it shall be referred to as single analysis.

6.3 When crude samples are taken and analyzed at various intervals depending upon purpose and process, it shall be referred to as series analysis.

6.4 *Single Analyses* – These shall be calculated as given below.

6.4.1 Evaluation shall be done on the basis of dry substance (DS) in percentage by mass.

6.4.2 Evaluation shall be done on the basis of the non-dry substance (NDS) also in percentage by mass.

6.5 *Series Analyses* – These shall be calculated as given below.

6.5.1 Evaluation shall be done on the basis of initial dry substance (IDS) in percentage by mass.

6.5.2 The results of analysis of a series of tests carried out to follow fermentation shall be calculated on the basis of the following assumptions :

- a) The ash content remains constant during fermentation from the quantitative point of view. The organic part however, decomposes and hence there is a quantitative reduction.
- b) All results may be converted and compared with each other with the aid of sample's ash content as well as IDS of the sample.

# IS : 9234 – 1979. METHOD FOR PREPARATION OF SOLID WASTE SAMPLE FOR CHEMICAL AND MICROBIOLOGICAL ANALYSIS

## 1. SAMPLE

1.1 This standard prescribes a method for preparation of samples of solid waste for chemical and microbiological analysis.

## 2. PREPARATION OF SAMPLE FOR ANALYSIS

2.1 The three basic operations required to prepare the sample for detailed analysis are drying, grinding or pulverizing, and mixing. The end products of these operations should be so thoroughly homogenized that portions weighing 100 to 200 mg may be extracted for analysis. The procedure for all types of organic materials is essentially similar, if compost samples have already been coarsely ground either in a hammer-mill or rasping device. The sample is dried before grinding. After grinding, it is subjected to mixing in a rotating mixer.

Note – When handling refuse, the analyst should use gloves, if possible of neoprene-coated canvas. He should also wear a face mask, such as a surgical mask, when preparing samples, especially when they are in finely divided form.

## 3. DRYING

3.1 A laboratory oven may be used for drying a small sample, and an industrial oven for a large sample. Weigh a pan, transfer the material to it and reweigh. Note the mass of the sample and dry in an oven at 70 to 75°C for 24 hours if the material is combustible, otherwise dry at  $105 \pm 1^\circ\text{C}$ . Remove the sample and allow to cool, preferably in a desiccator. Weigh, and again place in the oven for 1 to 2 hours. Repeat the process of heating, cooling and weighing till the difference in mass between two successive weighings is less than one percent of the total previous loss in mass. Calculate the moisture content as percentage of the original mass. However, if microbiological tests are also to be conducted, drying shall be done at 40 to 50°C.

## 4. GRINDING

4.1 Waste material may contain glass, ferrous and non-ferrous metals, plastics, etc. Glass and ceramics may be separated by judicious sieving, plastics may be hand-picked as they are not degradable and interfere in the determination of carbon/nitrogen ratio, and ferrous metals may be removed by a strong magnet. After removal of these, proceed with grinding using a hammer-mill, grinding mill or pulverizer.

4.1.1 *Procedure for Combustibles* – Place the sample collection box under the grinding machine. Plug the lead into the power outlet. Open the cut-off in the dust collecting system. Oil the grinder bearings with engine oil. Put on personal safety equipment. Start the motor and feed the sample into the mill. Turn off grinder motor and turn off the blower. Clean out the grinder and add this material to the ground sample.

Note – It is advisable to wear a transparent plastics face shield while feeding the material into the grinder. The analyst should not use his hand to help push material into the grinder past the feed slot. Do not open any grinding device while it is running. If the grinder clogs, turn off the motor before cleaning the apparatus.

4.1.2 *Procedure for Compost* – Put a 2 mm sieve into the grinding mill. Open the cut-off in the dust collection duct. Position the container under the delivery spout. Replace the 2-mm sieve with a 1-mm sieve and regrind the sample. Brush out all inside surface of the mill into a separate container. Put this material through a micro mill. Add the product to the main sample.

4.1.3 *Procedure for Non-Combustibles* – Adjust the movable pulverizer plate to give a maximum size of about 2 mm. Put the sample through the pulverizer. Screen the ground material through 2-mm and 250-micron sieves. The material passing through 250-micron sieve is the required sample.

## 5. MIXING

5.1 The final mixing or homogenization is accomplished by transferring the sample to a suitable container that is not more than half filled by it. Close the container tightly, position it in a rotating mixer and allow to mix for not less than 2 hours. Reduce the mixed sample in size if desired, by passing it through a sample splitter or by quartering. Weigh all metal, ceramic, plastics and glass removed during processing.

# IS : 10158 – 1982. METHODS OF ANALYSIS OF SOLID WASTES (EXCLUDING INDUSTRIAL SOLID WASTES)

## 1. SCOPE

1.1 This standard prescribes methods of analysis of solid wastes (excluding industrial solid wastes) for the determination of the following

- a) Volatile and non-volatile matter;
- b) Kjeldahl Nitrogen;



- c) Total Nitrogen;
- d) Carbon content;
- e) pH
- f) Calorific Value;
- g) Potassium and
- h) Phosphorous.

## 2. TERMINOLOGY

2.1 For the purpose of this standard the definitions of terms given in IS 9569-1980 and the following shall apply:

2.1.1 *Volatile Substance (V.S.)* – The portion in refuse sample which decomposes when heated upto 600°C.

2.1.2 *Non-Volatile Substance (N.V.S.)* – The portion of the sample which does not decompose when heated upto 600°C.

2.1.3 *Kjeldahl Nitrogen* – Nitrogen in ammonia and nitrogen present in organic compounds which can be catalytically reduced to ammonia. Nitrate and nitrite nitrogen is not covered.

## 3. VOLATILE SUBSTANCE AND NON-VOLATILE SUBSTANCE

3.1 *Principle* – When a substance is heated the organic substance is oxidised into volatile oxidation products whereas inorganic substances give solid oxidation products.

3.2 *Procedure* – Place about 5 g finely ground sample in constant mass silica or porcelain dish and heat in an electric furnace (muffle furnace) upto a temperature of 600°C for 2 hours. Allow the dish to cool in a dessicator and weigh it again.

3.3 *Calculation* – Calculate the volatile substance and non-volatile substance as percentage of the original mass as follows:

$$\text{Volatile Substance percent by mass} = \frac{\text{Initial Mass} - \text{Final Mass}}{\text{Initial Mass}} \times 100$$

$$\text{Non-Volatile Substance, percent by mass} = 100 - \text{VS}$$

Note – At 600°C not only organic matter is lost but some of the inorganic compounds like metal carbonates are also decomposed into carbon dioxide. Hence the value of VS is not the correct total organic matter. Therefore, it is advisable to call it loss in mass at 600°C.

## 4. KJELDAHL NITROGEN

4.1 *Principle of the Method* – The sample is digested with concentrated sulphuric acid in the presence of a catalyst to convert the organic nitrogen into ammonium sulphate from which the ammonia is liberated by distillation with concentrated alkali solution. The ammonia so evolved is absorbed in standard sulphuric acid and the excess acid is titrated with standard alkali solution. Alternatively, in the modified method, the ammonia evolved is absorbed in boric acid and titrated against standard acid.

4.1.1 No single digestion procedure which gives good results with all nitrogen containing compounds can be recommended. As a general guide, however, the use of potassium sulphate and a mercury catalyst as the most reliable mixture, particularly when prolonged digestion is required, is suggested. The mercury selenium catalyst is more effective, but prolonged digestion should be avoided. Copper sulphate and selenium have been effectively used as catalyst for the analysis of biological materials. This mixture is probably not as efficient as the mercury-selenium catalyst but its use obviates the necessity of precipitating mercury before distillation of the ammonia. The time of digestion is reduced when selenium is used as a catalyst. The use of oxidising agents, such as potassium permanganate or hydrogen peroxide, may be advantageous, particularly when a large amount of carbonaceous matter is to be destroyed. The organic nitrogen is not always completely converted into ammonium sulphate when the digest has become 'charfree', since some compounds, for example, pyridine carboxylic acids, do not char when heated with concentrated sulphuric acid. It is, therefore, particularly important not to confuse 'charring time' with 'digestion time'. In many cases, a considerable 'after boil' may be necessary to obtain complete conversion to ammonia.

4.2 *Quality of Reagents* – Unless specified otherwise, pure chemicals and distilled water (see IS : 1070–1977\*) shall be employed in tests.

Note – 'Pure chemicals' shall mean chemicals that do not contain impurities which affect the results of analysis.

4.3 *Apparatus* –

4.3.1 *Kjeldahl Flask* – 500 ml capacity.

4.3.2 *Distillation Assembly* – The assembly consists of a round bottom flask of 1000 ml capacity fitted with a rubber stopper having two holes, through one of which passes one end of the connecting bulb tube and

through the other end of the tap or separating funnel which dips into the contents of the flask. The other end of the bulb tube is connected to the condenser. The lower end of the condenser is attached by means of a rubber tube to a dip tube which dips into a known quantity of acid (sulphuric or boric), contained in a beaker of 500 ml capacity, to which 3 to 4 drops of indicator solution has been added.

Note — In order to avoid back suction of the liquid in the beaker, presence of positive pressure by introduction of gas (nitrogen gas or air free from carbon dioxide) would make the operation smoother.

#### 4.4 Reagents —

4.4.1 *Potassium Sulphate or Anhydrous Sodium Sulphate.*

4.4.2 *Copper Sulphate or Selenium Powder or Mercury or Any Other Suitable Mixed Catalyst — See 4.1.1.*

4.4.3 *Concentrated Sulphuric Acid — conforming to IS : 266—1977\**

4.4.4 *Sodium Hydroxide Solution — Dissolve about 450 g of sodium hydroxide (pellets, flakes, sticks or lumps) in 1000 ml of water.*

4.4.5 *Standard Sulphuric Acid — 0.5 N*

4.4.6 *Standard Sodium Hydroxide Solution — 0.25 N*

4.4.7 *Alkaline Sodium Sulphide Solution — Dissolve 20 g of sodium sulphide ( $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$ ) in water, dilute to 50 ml, add 600 ml of sodium hydroxide solution (see 4.4.4) and mix well.*

4.4.8 *Methyl Red Indicator Solution — See IS : 2263—1962\*.*

4.4.9 *Boric Acid Solution — Saturated. Dissolve 60 g of boric acid in 1 litre of hot water, cool and allow to mature for 3 days before decanting the clear liquid.*

4.4.10 *Mixed Indicator Solution — Methyl red and methyl blue prepared as prescribed in Table III of IS : 2263—1962\*.*

4.5 *Procedure — Weigh accurately a suitable quantity of the finely ground sample into the Kjeldahl flask. The quantity of the sample taken shall be such that the ammonia liberated neutralizes not more than 40 ml of standard sulphuric acid or boric acid taken in the beaker into which the dip tube dips. Add 15 g of potassium sulphate or anhydrous sodium sulphate, 0.5 to 1 g of the catalyst and 25 ml. or more if necessary, of concentrated sulphuric acid. Place the digestion flask in inclined position and close the flask with a loosely fitting, pear shaped, hollow glass stopper to prevent loss of sulphuric acid or entry of dust. Heat the mixture gently in a fume cupboard until the initial frothing has ceased. If the sample tends to foam or froth, heat very gently in the*

initial stages; a small piece of paraffin or zinc may also be added to reduce frothing, if necessary. Heat the liquid to boiling point. Continue boiling freely until the solution become clear and then boil for a further period of about two hours. Cool the contents of the flask.

4.5.1 Transfer completely the contents of the digestion flask into the round-bottom flask of the distillation assembly, using water. Add a few pieces of pumice stone. Place a measured volume (normally 50 ml is sufficient) of standard sulphuric acid in the beaker and add 3 drops of methyl red indicator. Fit up the distillation assembly. Add an excess of sodium hydroxide solution (or alkaline sodium sulphide solution where mercury is used as catalyst), through the separating funnel, and where mercury is used as catalyst, through the separating funnel, and mix with the contents of the flask by mild shaking, so as to make the solution in the flask. Cool tube with water, collecting the washings in the beaker. Titrate the excess of sulphuric acid in the beaker with standard sodium hydroxide solution. Carry out a blank determination in the same manner using the same quantities of all the reagents but without the sample.

#### 4.5.1.1 Calculation

##### 4.5.1.1 Calculation

$$\text{Nitrogen, percent by mass} = \frac{1.4 (V_2 - V_1)}{W} \quad N$$

Where

$V_1$  = volume in ml of standard hydroxide solution used to neutralize the excess acid in the determination with the sample

$V_2$  = volume in ml of standard sodium hydroxide solution used to neutralize the excess acid in the blank determination

$N$  = normality of the standard sodium hydroxide solution and

$W$  = mass in g of the sample taken for the test.

4.5.2 Alternatively, the ammonia evolved by distillation shall be absorbed in boric acid. Carry out digestion as prescribed in 4.5. Transfer completely the contents of the digestion flask into the round-bottom flask through the separating funnel. Rinse the separating funnel with water. The total volume of liquid in the distillation flask should not exceed half the capacity of the flask otherwise frothing may occur. Add excess of sodium hydroxide solution (or alkaline sodium sulphide

solution when mercury is used as catalyst) to make the solution alkaline. Connect immediately the round-bottom flask to steam trap and condenser. The condenser should be arranged to dip the dip tube in 50 ml of boric acid which is kept cool in the beaker. Add 2-3 drops of the mixed indicator. Distil about one third of the total volume of the solution in the flask, Cool and dismantle the distillation assembly. Rinse the tip of the condenser and the dip tube with water, collecting the washings in the beaker. Titrate the ammonia present in the distillate with sulphuric acid until the grass green colour changes to steel grey, a further drop then giving the purple colour.

#### 4.5.2.1 Calculation

$$\text{Nitrogen, percent by mass} = \frac{1.4 \times \underline{V} \times \underline{N}}{\underline{W}}$$

Where

$\underline{V}$  = volume in ml of standard sulphuric acid used in titration

$\underline{N}$  = normality of standard sulphuric acid, and

$\underline{W}$  = mass in g of the sample taken for the test.

## 5. TOTAL NITROGEN

**5.0 General** – The following method is applicable in determining the total nitrogen (ammonical, organic and nitrate) of urban refuse, compost etc.

### 5.1 Reagents –

#### 5.1.1 Sucrose

#### 5.1.2 Chromium Metal

#### 5.1.3 Hydrochloric Acid (Concentrated)

#### 5.1.4 Potassium Sulphate

#### 5.1.5 Mercuric Oxide

#### 5.1.6 Sulphuric Acid (Concentrated) – 95–98 percent.

#### 5.1.7 Zinc Metal (Granulated)

**5.1.8 Alkaline Thiosulphate Solution** – Dissolve 450 g sodium hydroxide in approximately 700 ml water, cool and add 32 g sodium thiosulphate and dilute with water to one litre.

#### 5.1.9 Boric Acid – 4 percent.

**5.1.10 Mixed Indicator** – Mix 10 ml of 0.1 percent bromocresol green in 95 percent alcohol with 2 ml of 0.1 percent methyl red in 95 percent alcohol. The colour produced by this indicator in boric acid is bluish purple. With a trace of ammonia the colour becomes bluish green. One drop in excess of acid turns the colour of the solution to pink.

### 5.1.11 Sulphuric Acid — 0.1 N.

### 5.1.12 Alundum

5.2 *Procedure* — Weight about 5 g of prepared solid sample (also run a blank by weighing 2 g of sucrose). Transfer the samples to 500 ml Kjeldahl flask. To each flask add 1.2 g chromium and 35 ml distilled water, keep it for 10 minutes with swirling. Now add 7 ml concentrated hydrochloric acid to each flask. Keep it for some time so that reaction occurs. Heat each flask for 5 minutes on burner. Cool and add 22 g potassium sulphate, 1.0 g mercuric oxide and 1.5 g alundum to each sample. Add 25 ml concentrated sulphuric acid to each flask. Heat each flask slowly in the initial stage and heat for about 2 hr with occasional swirling. When the digestion mixture becomes whitish yellow, allow the digestion mixture to cool. Add water and transfer the mixture in 200 ml volumetric flask and make up to 200 ml. Transfer 100 ml of this to nitrogen distillation assembly and proceed for distillation as given below:

5.2.1 *Distillation* — Transfer 100 ml of the solution obtained by digestion to a Kjeldahl distillation assembly. Add sodium hydroxide (40 percent) until solution becomes highly alkaline. When mercuric oxide catalyst is used then add alkaline thiosulphate solution instead of sodium hydroxide (40 percent). Add 0.5 g of zinc dust or zinc clipping to the distillation flask. Carry out distillation collecting distillate in an Erlenmeyer flask containing 50 ml of 4 percent boric acid and a drop of mixed indicator. Collect about 150 ml of distillate (total 200 ml in flask). Titrate this distillate with 0.1 N sulphuric acid.

5.3 *Calculation* — Calculate the total nitrogen content as percentage of the original mass as follows:

$$\text{Nitrogen, percent} = \frac{(\underline{A} - \underline{B}) \times \underline{N} \times 14 \times 100 \times 2}{\underline{E}}$$

Where

$\underline{A}$  = 0.1 N sulphuric used in the titration of the solid waste sample, ml and

$\underline{B}$  = 0.1 N sulphuric acid used in the titration blank, ml;

$\underline{N}$  = normality of standard sulphuric acid; and

$\underline{E}$  = mass in g of the solid waste sample.

## 6. CARBON

### 6.1 *Empirical Method*

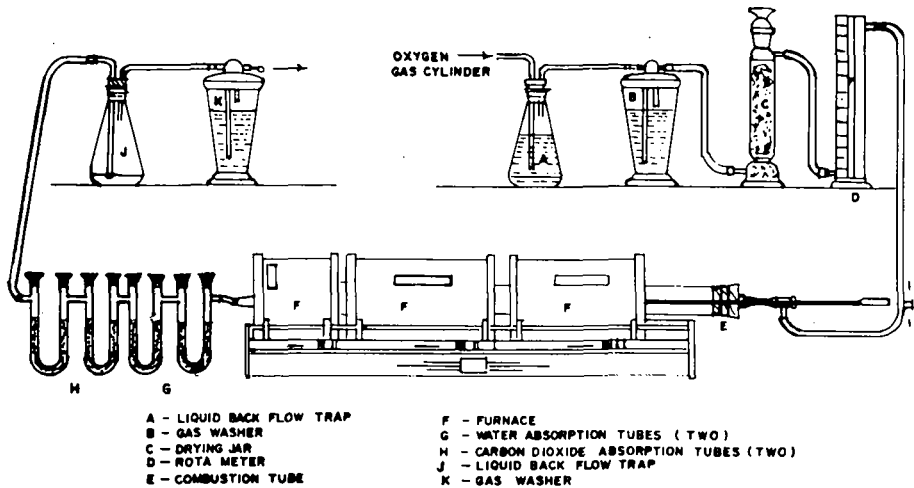


FIG II-1 CARBON-HYDROGEN ESTIMATION ASSEMBLY

6.1.1 *Principle* – The ratio of carbon content to volatile substance content remains constant, to some extent, for a particular type of refuse.

6.1.2 *Procedure* – Volatile substance is determined as described in 3 and the carbon content is calculated as follows:

$$\text{Carbon, percent} = \underline{A} \times \underline{VS}$$

Where

$\underline{A}$  = is a constant which depends on the composition of refuse of a particular place. A is calculated by determination of carbon content by the combustion method and calculated as follows:

$$\underline{A} = \frac{\text{Carbon, percent}}{\text{Volatile Substance, percent}}$$

## 6.2 Combustion Method

6.2.1 *Principle* – Carbon is determined gravimetrically after burning the sample in presence of oxygen and the carbon dioxide formed is estimated as sodium carbonate. The combustion is carried out in a 1 m long tube with 40 mm OD. The tube is tapered at one end. Leaving about 400 mm from non-tapered end, the materials are filled in this sequence; special mixture of asbestos, platinised asbestos and aluminium oxide, lead chromate, asbestos copper dioxide, asbestos, lead chromate, silver wool, lead dioxide and silver wire. The accelerator iron chips are added to the sample which ignites and starts the exothermic reaction.

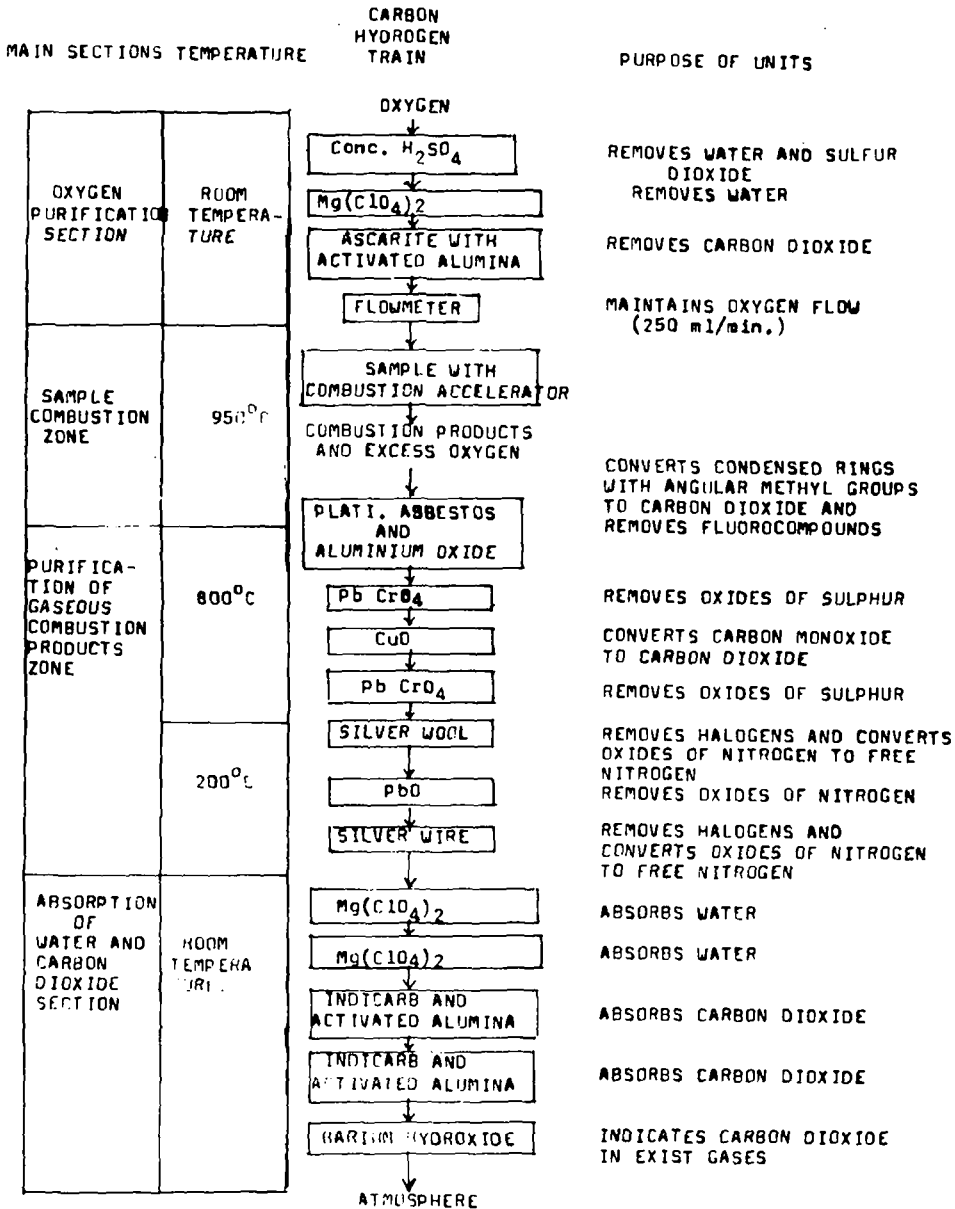


FIG. 1-2 GENERAL OUTLINE OF CARBON-HYDROGEN TRAIN.



6.2.1.1 This method can be used for raw garbage, compost and refuse from incinerator and other dry matter having carbon within a range of 0.5 percent to 83 percent.

6.2.1.2 The apparatus used essentially consists of three parts, the cleaning of inlet oxygen gas, the furnace with packed combustion tube and gas absorption unit.

6.2.2 Apparatus — A sketch of the apparatus is shown in Fig.II-1 and a general outline of the carbon hydrogen train is given in Fig.II-2.

6.2.2.1 *Glass Wool*

6.2.2.2 *Muffle furnace* — It has three parts :

Section	Operating temperature	Length
A	950°C	0.2 m
B	800°C	0.3 m
C	200°C	0.1 m

Note — It is important that the temperature of the zone in which lead chromate has been placed does not rise significantly above 800°C at any time.

6.2.2.3 *Combustion tube* — made of silica glass. 1 m long 35 mm ID and 40 mm OD. A schematic diagram of the packed combustion tube is shown in Fig.II-3.

6.2.2.4 *Combustion boat*

6.2.2.5 *Absorption jar for cleaning the oxygen gas*

6.2.2.6 *Container for absorption of carbondioxide produced*

6.2.2.7 *Analytical balance*

6.2.2.8 *Erlenmeyer flasks*

6.2.2.9 *Polythene tubing, rubber cork etc.*

6.2.3 *Reagents* — Unless otherwise specified, pure chemicals and distilled water (see IS : 1070-1977) shall be employed in the test. The reagents required are given below.

Note — Pure chemicals shall mean chemicals that do not contain impurities which affect the results of analysis.

6.2.3.1 *Oxygen 99.5 percent pure.*

6.2.3.2 *Sulphuric acid concentrated.*

6.2.3.3 *Magnesium per chlorate (anhydrous)(Dehydrite).*

6.2.3.4 *Ascarite (sodium hydroxide on asbestos-size 2.36 mm — 850 µm*

6.2.3.5 *Activated alumina size 2.36 mm — 1.18 mm.*

6.2.3.6 *Silver wire (0.16 mm dia).*

6.2.3.7 *Lead dioxide brown size 1.40 mm — 850 µm*

6.2.3.8 *Silver wool.*

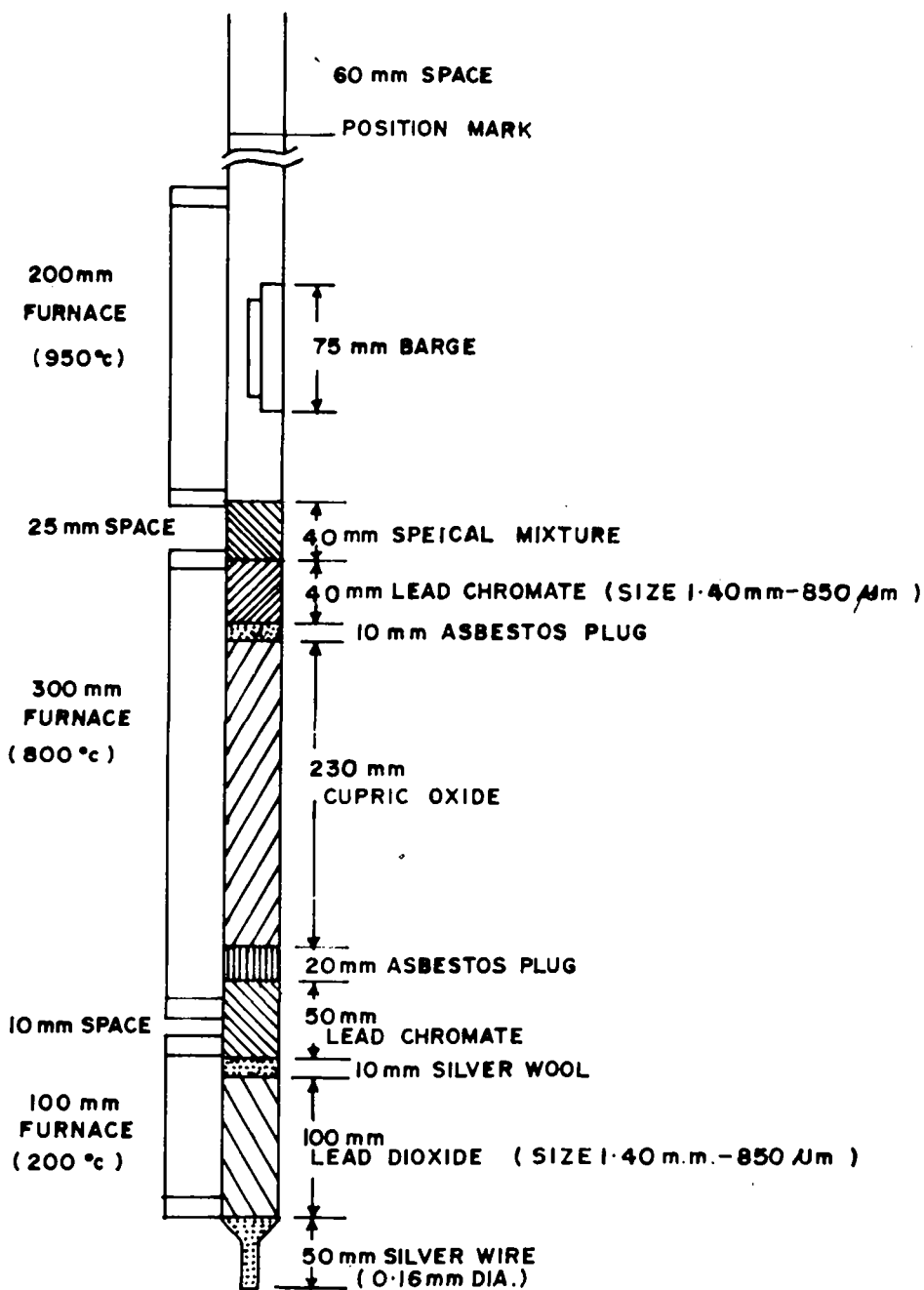


FIG II-3 PACKED COMBUSTION TUBE .

6.2.3.9 *Lead chromate* – Size 1.40 mm – 850  $\mu\text{m}$  or powder which has fused at 820°C for one hour and ground to about 1.40 mm – 850  $\mu\text{m}$  size.

6.2.3.10 *Cupric oxide (before using ignite at 600°C for 1 hr.)*

6.2.3.11 *Platinised asbestos 5 percent.*

6.2.3.12 *Aluminium oxide.*

6.2.3.13 *Accelerator chips (iron).*

6.2.3.14 *Indicarb size 3.55 mm – 1.70 mm.*

6.2.3.15 *Absorbent cotton.*

6.2.3.16 *Barium hydroxide solution* – Dissolve 12.0 g of  $\text{Ba}(\text{OH})_2$  in distilled water and dilute with distilled water to one litre.

Note – Distilled water used for dissolving  $\text{Ba}(\text{OH})_2$  shall be free from  $\text{CO}_2$ . Boiling the distilled water is one of the methods of ensuring this.

6.2.3.17 *Thymolphthalein solution* – Dissolve 10 g thymolphthalein in ethanol or methanol and dilute with same to 1 litre.

#### 6.2.4 Procedure

6.2.4.1 *Filling the combustion tube* – The combustion tube should be filled carefully so that the gases produced come in contact with a large surface area. Also the material should not be packed so much that gases cannot pass through it or required velocity of gas is not obtained. The procedure for filling is as follows:

- a) Twist ten to fifteen silver wire (150 to 200 mm) strands together and insert in the tapered end of the combustion tube;
- b) Hold the tube vertically with tapering end down;
- c) Add 100 g lead dioxide (about 100 mm layer) ;
- d) Insert 10 g silver wool (100 mm layer);
- e) Add approximately 50 g lead chromate (50 mm layer);
- f) Add asbestos loosely (20 mm layer);
- g) Add 500 g cupric oxide to form a 230 mm layer;
- h) Add asbestos loosely to form 10 mm plug;
- j) Add 37 g lead chromate to form a 40 mm layer;
- k) Add a 40-50 mm layer of the special mixture consisting of 20 g platinised asbestos plus 20 g asbestos plus 10 g of Aluminium oxide.

6.2.4.2 *Assembling of the combustion train* – Connect an oxygen cylinder with a regulator, which can afford 70 Kpa, to a 500 ml Erlenmeyer flask with two holed rubber cork, to serve as a back flow trap for liquid. Pass the gas from this flask through the gaswasher which

contains concentrated sulphuric acid. Dry the gas by passing through a jar containing magnesium perchlorate placed in the lower half of the jar and ascerite, topped with activated alumina in the upper half. Insert a small layer of glass wool beneath the magnesium perchlorate, and above the activated alumina. Let the oxygen flow through the jar from the bottom inlet at a flow rate of 250 ml per minute. Attach the combustion tube from the non-tapered end. Make a mark at a distance of 60 mm from the non-tapered end of combustion tube. This 60 mm length should always be outside. The mark helps the analyst in keeping the tube in correct position. Place aluminium foils around the tapered end to keep it hot and prevent water vapour from condensing. Attach the tapered end with two absorption U tubes each containing magnesium perchlorate between two layers of glass wool (for water vapour absorption). Another two absorption U tubes (for carbon dioxide) connected in series have a 10 mm layer of glass wool. Over this glass wool add 20 mm layer of indicarb. Cover the indicarb by a 5 mm layer of activated alumina. Fill rest of the space with glass wool. More than one such units can be used depending on the amount of carbon present in the sample. Attach this to the Erlenmeyer flask to prevent liquid back flow. Attach this to the container with barium hydroxide thymolphthaline solution. Use rubber tubing for all connection on tapered end of the combustion tube and tygon or polyethylene tubing on the other end.

**6.2.4.3 Conditioning of combustion tube** – Freshly packed tube contains moisture. It shall, therefore, be dried for two hours with 0.2 m furnace at 950°C, 0.3 m furnace at 800°C and 0.1 m furnace 200°C temperature and with the oxygen gas flowing through the tube at a rate of 250 ml per minute. Do not connect absorption container. Analyse sucrose initially to standardise the apparatus, till observed carbon and hydrogen content agree with theoretical values. The combustion train should be occasionally checked up as described above.

**6.2.4.4 Start up** – Set the temperature of the furnace at 950°C, 800°C and 200°C respectively. Open the rubber stop cock and allow the oxygen to flow through at 250 ml per minute. Open the glass stop cock to allow oxygen to flow through the combustion tube. Attach at least two absorption U tubes each for carbon dioxide and water. Allow the oxygen to flow through the system for about 10 minutes. Remove the absorption tube from the train and close each tube immediately. Record the mass of each tube, that is, carbon dioxide and water. These masses represent the initial mass of the absorption tubes. After this, again attach the absorption tubes to the train. When the gas starts flowing through the exit gas washer the train is ready for sample analysis.

Check up the flow of exit gas which should be 250 ml/min.

**6.2.4.5 Procedure for sample** – Transfer 1 to 2 g of the sample into previously weighed constant mass combustion boat. If sample is non uniform, upto 10 g may be taken. Sprinkle iron chips in each sample. Store each boat in desiccator. Cover the boats with lids and transfer them after removing the lid, at the insertion end of combustion tube. Remove stopper with attached sample inserter and place boat about half way into the tube. Then close the combustion tube by moving the sample inserter; twist the stopper tight into the tube. After this set a time at 60 minutes. Check the flow rate of oxygen after the gases start bubbling through exit gas washer. After about 5 minutes move the sample 25 mm towards the 950°C zone. After each of 3 successive 5 minute intervals move the sample boat towards 950°C zone.

After another 5 minutes move the boat completely in middle of 950°C zone. Allow the oxygen to flow through the train for the rest of 60 minutes. Remove the absorption tubes from the train and close them immediately so that they do not come in contact with the atmosphere. Record the mass of each tube of carbon dioxide and water.

**6.2.4.6 Shut Down** – Disconnect the absorption tube from the combustion tube and close each one to the atmosphere. Turn each furnace off. Turn off the oxygen flow first at the main regulator valve on the oxygen cylinder, then at the low pressure valve. Turn the glass stop cock to divert any oxygen flow from the combustion tube to the room. Immediately close the rubber stopcock.

**6.2.5** Calculate the theoretical concentration of either carbon or hydrogen in standard sample using the following equations:

$$E, \text{ percent} = \frac{N \times F \times 100}{S \times P}$$

Where

- E = The percent by mass of the element carbon or hydrogen
- N = The number of atoms of the element in a molecule of the standard.
- F = a factor derived by dividing the gram atomic weight of the element by the gram molecular weight of the standard.
- S = the mass of the total sample
- F = the decimal fraction representing the concentration of the standard compound in the total analysed sample.

### 6.2.5.1 Sample

$$C = \frac{(A - B) \times (X) (100)}{S}$$

Where

- C = carbon, percent  
A = the sum total increase in the mass of carbon dioxide absorbing tube as determined in unknown analysis.  
B = the sum of total increase in the mass of carbon dioxide absorbing tube as determined in the blank.  
X = a factor derived by dividing the gram atomic weight of carbon by the gram molecular weight of carbon dioxide for e.g.  $(12.01)/(44.01) = 0.2729$  and  
S = mass of the sample.

## 7. MEASUREMENT OF pH

### 7.1 Apparatus

7.1.1 *pH meter* — with a glass electrode.

7.2 *Procedure* — Place 10 g of the sample in a flask, add 500 ml distilled water and stir for 3-5 minutes. Let the mixture settle for 5 minutes and measure the pH using a pH meter with a glass electrode, previously calibrated and corrected for temperature.

## 8. CALORIFIC VALUE

8.1 Determine the calorific value in accordance with the method prescribed in IS : 1350 (Part II)—1970.

## 9. POTASSIUM

9.1 *Principle*— Solid waste containing organic matter is decomposed by treatment with sulphuric-nitric acid mixture. Ashing is done to convert to their respective sulphates and the residue is treated further with acid mixture containing HF to make it silica free. Sample is then subjected to flame photometric analysis.

### 9.2 Reagents

9.2.1 *Acid Mixture* — 100 ml of 1:1  $H_2SO_4$  + 650 ml of conc.  $HNO_3$  + 250 ml of distilled water.

9.2.2 *Nitric Acid* — 5 percent.

9.2.3 *HF* — 40 percent (m/m).

### 9.3 Procedure

9.3.1 Take 1 g of sample and treat with 5 ml of concentrated sulphuric acid and 5 ml of concentrated nitric acid. Heat until brown fumes cease to come. Cool. Again add 5 ml of concentrated nitric acid. Heat till brown fumes disappear. Cool. Add 10 ml of hydrogen peroxide and heat to fumes. Ignite at 600°C till all the carbonaceous matter burns off. This will be complete in one hour.

9.3.2 Treat the ashed residue with 10 ml of acid mixture and 10 ml of HF in a platinum dish. Heat to dryness. Repeat the addition of acid mixture and 10 ml of HF. Heat to dryness on a water bath. Cool. Add 50 ml of 5 percent concentrated nitric acid. Heat to dryness on a water bath. Filter, if necessary, and make up the volume to 250 ml.

9.3.3 Subject aliquot of this solution to any calibrated flame photometer by using suitable filter for potassium.

## 10 PHOSPHORUS

### 10.1 Method A — Quinoline Phosphomolybdate Method (For High Concentration).

10.1.0 *Outline of the Method* — This method involves the formation of phosphomolybdic acid in a solution free from ammonium salts, followed by its precipitation as the salt of quinoline. Finally the quinoline phosphomolybdate is titrated with sodium hydroxide.

10.1.0.1 *General* — This method has some advantages over the ammonium phosphomolybdate method, namely, the precipitate is less soluble than ammonium phosphomolybdate, of constant composition, free from absorbed or occluded impurities and free from cations which interfere in the subsequent titration of the precipitate.

The method is applicable in the presence of calcium, magnesium, iron, aluminium, alkali salts, citric acid and citrates. Chromium present upto 18 times the phosphorus content and titanium upto 3.5 times have no effect on the method. The Vanadium shall not exceed one-fifth of the phosphorus content. Nitric acid may be substituted for hydrochloric acid. Sulphuric and hydrofluoric acids are deleterious, but the effect of hydrofluoric acid may be avoided by the addition of boric acid. The interference of soluble silicates is avoided by the addition of citric acid with which molybdic acid forms a complex of such stability that its reaction with silicic acid is prevented, whereas the reaction with phosphoric acid proceeds normally. The interference of ammonia is avoided in the same manner.

### 10.1.1 Reagents

**10.1.1.1 Quinoline Hydrochloric Solution** – Add 20 ml of purified quinoline to 500 ml of hot water acidified with 25 ml of concentrated hydrochloric acid conforming to IS : 265–1976. Cool and dilute to one litre.

The quinoline used shall be purified and distilled as follows:

Dissolve the technical grade quinoline in concentrated hydrochloric acid and add excess zinc chloride solution. This precipitates quinoline as a complex salt ( $C_9H_7N_2 \cdot ZnCl_4$ ) and in well-defined crystals. Separate and wash the crystals with cold dilute hydrochloric acid. Regenerate the pure quinoline by sodium hydroxide solution. Dry and distil to yield pure and distilled quinoline.

**10.1.1.2 Citro-molybdate reagent** – prepared as follows :

- a) Dissolve 150 g of sodium molybdate ( $Na_2MoO_4 \cdot 2H_2O$ ) in 400 ml of water.
- b) Dissolve 250 g of citric acid in 250 to 300 ml of water and 280 ml of concentrated hydrochloric acid (conforming to IS : 265–1976). Pour with stirring solution (a) to solution (b) cool and filter through a filter pad. A slight greenish colour is obtained on mixing which may deepen when exposed to sunlight. Add in drops, a 0.5 percent (m/v) solution of potassium bromate to discharge the colour. Store the solution in coloured, air tight, stoppered glass bottles in the dark.

**10.1.1.3 Mixed indicator solution** – Mix 3 volumes of alcoholic phenolphthalein solution and 1 volume of alcoholic thymol blue solution (see Table 3 of IS : 2263–1962).

**10.1.1.4 Standard sodium hydroxide solution** – Carbonate free 0.5 N and 0.1 N (see IS : 2316–1968).

**10.1.1.5 Standard hydrochloric acid** – 0.5 N and 0.1 N (see IS : 2316–1968).

**10.1.1.6 Dilute hydrochloric acid** – 10 percent, dilute 100 ml of hydrochloric acid (conforming to IS : 265–1976) to 1 litre with water.

**10.1.2 Procedure** – Take in a 250 ml conical flask an aliquot of the clear solution of the material, containing about 50 mg of phosphorus pentoxide (30 mg of P) present as orthophosphate in about 100 ml (see Note 1 under 10.1.2.1). Add 50 ml of citromolybdate reagent and bring to boil. Add 5 drops of quinoline hydrochloride solution stirring during the addition. Again heat to boiling and add quinoline hydrochloride solution drop by drop with constant stirring until 2 ml have been added. To the gently boiling solution add the quinoline hydro-



chloride solution few millilitres at a time with constant stirring until a total of 60 ml has been added. In this manner, a coarsely crystalline precipitate is produced. Allow to stand on the hot-plate for 15 minutes and then cool to room temperature. Filter through a filter paper or pulp and employing suction and wash the flask, precipitate and filter with cold water until they are free from acid. Transfer the filter pad and the precipitate to the original flask and rinse the funnel with water into the flask. If necessary, wipe the funnel with a small piece of damp filter paper to ensure complete removal of the precipitate and place the paper in the flask. Dilute to about 100 ml with water. Stopper the flask and shake it vigorously until the pulp and the precipitate are completely disintegrated. Remove the stopper and wash it with water, returning the washing to the flask. From a burette add 50 ml of 0.5 N standard sodium hydroxide solution, shaking the flask during the addition. Shake vigorously until all the precipitate dissolves (see Note 2 under 10.1.2.1). Add 1 ml of mixed indicator solution and titrate the excess of sodium hydroxide solution with 0.5 N hydrochloric acid until the indicator changes from violet to green blue and then very sharply to yellow.

10.1.2.1 Carry out a blank determination using all reagents, without the sample and using exactly 0.1 N standard sodium hydroxide solution and 0.1 N standard hydrochloric acid instead of 0.5 N acid and 0.5 N alkali.

Note – The volume should not exceed 100 ml, as any reduction in the concentration of hydrochloric acid may lead to the formation of a cream coloured precipitate of the wrong composition. To avoid such contamination in the presence of sulphates, a higher concentration of hydrochloric acid is necessary.

Note 2 – Examine the disintegrated paper pulp carefully for specks of undissolved precipitate which sometimes dissolves in excess of sodium hydroxide with difficulty.

### 10.1.3 Calculation

$$\text{Phosphates (as P),} \\ \text{percent by mass} = \frac{0.05965 [V_1 - V_2 - \frac{(V_3 - V_4)}{5}]}{M}$$

$$\text{Phosphates (as } P_2O_5), \\ \text{percent by mass} = \frac{0.1366 [V_1 - V_2 - \frac{(V_3 - V_4)}{5}]}{M}$$

Where

$V_1$  = Volume in ml of 0.5 N sodium hydroxide solution used with the sample.

$\underline{V}_2$  = Volume in ml of 0.5 N hydrochloric acid used with the sample.

$\underline{V}_3$  = Volume in ml of 0.1 N sodium hydroxide used in the blank.

$\underline{V}_4$  = Volume in ml of 0.1 N hydrochloric acid used in the blank, and

$\underline{M}$  = Mass in g of the material contained in the solution taken for the precipitation.

## 10.2 Method B — Method Based on the Reduction with stannous chloride (for Concentrations below 0.003 mg/l)

10.2.0 Outline of the Method — A blue colour is produced by the reduction of phosphomolybdic acid with freshly prepared stannous chloride solution.

### 10.2.1 Apparatus

10.2.1.1 Separating Funnels — of 200 ml capacity.

10.2.1.2 Nessler Cylinder — of 50 ml capacity (see IS : 4161–1967).

10.2.1.3 pH Meter — glass electrode type.

### 10.2.2 Reagents

10.2.2.1 Ammonium Molybdate Solution — Dissolve 10 g of ammonium molybdate in 100 ml of water. When cool, add the solution to 300 ml of 1 : 1 sulphuric acid. Keep the reagents in a glass bottle, protected from light.

10.2.2.2 Stannous Chloride Solution — Warm 0.1 g of tin foil in 2 ml of hydrochloric acid and drop of 4 percent (m/v) copper sulphate solution in a test tube until no more tin dissolves; cool and dilute to 10 ml with water. The reagent shall be prepared freshly for each determination.

10.2.2.3 Standard Phosphate Solution — Dissolve 3.77 g of sodium hydrogen phosphate ( $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$ ) in water and dilute to 1000 ml. One millilitre of the solution contains 1.0 mg of phosphate (as  $\text{PO}_4$ ). It may be diluted suitably to contain 10, 25, 50 or 100 mg of phosphate per millilitre.

10.2.2.4 Ether — Conforming to IS : 336–1964.

10.2.2.5 Hydrochloric acid — Conforming to IS : 265–1976.

### 10.2.3 Procedure

10.2.3.1 Prepare the solution. Take a convenient aliquot of the prepared solution, so as to contain 0.025 mg of phosphorus (as  $\text{P}_2\text{O}_5$ ). Transfer the solution to a platinum dish and dilute to 50 ml. Digest on a steam-bath for 20 minutes. Cool, adjust the pH to about 4 and dilute to 75 ml. Add 1 ml of ammonium molybdate reagent and mix well. When it is dissolved adjust the pH to 2 by adding dilute hydro-

chloric acid. Check the pH using pH meter (glass electrode). Heat to boiling, cool to room temperature, add 10 ml of concentrated hydrochloric acid and dilute to 100 ml with water. Transfer the solution to a separating funnel, add 35 ml of ether, shake vigorously and allow to separate. Draw off the aqueous phase which may contain silicates and discard. Wash the ether phase with 10 ml of hydrochloric acid and allow to separate. Drain off and discard this aqueous phase. Drain the ether layer quantitatively to a Nessler cylinder and develop the colour by adding 0.15 ml of stannous chloride and develop the colour by adding 0.15 ml of stannous chloride reagent. Mix well and make up to mark with ether.

10.2.3.2 Transfer several aliquots of the standard phosphate solution to separating funnels and develop the colour following the steps described in 10.2.3.1.

10.2.3.3 Compare the colour with those produced with the standard phosphate solution. Note the volume of the standard phosphate solution with which the colour of the test solution matches closely.

#### 10.2.3.4 Calculation

$$\text{Phosphate (as PO}_4\text{),} \\ \text{percent by mass} = \frac{100 \times f \times V}{\underline{M}}$$

Where

$f$  = mass in g of phosphorus (as  $\text{PO}_4$ ) equivalent to 1 ml of standard phosphate solution.

$\underline{V}$  = Volume in ml of standard phosphate solution matching closely with colour of the test solution and

$\underline{M}$  = Mass in g of the material in the aliquot used for test.

Note – The colour is produced only in presence of orthophosphates. Meta and pyro phosphate should be completely hydrolyzed before determination. Free acids and alkalis which depress the colour development should be neutralized. Organic acids like citric, tartaric and oxalic inhibit the colour formation. If organic matter is present in appreciable amounts, it should be removed. Ferric iron exceeding 1 ppm should be reduced to ferrous iron as well as arsenate to arsenite.

**PREPARATION OF REFUSE SAMPLES FOR MICROSCOPIC ANALYSIS**

The following method can be used for the isolation of human intestinal parasites from refuse samples:

- 1 100 ml of 0.2% sodium hypochlorite is added to refuse sample weighing 200 g and which is free of unusually large stones, etc.
- 2 The sample is then mixed with water and homogenized in a blender for 2 min.
- 3 The supernatant is decanted and the sediment washed with water, accompanied by stirring with a glass rod. The process of washing and decantation is repeated till the decanted liquid measures 1,000 ml.
- 4 A 100-ml portion of this liquid is then strained, first through a coarse wire gauze (opening size: 4 mm) and then through a fine wire gauze (opening size: 2 mm).
- 5 A 10-ml sample of this strained liquid is then centrifuged at 2,000 rpm for 1 min. The supernatant from the 12 ml centrifuge tube is then decanted.
- 6 The sediment in the centrifuge tube is then mixed with fresh water and again centrifuged at 2,000 rpm for 1 min. and the supernatant decanted.
- 7 The sediment remaining in the centrifuge tube is mixed with 8 ml of 10 per cent formalin and 2 ml of ether and then centrifuged at 1,000 rpm for 1 min. The supernatant is decanted and the sediment made upto 50 ml with water.
- 8 The suspension of the sediment in water is taken in a Sedgewick Rafter Counting Cell and subjected to microscopic test.
- 9 The 50 ml suspension contained 1 g of sediment and the counts from the Sedgewick Rafter Cell will be per ml.

$$\text{Eggs/gm} = \text{eggs/ml} \times 25$$

(A) *Physical Characteristics of Refuse from Indian Cities (during 1971-73)*  
 (% on wet weight basis)

Sr. No	Name of the City	Paper	Plastics	Rags	Metals	Glass	Total Compo- stable Matter
1	2	3	4	5	6	7	8
1	Aurangabad	4.51	0.28	3.36	0.52	0.67	36.30
2	Bangalore	1.91	0.32	0.75	0.32	0.21	53.83
3	Bikaner	1.03	0.52	3.59	0.14	0.53	14.52
4	Calicut	6.03	1.75	2.02	0.38	0.06	66.05
5	Coimbatore	3.08	0.13	4.24	0.54	0.40	35.24
6	Gorakhpur	1.97	0.62	3.68	0.31	0.18	34.92
7	Gwalior	4.58	0.65	2.02	0.57	0.38	30.03
8	Jabalpur	2.01	0.69	1.68	0.39	0.36	39.87
9	Jodhpur	1.43	0.31	3.32	0.21	0.15	19.81
10	Kurnool	1.07	0.28	1.08	0.24	0.08	40.57
11	Madurai	7.81	1.44	4.23	0.70	0.52	26.51
12	Patna	3.00	0.20	3.16	0.27	0.15	23.24
13	Raipur	1.83	0.66	1.31	0.44	0.23	38.44
14	Rajkot	1.44	0.53	1.35	0.50	0.14	55.38
15	Sangli	3.04	0.35	2.13	0.21	0.37	51.24
16	Surat	3.03	1.01	2.22	0.37	0.28	44.26
17	Tiruchirapalli	5.57	1.62	6.36	0.29	1.28	45.99
18	Trivandrum	3.62	0.93	1.43	0.38	0.14	71.78
19	Udaipur	2.38	0.28	3.18	0.16	0.57	31.03
20	Vijaywada	1.47	0.16	1.31	0.14	0.27	31.94
21	Ahmedabad	3.02	0.84	4.11	0.42	0.23	49.30
22	Allahabad	3.82	8.69	2.61	0.56	0.39	44.50
23	Baroda	4.78	0.29	3.32	0.60	0.25	39.25
24	Bhopal	7.71	0.55	5.38	0.56	0.75	38.67
25	Chandigarh	6.17	8.33	5.24	0.22	0.21	34.74
26	Delhi	6.29	0.85	4.70	1.21	0.57	35.42
27	Hyderabad	4.81	0.84	3.16	1.23	0.93	39.46
28	Jaipur	3.03	0.80	5.98	0.61	0.39	25.89
29	Kanpur	2.97	0.63	2.77	0.39	0.38	41.09
30	Madras	7.85	0.88	4.85	0.95	0.97	47.97

1	2	3	4	5	6	7	8
31	Tatanagar	3.48	0.45	2.43	0.45	0.33	27.38
32	Calcutta	3.18	0.65	3.60	0.66	0.38	40.38
33	Howrah	4.62	0.71	2.75	0.16	0.29	34.99
34	Gauhati	3.46	0.18	0.29	0.68	0.28	50.59
35	Nagpur	3.51	0.39	4.07	0.65	0.58	41.79
36	Kota	1.09	0.27	2.70	1.13	0.22	48.76
37	Pune	8.74	0.72	1.63		0.58	67.64
38	Thane	5.5	1.00	2.25	0.30	0.25	53.00
39	Ajmer	1.44	1.02	3.28	0.31	0.40	38.15
40	Bombay	4.89	2.92	2.48	2.46	0.72	59.78
	Average	4.14	0.69	3.83	0.50	0.40	41.24
	Standard Deviation	2.73	0.52	1.40	0.42	0.26	12.59

(B) *Chemical Characteristics of Refuse from Indian Cities (during 1971-73)*  
(% by dry weight basis)

Sr No	Name of City	Mois- ture	O.M.**	N <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	HCV in Kcal/kg	Per Capita kg/day
1	2	3	4	5	6	7	8	9
1	Aurangabad	18.23	20.52	0.58	0.75	0.51	603	0.42
2	Bangalore	33.15	20.18	0.55	0.81	1.11	726	0.32
3	Bikaner	15.43	11.93	0.42	0.45	0.78	515	0.29
4	Calicut	35.44	25.44	0.57	0.83	0.51	844	0.15
5	Coimbatore	19.78	25.85	0.65	0.69	1.07	1077	0.31
6	Gorakhpur	13.25	16.18	0.57	0.65	0.72	783	0.21
7	Gwalior	18.85	22.42	0.72	0.79	1.05	935	0.27
8	Jabalpur	16.60	25.35	0.64	0.65	0.77	1082	0.30
9	Jodhpur	9.00	15.53	0.53	0.51	0.85	653	0.20
10	Kurnool	24.75	29.26	0.92	0.73	1.06	1265	0.20
11	Madurai	26.84	25.52	0.82	0.69	0.90	1077	0.38
12	Patna	13.90	14.14	0.56	0.77	0.74	631	0.48
13	Raipur	13.61	34.14	0.35	0.68	1.19	1438	0.32
14	Rajkot	18.06	24.79	0.68	0.62	0.56	879	0.07

1	2	3	4	5	6	7	8	9
15	Sangli	20.20	27.49	0.69	0.65	0.53	907	0.23
16	Surat	18.40	22.90	0.66	0.78	0.61	965	0.15
17	Tiruchirapalli	42.48	31.71	0.93	0.71	1.07	1399	0.21
18	Trivandrum	26.91	25.49	0.82	0.49	0.49	1114	0.12
19	Udaipur	15.30	27.58	0.84	0.78	1.04	1082	0.14
20	Vijaywada	17.89	24.23	0.64	0.42	0.69	1005	0.17
21	Ahmedabad	23.43	25.18	0.41	0.53	0.52	984	0.24
22	Allahabad	16.55	16.55	0.59	0.59	0.67	727	0.20
23	Baroda	21.89	21.15	0.64	0.57	0.53	786	0.29
24	Bhopal	27.74	30.71	0.70	0.65	0.99	1294	0.26
25	Chandigarh	26.33	23.64	0.53	0.50	0.55	1012	0.36
26	Delhi	26.98	25.42	0.60	0.71	0.60	1215	0.21
27	Hyderabad	11.39	25.91	0.59	0.59	0.61	1125	0.33
28	Jaipur	21.05	15.74	0.44	0.78	0.51	525	0.28
29	Kanpur	18.56	21.01	0.55	0.68	0.64	709	0.55
30	Madras	38.63	29.71	0.57	0.48	0.76	1068	0.32
31	Tatanagar	15.61	14.88	0.39	0.67	0.45	616	0.45
32	Calcutta	41.11	35.24	0.55	0.58	0.41	1504	0.50
33	Howrah	-	21.28	0.54	0.86	0.55	859	0.59
34	Gauhati	19.40	28.50	0.65	0.61	0.60	1127	0.24
35	Nagpur	22.45	29.44	0.65	0.76	0.66	1178	0.22
36	Kota	10.00	45.75	0.67	0.88	0.74	1640	0.25
37	Pune	38.51	40.92	0.82	0.60	0.54	-	0.24
38	Thana	20.00	40.00	0.57	1.10	0.75	1490	0.23
39	Ajmer	10.00	40.99	0.80	0.43	0.60	1352	0.24
40	Bombay	50.60	23.60	0.93	0.89	0.34	1341	0.49
	Average	22.52	25.68	0.64	0.66	0.71	1014	0.27
	Standard Deviation	9.80	7.77	0.50	0.18	0.22	291	0.11

Organic Matter \*\*

**SANITARY PROVISIONS UNDER BOMBAY MUNICIPAL ACT  
SCAVENGING AND CLEANSING**

365 For the purpose of securing the efficient scavenging and cleansing of all streets and premises, the Commissioner shall take measures for securing:

- a) the daily surface-cleansing of the streets in (Greater Bombay) and the removal of the sweeping therefrom;
- b) the removal of the contents of all receptacles and depots and of the accumulations at all places provided or appointed by him under section 367 or 368 for the temporary deposit of any of the matters specified in the said sections.

366 All matters collected by municipal servants or contractors in pursuance of the last preceding section and the section 369. This refers to excrementitious matter from privies, urinals and cesspools and carcasses of dead animals deposited in any public receptacle, depot or place under section 367 shall be the property of the Corporation.

367 The Commissioner shall provide or appoint in proper and convenient situations public receptacles, depots and places for the temporary deposit or final disposal of:-

- a) dust, ashes, refuse and rubbish;
- b) trade refuse;
- c) carcasses of dead animals and excrementitious matter and provided that -
  - i) the said matters shall not be finally disposed of in any place or manner in which the same have not heretofore been so disposed of, without the sanction of the Corporation or in any place or manner which (the State Government) think fit to disallow;
  - ii) any power conferred by this section shall be exercised in such manner as to create the least practicable nuisance.

368 1) It shall be incumbent on the owners and occupiers of all premises to cause all dust, ashes, refuse, rubbish, and trade refuse to be collected from their respective premises and to be deposited at such times as the Commissioner, by public notice, from time to time, prescribes in the public receptacle, depot or place provided or appointed under the last preceding section or the temporary deposit or final disposal thereof.



- 2) Provided that the Commissioner, may, if he thinks fit, by written notice require the occupier and owner or either of them of any premises, to cause all dust, ashes, refuse and rubbish, but not trade refuse to be collected daily, or otherwise periodically, from the said premises and deposited temporarily upon any place forming the part of the said premises which the Commissioner appoints in this behalf and it shall be incumbent on the said occupier and owner or either of them to cause the said matters to be collected and deposited accordingly.
- 3) It shall be incumbent on the owners of all premises to provide receptacles of a size to be prescribed by the Commissioner for the collection therein of all dust, ashes, refuse, rubbish and trade refuse to be collected from such premises. Such receptacles shall at all times be kept in good repair and condition and shall be provided in such number and place and retained in such positions as the Commissioner may, from time to time, by written notice direct.
- 4) It shall be also incumbent on the owners and occupiers or either of them of all premises when required by the Commissioner of written notice so to do, to employ servants for the purpose of carrying out and complying with the requirements of sub-section (1) and (2) of this section.

(Amendment of section 368 of Bom-III of 1888). In section 368 of the Bombay Corporation Act, after sub-section (4), the following sub-section shall be added - namely:

- 5) Notwithstanding anything contained in this section, if the owner or occupier of any trade premises desired permission to deposit trade refuse, collected daily or periodically from the premises, temporarily upon any place appointed by the Commissioner in this behalf, the Commissioner may, on his application, and on payment of such charges as the Commissioner may, from time to time fix, allow the applicant to deposit the trade refuse accordingly.
- 372 a) Who is bound, under section 368 or section 370. This relates to excrementitious and polluted matter, to cause the removal of dust, ashes, refuse (rubbish and trade refuse) or of excrementitious or polluted matter, shall allow the same to accumulate on his premises for more than twenty four hours or neglect to cause the same to be removed to the depot, receptacle or place provided or appointed for the purpose;

- b) shall remove any dust, ashes, refuse (rubbish or trade refuse) or any excrementitious or polluted matter, otherwise than in conformity with the requirements of any public or written notice at the time being in force under section 368, or use for the removal of any excrementitious or polluted matters any vehicle or vessel not having a covering proper for preventing the escape of any portion of the contents thereof or of the stench therefrom;
- c) shall, whilst engaged, in the removal of any dust, ashes, refuse (rubbish or trade refuse) or of any excrementitious or polluted matter, fail forthwith thoroughly to sweep and cleanse the spot in any street upon which, during removal, any portion thereof may fall and entirely to remove these sweepings;
- d) shall place or set down in any street any vehicle or vessel for the removal of excrementitious or polluted matter, or suffer the same to remain in any street for any greater length of time than is reasonably necessary;
- e) shall throw or place any dust, ashes, refuse (rubbish or trade refuse) or any excrementitious or polluted matter, on any street, or in any place not provided or appointed for this purpose under section 367 or 368;
- f) who is the owner or occupier of any building or land, shall allow any filthy matter to flow, soak or be thrown therefrom, or keep or suffer to be kept therein or, thereupon, anything so as to be a nuisance to any person, or negligently suffer any privy-receptacle or other receptacle or place for the deposit of filthy matter or rubbish on his premises to be in such a state as to be offensive or injurious to health;
- g) shall deposit the skin or otherwise dispose of the carcass of any dead animal at a place not provided or appointed for this purpose under section 367.

373 If it shall in any case be shown that dust, ashes, refuse (rubbish or trade refuse) or any excrementitious or polluted matter, has or have been thrown or placed on any street or place, in contravention of clause (a) of the last preceding section, from some building or land, it shall be presumed, until the contrary proved, that the said offence has been committed by the occupier of the said building or land.

385 1) It shall be the duty of the Commissioner to provide for the removal of the carcasses of all animals dying within (Greater Bombay).

- 2) The occupier of the premises in or upon which any animals shall die or in or upon which the carcass of any animal shall be found, and the person having the charge of any animal which dies in the street or in any open place, shall within three hours after the death of such animal or, if the death occurs at night, within three hours after sunrise, report the death of such animal at the municipal health department office of the division of the (Greater Bombay) in which the death occurred or in which the carcass is found and shall not unless authorised by the Commissioner in this behalf, remove or permit to be removed the carcass of any animal dying in or upon any place within Greater Bombay.
- 3) For every carcass so removed by municipal agency, a fee for the removal of such amount as shall be fixed by the Commissioner, shall be paid by the owner of the animal or, if the owner is not known, by the occupier of the premises in or upon which, or by the person in whose charge, the said animal died.

THE CALCUTTA MUNICIPAL CORPORATION BILL, 1980

(Part V. - Civic Services - Chapter XX - Solid Wastes. Clauses 322-329)

CHAPTER XX

Solid Wastes

*A. Functions in relation to solid wastes*

Collection, removal and disposal of solid wastes.

322. For the purpose of securing the efficient scavenging and cleansing of all streets, public places and premises in Calcutta, the Corporation shall undertake the functions of collection, removal and disposal of solid wastes.

Provision for receptacles, depots and places for temporary deposit.

323 (1) The Corporation shall provide or appoint in proper and convenient situations public receptacles, depots and places for the temporary deposit of -

- (a) rubbish;
- (b) offensive matter;
- (c) trade refuse;
- (d) carcasses of dead animal;
- (e) excrementitious and polluted matter.

(2) Different receptacles, depots or places may be provided or appointed for the temporary deposit of any of the matters specified in sub-section (1).

Provision of vehicles or other suitable means for removal of solid wastes

324 (1) The Corporation shall provide vehicles or other suitable means and where necessary covered vehicles or vessels for the removal of solid wastes.

(2) The Corporation may construct, acquire, operate, maintain, develop or manage any garage or work for proper maintenance of the vehicles or vessels or means for removal of solid wastes under sub-section (1).

Appointment of places for disposal and final disposal of solid wastes

325 The Mayor-in-Council may cause the solid wastes to be disposed of at such place or places within or outside Calcutta and in such manner as it considers suitable.

Provided that no place, which has not been before the commencement of this Act used for the purposes

specified in this section, shall be used except in conformity with the provisions of the West Bengal Town and Country (Planning and development) Act, 1979 and without the approval of the Corporation: *West Ben. Act XIII of 1979.*

Provided further that the solid wastes shall not be finally disposed of in any manner in which the same have not heretofore been so disposed of without the sanction of the Corporation or in any manner which the State Government may think fit to disallow.

Solid wastes to be the property of the Corporation

326 All matters deposited in public receptacles, depots and places provided or appointed by the Corporation and all solid wastes collected shall be the property of the Corporation.

Provision of means of processing of solid wastes.

327 The Corporation may, for the purpose of receiving, storing, treating, processing and disposing solid wastes or converting such solid wastes into compost or other matter, construct, acquire, operate, maintain, develop and manage any work within or outside Calcutta and run it on a commercial basis.

Solid wastes may be used for land filling.

328 The Mayor-in-Council may, subject to the regulations made in this behalf, cause to be utilized solid wastes for filling up any well, tank or low land and perform this function on a commercial basis within or outside Calcutta.

Solid waste management.

329 Subject to the other provisions of this Chapter, the Municipal Commissioner shall perform all the functions and manage all the places or works related to collection, removal and disposal of solid wastes accumulating in Calcutta.

Municipal Commissioner to provide for cleansing of streets and removal of solid wastes.

330 (1) The Municipal Commissioner shall take measure for securing -

- (a) the daily surface cleansing of all streets in Calcutta and removal of sweeping therefrom;
- (b) the removal of the contents of all receptacles and depots and of the accumulations at all places provided or appointed by the Corporation under the provisions of this Act for the temporary deposit of rubbish, trade refuse,

carcasses of dead animals and excrementitious and polluted matter;

- (c) the removal of special wastes and hazardous wastes and other solid wastes from premises.

(2) The Municipal Commissioner may, by public notice, issue directions as to the time at which, the manner in which, and the conditions subject to which, any matter referred to in sub-section (1) may be removed along a street or may be deposited or otherwise disposed of.

(3) The Municipal Commissioner shall make adequate provision for preventing receptacles, depots, places, vehicles and vessels referred to in this Chapter from becoming sources of nuisance.

Special  
sanitary  
arrangements  
at certain places.

331 (1) The Municipal Commissioner may make such special arrangements, whether permanent or temporary, as he considers adequate for maintaining sanitation in the vicinity of any place of religious worship or institutions or places to which large number of persons resort on particular occasions in any place used for holding fairs, festivals, sports or cultural or social events.

(2) The Municipal Commissioner may require any person having control over any such place to pay to the Corporation fees at such rates as the Mayor-in-Council from time to time determine.

*B. Collection and Removal for Solid Wastes*

Duties of owners  
and occupiers to  
collect and de-  
posit rubbish,  
etc.

332 It shall be the duty of the owners or the occupiers as the case may be, of all premises -

- a) to have the premises swept and cleaned;
- b) to cause all rubbish and offensive matters to be collected from their respective premises and to be deposited, at such time as the Municipal Commissioner by public notice specifies, in public receptacles, depots or places provided or appointed by the Corporation or in receptacles provided under clause (c) for the temporary deposit or final disposal thereof;
- c) to provide receptacles of the type and in the manner specified by the Municipal Commissioner for the

collection therein of all rubbish and offensive matters from such premises and to keep such receptacles in good condition and repair.

Removal of solid wastes accumulated on non-residential premises.

- 333 The Municipal Commissioner may if he thinks fit -
- a) by written notice, require the owner or the occupier of any premises used -
    - i) as factory, workshop or for carrying on any manufacture, or
    - ii) as a trade premises or shop or as market or slaughter house, or
    - iii) as a hotel, eating house, or restaurant, or
    - iv) as a hospital or nursing home, or
    - v) as a warehouse or godown, or
    - vi) as a place to which large number of persons resort, or
    - vii) in any other way, whether rubbish, offensive matter, filth, trade refuse, special wastes, hazardous wastes or excrementitious, and polluted matters are accumulated in large quantities, to collect such matters accumulating thereon and to remove the same at such time and in such trailers or receptacles and by such routes as may be specified in the notice to a depot or place provided or appointed by the Corporation, or
  - b) after giving such owner or occupier notice of his intention, cause all rubbish including building rubbish, offensive matter, trade refuse, special wastes, hazardous wastes or excrementitious and polluted matter accumulated in such premises to be removed, and charge the said owner or occupier for such removal such fee as may, subject to the rates determined by the Mayor-in-Council be specified in the notice issued under clause (a); provided that no rate shall be less than such unit cost of removal of solid wastes (including the cost for debt servicing, depreciation and other charges, if any, of vehicles or vessels or means for removal) as the Mayor-in-Council may determine from time to time, or

- c) by written notice, requires the owner or the occupier of any premises referred to in clause (a) to provide receptacles or trailers or other means on such premises constructed from such materials and of the type and in the manner specified by the Municipal Commissioner for the collection therein of all rubbish including building rubbish, offensive matter, filth, trade refuse, special wastes, hazardous wastes or excrementitious and polluted matters accumulating in the premises.

Temporary deposit of rubbish, etc. in bustees and removal thereof.

334 (1) Any land that may be required in any bustee for temporary deposit of rubbish, offensive matters, sewage or carcasses of animals accumulating in such bustee shall be provided by the owner of such bustee.

(2) The Corporation or any other statutory authority may subject to the provisions of the West Bengals Slum Areas (Improvement and Clearance) Act, 1972, provide in proper and convenient situations public receptacles, depots and places for the temporary deposit of rubbish, offensive matters, sewage or carcasses of animals accumulating in bustees.

(3) It shall be the duty of the owners or the occupiers, as the case may be, of all huts -

- a) to have the huts swept and cleaned;
- b) to cause all rubbish including building rubbish, offensive matters, sewage or carcasses of animals to be collected from their respective huts and to be deposited in the public receptacles, depots and places provided under sub-section (2) at such times as the Municipal Commissioner by public notice specifies.

Collection and removal of filth and polluted matter

335 When the Municipal Commissioner has given public notice of his intention to provide in a certain portion of Calcutta for the collection, removal and disposal by the employees or contractors of the Corporation of all excrementitious and polluted matters from privies, urinals and cesspools, it shall be lawful for the Municipal Commissioner to take measures for the daily collection, removal and disposal of such matters from all premises



situated in the said portion of Calcutta:-

Provided that in areas where the sewers have been laid, the Municipal Commissioner may, in accordance with such scheme as may be prepared for such purpose or otherwise, require the owner or the occupier, as the case may be, of any premises to convert the service privies to sanitary latrines and such owner or occupier shall comply with the orders of the Municipal Commissioner.

*C. General Provisions in relation to Solid Wastes*

Prohibition  
against  
deposit of  
solid wastes.

336 (1) No person shall deposit or cause or permit to be deposited or throw upon or along any public street, public place, land belonging to the Corporation or any unoccupied land or on the bank of a water course any solid waste except in accordance with the provision of this Act.

(2) Without prejudice to the generality of the foregoing provision, no person shall deposit or cause or permit to be deposited any building rubbish in or along any street, public place or land except in conformity with the conditions of prior permission from the Municipal Commissioner;

Provided that no permission shall be given until an advance payment of a fee for the removal by the employees or contractors of the Corporation of such rubbish has been made in accordance with such rates as may be determined by the Mayor-in-Council from time to time; Provided further that if the Municipal Commissioner thinks fit he may, for reasons to be recorded, refuse to give such permission.

Presumption  
as to offender

337 If any rubbish, offensive matter, trade refuse, special waste, hazardous waste or excrementitious and polluted matter accumulating on any premises is deposited in any place in contravention of the provisions of this Act, it shall be presumed, unless the contrary is proved, that such contravention has been committed by the occupier of such premises.

Depositing or  
throwing any

338 Whoever deposits or throws or causes or permits to be deposited or throws any solid waste on any place in

solid waste in contravention of the provisions of this Act.

Municipal Commissioner's power to get places scavenged and cleansed.

Municipal Commissioner to sanction building plan in certain cases except in conformity with regulations for solid wastes

contravention of the provisions of this Act, shall, subject to such regulations as may be made in this behalf, be punishable with fine which shall not be less than fifty rupees and more than five thousand rupees for each such offence.

339 If any street or public place under the control of Government or any statutory body, or any premises to which large number of persons resort to, is not properly or regularly scavenged or is, in the opinion of the Municipal Commissioner, in a filthy and unwholesome condition, the Municipal Commissioner may, by written notice, require the owner or the occupier to do the scavenging or cleansing or may cause scavenging or cleansing to be done and the cost of such scavenging or cleansing shall be recovered from the owner or the occupier thereof.

340 (1) The Corporation may by regulations determine any class or classes of buildings in the cases of which the Municipal Commissioner shall not sanction any building plan except in conformity with the regulations framed by the Corporation for construction on the premises of receptacles for temporary deposit of solid wastes.

(2) The Corporation may by regulations determine the types, materials of construction or designs on the basis of which such receptacles, trailers or other means for removal of solid wastes may be constructed and where these may be located in any premises, and the person applying for sanction of building plan shall be bound to construct the same accordingly.

(3) Without prejudice to the generality of the foregoing provision, the Corporation shall by regulations specify the requirements for receptacles, trailers or other means for removal or for temporary deposit of solid waste in premises used as -

- a) markets, or
  - b) hotels or restaurants, or
  - c) hospitals or nursing homes, or
  - d) factories registered under the Factories Act, 1948
  - e) buildings with a height of 18 metres or more.
- 63 of 1948.*

Power to inspect premises for sanitary purposes.

Notice to be given by methar etc. before withdrawing from work.

341 The Municipal Commissioner may inspect within sunrise or sunset any premises for the purpose of ascertaining compliance with the provisions of this Chapter.

342 Notwithstanding anything to the contrary contained in any other law in force for the time being, no methar or other employee of the Corporation who is employed to remove or otherwise deal with any rubbish, offensive matter, filth, trade refuse, or other solid waste, shall, without giving the Municipal Commissioner any notice of his intention so to do or without the permission of the Municipal Commissioner, withdraw from his duties.

RELEVANT EXTRACTS FROM MUNICIPAL COUNCILS  
AMENDMENT ACT, No.12 OF 1959 OF PARLIAMENT OF CEYLON.  
DATE OF ASSENT, MAY 15, 1959

CHAPTER 252 - MUNICIPAL COUNCILS

*Part IV - Status, Powers & Duties of Municipal Councils*

- General duties of Council
- 46 Every Municipal Council shall, within the Municipality, have the following duties :
- a) to maintain and cleanse all public streets and open spaces vested in the Council or committed to its management;
  - b) to enforce the proper maintenance, cleanliness and repair of all private streets;
  - c) to supervise and provide for the growth and development of the Municipality by the Planning and widening of streets, the reservation of open spaces, and the execution of public improvements;
  - d) to abate all nuisances;
  - e) to establish and maintain (subject to the extent of its resources) any public utility service which it is authorized to maintain under this Ordinance and which is required for the welfare, comfort or convenience of the public;
  - f) generally to promote the public health, welfare and convenience, and the development, sanitation and amenities of the Municipality.

*Part V - Powers and Duties as to Streets*

- Power to throw rubbish upon adjacent land
- 55 In the tracing, measuring, making, working, opening, altering, turning, repairing, clearing, or improving of any existing or intended street within any Municipality, or building, excavating, repairing, clearing, or improving any bridge, fence, drain, dam, or ditch thereupon or in any way connected therewith, it shall be lawful for the proper officer of the Municipal Council to throw

upon any lands adjacent or near to the street such earth, rubbish, or materials as it may be necessary to remove from the place of any such work.

*Part VI - Powers and Duties as to Public Health  
(Conservancy and Scavenging)*

129 It shall be the duty of the Council, so far as is reasonably practicable, to take all necessary measures in every part of the Municipality :

- a) for properly sweeping and cleansing the streets, including the footways, and for collecting and removing all street refuse;
- b) for securing the due removal at proper periods of all house refuse, and the due cleansing and emptying at proper periods of all latrines and cesspits; and
- c) for the proper disposal of all street refuse, house refuse and night-soil.

All refuse collected to be property of Council

130 All street refuse, house refuse, night-soil or other similar matter, collected in any Municipality under the provisions of this part shall be the property of the Council, and the Council shall have full power to sell or dispose of all such matter and the money arising therefrom shall be paid to the credit of the Municipal Fund.

Places for disposal of refuse and keeping equipment

131 The Council shall from time to time provide places convenient for the proper disposal of all street refuse, house refuse, night-soil, and similar matter removed in accordance with the provisions of this part, and for keeping all vehicles, animals, implements, and other things required for that purpose or for any of other purposes of this Ordinance, and shall take all such measures and precautions as may be necessary to ensure that no such refuse, night-soil, or similar matter removed in accordance with the provisions of this part is disposed of in such a way as to cause a nuisance.

*Part XIII - Bylaws*

Matters with respect to which bylaws may be made

272 In particular and without prejudice to the generality of the powers conferred by the preceding sections, bylaws may be made by a Municipal Council for and with respect to all or any of the following matters, namely :

X X X X

5 Sanitation, including :

- a) the prevention and abatement of nuisance;
- b) the removal and disposal of night-soil, and the charging, levying, and recovering of fees for such removal and disposal;
- c) the inspection, regulation, maintenance, and cleansing of all drains, privies, earthclosets, cesspools, ash-pits, and sanitary appliances, the closing of buildings or parts of buildings unfit for human habitation, and the prohibition of their use for such habitation;
- d) the conservancy of private premises;
- e) the regulation of any houses or places established for the reception of persons suffering from infectious diseases, and for the imposing and recovering of fees for the use and occupation of such houses or places;
- f) the cleansing, disinfection, and destruction of temporary buildings and infected articles, and the cleansing and disinfection of buildings;
- g) the regulation and control of swine;
- h) the prevention of malaria and the destruction of mosquitoes and other diseases braring insects;
- i) the licensing, regulation, inspection and control of stables and cattle galas;
- j) washing and bathing, including the regulation, supervision, inspection and control of bathing places (other than bathing places established by the Council) and places for washing animals (other than places for washing animals established by the Council).

6 Streets, including:

- a) the improvement, making, repairing, cleansing, watering, and lighting of streets;
- b) the prevention and abatement of obstructions and encroachments on streets, roads, and canals;
- c) the regulation of traffic in streets;
- d) the erection of hoardings and other temporary structures, and the charging of fees for the same.

RELEVANT EXTRACTS FROM BYE-LAWS AND REGULATIONS  
OF THE MUNICIPAL COUNCIL OF COLOMBO

*Revised upto August 31, 1958*

Householder  
to deposit  
rubbish in  
proper  
receptacles

31 Any person who is desirous that ashes, sweepings, refuse, or other rubbish (other than refuse from premises where any trade is carried on) from his premises shall be removed from the scavengers of the Council, shall deposit the same in covered tubs, boxes, or other like receptacles of such shape and size as shall be approved in writing by the Chairman, on the side of the street outside his premises at such hours daily as the Chairman shall from time to time appoint by notice duly given; and shall remove the said tubs, boxes, or other like receptacles within half an hour after the emptying of such tubs, boxes, or other like receptacles by the scavengers. No person shall place any ashes, sweeping, refuse or other rubbish on any street, except in covered tubs, boxes, or other receptacles as aforesaid, or except at such hours as aforesaid.

32 No person shall deposit dust, ashes, rubbish, sewage, soil, dung or filth at any place within the Municipality of Colombo, except in such places as the Chairman shall from time to time appoint.

33 No person shall collect or remove dirt, dust, ashes, rubbish, sewage, soil, dung or filth from any street or public place within the Municipality of Colombo, unless he be authorized to do so in writing by the Chairman.

Removal of  
trade refuse

34 Refuse from premises where any trade is carried on will be removed by the Municipal Council on application to the Chairman at such rates as may from time to time be fixed by him.

Owner of  
alleys to supply  
receptacles

35 The owner of any building let in apartments, flats, or portions shall provide the occupier of every separate tenement or portion of such building with covered tubs, boxes or other receptacles for the deposit of sweepings, refuse or other rubbish.

Picketing animals, & c. forbidden

36 No person shall picket animals or collect carts, or form an encampment upon any public ground within the Municipality, or on any ground or place belonging to or in charge of the Municipal Council, without the written permission of the Chairman.

Use of public ground

37 No public ground or place within the Municipality or ground or place belonging to or in charge of the Municipal Council, shall without the written permission of the Chairman be used for any purpose prohibited by the Chairman by public notice.

Against committing disturbance, hours during which grounds are open.

38 No person using any public or recreation ground belonging to or in charge of the Municipal Council, shall commit a disturbance there or behave so as to annoy other persons lawfully using the ground. Such grounds will be open to the public generally during the hours of day-light, and until the gates are closed for the night, subject to the condition of good behaviour and conformity to the rules laid down by the Municipal Council.

Tanks in any public or recreation ground not to be used for bathing or committing any nuisance in.

39 No person using any public or recreation ground belonging to or in charge of the Municipal Council with a tank in it shall bathe in such tank, or do any other act tending to foul the water thereof, or commit any nuisance therein, or pluck plants or flowers without the leave of the Chairman, or do any injury to the trees and shrubs in the ground.

Persons not to pluck plants or flowers.

Seats in any public or recreation ground not to be misused.

40 No person shall lie down or put either of his feet on any seat provided by the Municipal Council in any public place or recreation ground.

41. No person suffering from any loathsome, infectious, or contagious disease shall sit on or make use of any seat provided by the Municipal Council in an public or recreation ground.

42 No male above the age of twelve years shall sit upon or make any use of any seat in any public place or recreation ground which is labelled "for women and



children only". The burden of providing that he is under 12 years shall be on any person charged under this bye-law.

Stabling in  
verandah, & c.  
forbidden

43 No person shall make use of any varandah of a dwelling-house or any portion of a dwelling-house not properly adopted for the purpose\*, and previously approved by the Chairman, or any part of any street, pavement, or the Municipal property, for stabling, washing, or grooming any cattle, horse, or any other animal.

*\*Gazette No.8, 036 of March 9, 1934.*

*Extract of Some of the sections of the Environmental Public Health Acts 32 of 1968 & 38 of 1970 of Republic of Singapore*

3 (1) There shall be established a Public Health Authority consisting of the Director of Medical Services in charge of the Public Health Division of the Ministry of Health.

Public  
Health  
Authority

(2) The authority shall exercise overall professional direction in all matters relating to this Act, subject to the general or special directions of the Minister.

(3) The authority shall have and may exercise Medical Officer of Health and a Public Health Engineer by or under this Act.

(4) The authority may maintain at the Institute of Health or elsewhere one or more training centres for the purpose of training public health personnel and may, on its own or in collaboration with other agencies, conduct such training programmes and courses as the authority deems necessary for the purposes of this Act and any other written law as well as for such other purposes as the authority may think fit. The authority may award such certificates and diplomas to successful candidates on completion of any courses of training conducted by the authority as the authority may think fit.

(4)-(1) The President may, by notification in the Gazette, appoint an Officer to be styled the Commissioner of Public Health, and such number of Deputy Commissioners of Public Health and Assistant Commissioners of Public Health as he may think fit.

Appointment  
of Commis-  
sioner, Deputy  
Commissioners  
and Assistant  
Commissioners  
of Public  
Health

(2) The Commissioner shall have the superintendance of all matters relating to this Act, subject to the general or special directions of the Minister and the Authority.

(3) The Deputy Commissioners of Public Health and the Assistant Commissioners of Public Health shall have and may exercise all the powers conferred on the Commis-

sioner by or under this Act, subject to such limitations as the Commissioner may deem fit to impose.

(4) The Commissioner, the Deputy Commissioners and the Assistant Commissioners of Public Health shall be subject to the supervision of the Authority.

5 The Minister may, by notification in the Gazette, appoint one or more Public Health Engineers for the purposes of this Act.

Public  
Health  
Engineers

6 The Minister may appoint such number of Public Health auxiliaries and other employees as he may think fit for the purposes of this Act.

Public  
Health  
Auxiliaries  
and other  
employees

7. The Minister may appoint such number of committees as he may deem necessary for any of the purposes of this act.

Committees

X X X X

11 (1) The Commissioner may cause any number movable or fixed dustbins or other convenient receptacles wherein dust, dirt, ashes and rubbish may be temporarily deposited to be provided and placed in proper and convenient situations in public streets and private streets and in such other places as he may think fit, and may cause vehicles to go round to collect the same.

Dustbins  
in streets

(2) No dung, night-soil or human excreta or trade refuse, stable refuse or garden refuse shall be deposited in any such receptacle or vehicle :

Provided that such garden refuse comprising grass, small twigs and the like as may be reasonably accommodated in such receptacles may be placed therein.

(3) Any person who deposits or causes or permits to be deposited any dung, night-soil or human excreta or trade refuse, stable refuse, or except as provided in subsection (2) of this section, garden refuse in any such receptacle or vehicle as aforesaid shall be guilty of an offence under this Act and shall be liable on conviction to a fine not exceeding five hundred dollars.

12 (2) The Commissioner may, with the approval of the Minister, at any time, apply to all houses, lands, buildings and other erections within such area or areas as are from time to time delineated by him for this purpose any system which he thinks fit for the collection and removal of night-soil, humn excreta, dust, dirt, ashes, offal, rubbish, refuse and waste matter of every description from such houses, lands, buildings and other erections.

Commissioner  
may apply  
systems for  
collection and  
removal of  
refuse

(2) Before any such system is applied to any area under this section, one month's prior notice thereof shall be served on the occupier of any house or other building within the area to which such system is to be applied.

(3) The notice mentioned in sub-section (2) of this section shall be in the Malay, Chinese, Tamil and English languages.

X X X X

18 The Commissioner may acquire, construct and maintain such refuse disposal grounds, incinerators or other system for the disposal of refuse as he may deem necessary.

Maintenance  
of disposal  
grounds and  
incinerators  
for refuse

19 (1) Any occupier of any house or premises who keeps or allows to be kept for more than forty-eight hours, or otherwise than in some proper receptacle, so as to be a nuisance to his neighbours, any dirt, dung, bones, ashes, nightsoil, filth, refuse or any noxious or offensive matter in any part of such house or premises or suffers such receptacle to be in a filthy or noxious state or neglects to employ proper means to remove the filth therefrom and to cleanse and purify the same, shall be guilty of an offence under this Act and shall be liable on conviction to a fine not exceeding five hundred dollars and to a further fine not exceeding fifty dollars for every day during which the offence is continued after conviction.

Penalty on  
occupier of  
house not  
removing  
the refuse

(2) Without prejudice to any proceedings under sub-section (1) of this section and whether before or after the commencement or conclusion of such proceedings, the cause of the nuisance may be removed by the Commissioner who may recover the costs and expenses thereby incurred from

the occupier or the owner of the house or premises in the manner provided under section 124 of this Act.

20 All dirt, dust, ashes, rubbish, sewage, nightsoil, dung, filth and trade refuse, garden refuse and stable refuse, scrap metal, bottles and any matter or thing collected by the employees, contractors or agents of the Government from streets, houses, privies, sewers and cesspools or brought by any person to the Government refuse disposal ground or incinerator shall be the property of the Government which may sell or dispose of the same as it thinks proper.

All rubbish etc.collected to be the property of Government

X X X X

22 (1) In any area to which a system for the collection and removal of night-soil has been made applicable by the Commissioner under the provisions of sub-section (1) of section 21 of this Act :

Prohibition against unauthorised collection of night-soil

- a) no person other than an employee, contractor or agent of the Commissioner shall, except with the permission in writing of the Commissioner or except as required by the Commissioner under section 23 of this Act, collect or remove any night-soil, and
- b) no person shall refuse any service for the collection and removal of night-soil provided by the Commissioner, either directly or through contractors or agents.

(2) Any person who contravenes the provisions of sub-section (1) of this section shall be guilty of an offence under this Act and shall be liable on conviction to a fine not exceeding one thousand dollars.

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