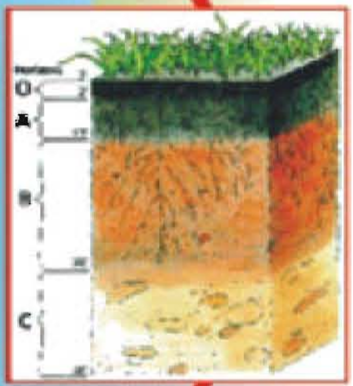
ENVIRONMENTAL EDUCATION AND SOLID WASTE MANAGEMENT



A. Nag
K. Vizayakumar

NEW AGE INTERNATIONAL PUBLISHERS

ENVIRONMENTAL EDUCATION
AND
SOLID WASTE MANAGEMENT

This page intentionally left blank

ENVIRONMENTAL EDUCATION
AND
SOLID WASTE MANAGEMENT

A. Nag
K. Vizayakumar

PUBLISHING FOR ONE WORLD

NEW AGE INTERNATIONAL (P) LIMITED, PUBLISHERS

New Delhi • Bangalore • Chennai • Cochin • Guwahati • Hyderabad
Jalandhar • Kolkata • Lucknow • Mumbai • Ranchi

Visit us at **www.newagepublishers.com**

Published by New Age International (P) Ltd., Publishers

ISBN (13) : 978-81-224-2343-3

PUBLISHING FOR ONE WORLD

NEW AGE INTERNATIONAL (P) LIMITED, PUBLISHERS
4835/24, Ansari Road, Daryaganj, New Delhi - 110002
Visit us at **www.newagepublishers.com**

Dedicated to the memory of

Late Dr. Sikha Nag

This page intentionally left blank

PREFACE

The globe we live in have two types of environments, one is natural environment of air, soil, water, hills, trees (abiotic), etc., and the other one is plant, animals (biotic), etc., which is to called social environment. Man has managed to create comfortable habitat, using science and technology, religion and politics. In fact both the environments are lively and lovely. But with comfort comes propagation, the biological growth qualitative and quantitative, resulting in unhealthy by-products, which are in the form of solid, liquid and gaseous. Soon we find our paradise is transformed into inferno by our own activities. This text is the story of such human behaviour, its enormity and a modest gesture to think how to avoid catastrophe. It is the awareness of the undesirable changes occurring around us that has led to the study of pollution of different kinds.

Pollution, having many definitions, ultimately indicates loss of equilibrium in the ecosystems, depending on the affected ecosystems, i.e. terrestrial, aquatic, atmospheric, the contributing pollutant may be solid, liquid or gaseous. But though uncommonly, these also happen to be in multiple states, solid waste in contact with hydrosphere may not only contaminate the water bodies, in turn may initiate fermentation and evolution of obnoxious gaseous pollutants. Often one thinks that of the huge solid municipal dumps containing mainly domestic refuge of mixed materials, i.e. glass, metal, kitchen wastes, ashes from fires, broken utensils, papers and worn out clothing. In a small agricultural community nature accepts these wastes into her natural cycle. Animals consume food residues and other materials are rapidly incorporated into the solid.

The industrial revolution in the developing countries concentrated people in urban areas of very high population density and added new sources of wastes from shops, institutions and factories. Apart from any question of public health it is impossible to accommodate these wastes, arising at a rate of upto one ton/family/year within the urban areas. Furthermore quantitatively, the fall out of thermal power plants, the excess of rejects of ceramic factories, cement factories; steel plants or such other operations are enormous.

Disposal and transport of solid waste remain as the major management problems. Innovations on refuse and recycling sometimes reach its own limitations. Depending on the nature of raw materials, variations in the nature and composition of industrial solid wastes prevent planning of routine or common methods of disposal. Solid wastes rich in organic matter i.e. agro residues, dairy or slaughterhouse wastes may be ecofriendly to some extent but fouling and health hazard are inherent.

Aboitic industrial residues on the other hand may not be of immediate hazard to animal life but pose eco incompatibility in the time scale. The legislation is there and is desirable to limit the proliferation of solid waste out of bounds. But no amount of legislation is enough until the public awareness and feeling for fellowmen are not there to improve the quality of life. Though management is the final aim of this story, in the first chapter we will try to identify different aspects of environment where we live. The next three chapters are based on different environmental resources of the solid wastes, their nature and classification, their common ways of treatment. Possibilities of reuse, recovery and recycling in some cases are also discussed. The financial and economic aspect of the same is presented in chapter five. In the sixth chapter we will look forward to public awareness and participation in the abatement and management aspect of the solid waste problems The concluding seventh chapter will have the optimization system, analysis and the planning aspect of the entire subject.

We are grateful to Prof. K. B. De for his suggestions during the preparation of manuscript.

The text is organized in a manner to cater to the need of students, researchers, managerial organizations and readers at large. We welcome opinions, suggestions and added information, which will improve the next edition and help the readers in future. Readers' satisfaction will be the best reward for authors.

—Authors

CONTENTS

This page intentionally left blank

CHAPTER 1

ENVIRONMENTAL EDUCATION AND MANAGEMENT

1.0. INTRODUCTION

Environmental problems have attracted the attention all over the world during last two decades. People are becoming increasingly conscious of variety of problems like global warming, acid rain, pollution in air, water and land etc. No nation in the world has been spread nor any citizen untouched.

Environmental problems in the world can be classified into three categories;

(*a*) Those arising from condition of poverty and under development

(*b*) Those arising as negative effects of the very process of development

(*c*) Man made pollution

The first category problem gives impact on the health and integrity of natural resources as a result of poverty and inadequate availability for a large section of population of the means to fulfill basic human needs.

The second category deals with the unintended side- effects of efforts to achieve rapid economic growth and development as a result it would fall distortions imposed on national resources from planned development projects and programme.

The third category is totally man made pollution, which not only damages natural resources immediately, but also its after effect is also dangerous. Bombardment in any country affects huge population and environment immediately. It also takes long time for environment to remove its residual effect.

Therefore we think for sustainable development that is concept of good and sound economic growth that can be maintained indefinitely with or no minimal damage to the environment. The factors that can promote sustainable development are as follows:

(*i*) Environmental Education

(*ii*) Population stabilization and health care

(*iii*) Solid waste management

(*iv*) Greening the uncultivated land

(*v*) Water pollution control

(*vi*) Air pollution control

(*vii*) Nonpolluting renewable energy

(*viii*) Conservation of biological diversity (*ix*) Human settlement without congestion

(*x*) Integrated land use planning and watershed management.

For a sustainable development, as mentioned above, the younger generation needs to be made aware of the deteriorating environmental condition and its after math and the expected rectification measures, alternatively other abatement methods; for which formal environmental education is necessary even at the school level.

1.1. ENVIRONMENTAL EDUCATION

It is education through, about and for environment. Through environmental education teaching-leaning can be carried out through environment. The objectives of environmental are three domains:

(*a*) Cognitive, (*b*) Affective and (*c*) Psychometer

The objectives in the cognitive domain are as follows:

(*i*) To help acquire knowledge of biotic and abiotic environment

(*ii*) To help understand the unchecked population growth and interpret them for the socio-economic development of the county

(*iii*) To check unplanned resources utilization on the world

(*iv*) To help diagnose the different causes of environmental pollution and to suggest remedial measures

(*v*) To help diagnose the cause of social tension and to suggest methods for avoiding them

The lists of the affective objects are as follows:

(*i*) To help acquire interest in the flora and fauna of the locality and distant.

(*ii*) To know interest in the community people and also their problems.

(*iii*) To value equality, justice and truth.

(*iv*) To respect the national boundaries of all countries

The objectives of psychomotor domain are as follows:

(*i*) To participate in afforestation programming

(*ii*) To participate in programming aimed at minimizing air, water, soil and noise pollution

(*iii*) To participate in programming aimed at preventing food adulteration.

(*iv*) To participate in programming of rural and urban planning such as solar heaters, gobar gas plants etc.

The goals of environmental education are as follows

(*i*) To provide every person acquire knowledge and to improve their environment.

(*ii*) To create awareness that includes making the individual conscious about the physical, social and aesthetic aspects of the environment.

(*iii*) To create a new attitude or a pattern of behaviour of individuals, groups and society as a whole towards the environment.

(*iv*) To help individuals skills for identifying and solving the problem of environment.

To bring awareness of environmental education there should be effort on following categories:

(1) Formal environmental education (2) Non-Formal environmental education (3) Environmental Information

1. Formal environmental education is categorized in the following stages.

(*i*) School stage: Here the emphasis should be mostly (75 %) on building up awareness, followed by real-life situations (20 %) and conservation (5 %). Thus attempt should only sensitize the child about environment. In the school education NCERT or different state level syllabus can take vital role in designing syllabi, textbooks, help books, guidebooks and teaching materials for students and teachers.

(*ii*) College and University stage: The environmental education through colleges and universities are in the following ways:

- (*i*) Colleges can provide training to the graduates about the environment and tackle the environment problems.
- (*ii*) All graduate courses should have environmental topics into the various subjects to be provided with a minimum one subject of environmental chemistry and ecology (in one semester).
- (*iii*) In Post graduate level it is best to integrate topics into various subjects such as physical, biological and social sciences
- (*iv*) University Grant Commission should draw up the syllabi for various disciplines and induce their adoption.
- (*v*) There will be package books on environmental problems and solution available to the students.
- (*vi*) Environmental training to the university teachers is urgently needed.
- (*vii*) Environmental laws should be taught in law colleges.
- (*viii*) Graduate and postgraduate programmes on environmental management should be started in several centers.

2. Non-Formal environmental education: It is designed for any age group, working in social, economic and cultural development of the community. It can be done through mass media in the following ways:

- (*i*) Media personal should be trained to become proficient in spreading environmental consciousness.
- (*ii*) Mass media, Press, Radio and TV, should develop environmental education professionals.
- (*iii*) Mass communication techniques appropriate to the conditions target audience should be developed.
- (*iv*) Traditional techniques like folk plays, puppet shows etc. should be used for environmental education.
- (*v*) Painting and environmental essay competition should be organized nationally.
- (*vi*) Posters depicting environmental problem should be exhibited widely.
- (*vii*) Traveling environmental exhibitions in different vans periodically tour through rural areas.

(*viii*) Pamphlets, booklets on environment prepared by professionals should be widely distributed.

(*ix*) Railway passengers should be provided with booklet describing the ecosystem components and impact caused on them.

(*x*) An attractive environmental information folder may be given to tourists arriving in this country.

(*xi*) A Gandhian style mass movement for environmental protection may be started.

(*xii*) Stories, cartoons and plays on environmental issues should be produced.

(*xiii*) Feature films on environmental protection may be shown in rural and urban areas.

(*xiv*) Documents dealing with environmental questions should be produced through cinema circuit.

(*xv*) All popular environmental materials must be simultaneously produced in the all-official languages in India.

(*xvi*) Representatives of the people should be fed with suitable environmental literature.

For the protection of environment there should be fundamental knowledge of ecology specially components of ecosystem.

1.2. Ecology is the study of the relationship of living organisms to each other and their surroundings. Modern ecology is based on interdisciplinary science linking physical, biological and social sciences such as

Genes ⟶ Cells ⟶ Tissues ⟶ Organs ⟶ Population

Communities ⟶ Abiotic components (matter + energy) ⟶ Ecosystems

Ecosystem is the functional unit of ecology that deals with the interaction between living object and nonliving matter of the environment of the place. The two abiotic components of ecosystem are (*i*) Climatic regime which includes rain cycle, humidity, soil factors, altitude etc. (*ii*) Inorganic substances like vital elements such as C, H_2, N_2, P etc.

The three biotic factors of ecosystem are (*i*) Producers (green plants) (*ii*) Consumers (Herbivores or Carnivores) (*iii*) Decomposers (Saprophases) such as bacteria and fungi.

The origin of community depends upon food. The community contains green plants that prepare food from inorganic substances in presence of sunlight. Herbivorous animals consume those green plants and carnivorous animals eat those herbivorous animals. Herbivorous animals direct consumer and carnivorous are indirect consumers. Fungi and bacteria live on decay organic matters and the waste products of the animals.

In nature several organisms of higher tropic level may eat same organisms or some organism may feed upon several organisms of lower level. Thus in an ecosystem there are several food chains linked together to form a complex which is called food web.

Species with wide geographical distribution almost develop locally adapted population called ecotype that has optima and limits of tolerance adjusted to local conditions.

The zone where two or more different communities meet and integrate is a transition zone or ectone.

The zone on integration may be narrow or wide, local or regional.

Biome is a broad ecological unit characterized by uniformly and distinctive life formed of the climatic species, plant or animal. It is subdivided into smaller units distinguished by uniformity and distinctness in the species composition of the climate and its successional stages.

Ecological niche denotes the specific position of species within the community which very often denotes the functional status of species.

All the components of ecosystem such as biotic and abiotic system are interrelated in the following ways:

(*i*) Interaction and influence: Any change in biotic components may disorder abiotic components or vice versa. Deficiency of minerals and water (abiotic components) may hamper the growth of plants and may dry up. Similarly increase in the number of nitrify bacteria in the soil may decrease in the soil nitrogen.

(*ii*) Functional interdependence: The abiotic components are two functional groups:

- (*a*) Nutritional circuit: It supplies nutrition to biotic system for their different activities.
- (*b*) Energy circuit: It is related to the solar energy, heat energy and stored energy to ATP. Producers convert solar energy to chemical energy that is used for their growth and different activities.

(*iii*) Interdependence of biotic components: There is close relationship between biotic components for their survival. Consumers utilize directly or indirectly the energy consumed by the producers. Decomposers also need dead bodies of producers and consumers for their nutrition.

Thus interactions may affect the various organisms in the following ways :

(*a*) It may have negative effect to each other and competition for survival such as big one eating small one or feeding on host organism (parasitism)

(*b*) One may be food for another (predation)

(*c*) It may be harming others without any benefit for it (amensalism)

(*d*) It may be harmful to others (antagonism)

(*e*) It may be beneficial to both groups living together (symbiosis)

(*f*) It may be something to destroy bacteria (antibiosis).

1.3. INDUSTRIAL ECOLOGY AND INDUSTRIAL SYSTEMS

There are four major inputs required to make a product such as (*a*) Capital (*b*) Materials (*c*) Energy (*d*) Labor. The relative amount of the each component can vary greatly and waste or environmental degradation occurs in the result of making or disposing of the product.

The product has increased due to efficient machines. The share of labor required to provide products has decreased markedly relatively to capital, energy and materials. Minimization of labor can put a significant strain resource and result in increased energy use. Therefore it requires optimized balance. A key aspect of industrial ecology is optimization of materials utilizing the following pathway;

Raw material ⟶ Finished material ⟶ Component ⟶ Product ⟶ Waste .

A well-designed industrial ecosystem also optimizes energy and capital utilization in most efficient manner with environmental protection. Therefore concepts of industrial ecology are a part of environmental education.

1.4. ENVIRONMENTAL INFORMATION

Department of environment set up a plan programme of Environmental Information System (ENVIS) in 1982. It is a decentralized system using distributed network of data bases for collection of environmental information.

Some specific activities are taken by ENVIS as follows:

(*i*) Environmentally sound and appropriate technologies.

(*ii*) Parliamentary questions and media as related to the environment.

(*iii*) To get information for water, air pollution and toxic chemicals for particular area.

(*iv*) Coastal and offshore ecology.

(*v*) Environmental education and mapping of in Eastern Ghats.

(*vi*) Eco-toxicology, biodegradation and environmental impact assessment

(*vii*) Renewable energy and environment.

(*viii*) To maintain biological diversity in Western Ghats.

(*ix*) Environmental education and management in Madhya Pradesh.

1.5. LIFE CYCLE ASSESSMENT (LCA)

Life Cycle Assessment (LCA) is defined as a systematic inventory and comprehensive assessment of the environmental effects of two or more alternative activities involving a defined product in a defined space and time including all steps and co-products in its life cycle In other words, LCA should yield a complete picture of environmental impact of the product. It is a useful, through underdeveloped, environmental magnetic tool. It has the following phases:

(*i*) Planning : In this phase, decisions are taken which determine the complexity of study. It also determines the range of results and gain from that results.

(*ii*) Screening : It has identified the parameters of interest and the alternatives of concern. One must decide where and how to gather the significant data. At this stage decision has taken to distinguish from one product to another.

(*iii*) Data Collection : It may be defined as an object data-based process of quantifying energy and raw material requirements, air emission, water borne effluents, solid waste and other environmental releases throughout the life cycle of a product process or activity.

(*iv*) Data treatment : There is quality control on the data. There is often a desire to reduce all the results to single parameters particularly financial.

(*v*) Evaluation : Finally sensitivity analysis of the data will assess the significance of the difference. Impacts and improvement may be analyzed.

1.6. ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

Environmental Impact Assessment (EIA) is an important responsibility assigned to the Department of Environment that evaluates environmental implications and incorporation of necessary safeguards for such activities having a bearing on environmental quality. The stage of EIA includes the following :

1. Screening

In that area it is to decide which projects should be subject to environmental assessment? Criteria used include threshold, size of project and sensitivity of the environment.

2. Scoping

The process defines the key issues that should be included in the environmental assessment.

3. EIS Preparation

It is the scientific and objective analysis of the scale, significance and importance of impacts identified. Various methods have been developed to perform this task.

4. Review

The project proponent normally produces environmental assessments. It is usual for a review to be undertaken by a government agency or independent review panel. The review panel guides the study and then advises the decision makers.

There are three options for preparation of EIA which are as follows:

1. Legislative option

It is the formal legal approach in which environmental assessment procedures become law and are enforced by the court.

2. Middle ground option

It is adoption of environmental assessment principles within accepted planning procedures.

3. Policy option

Systems are developed and incorporated within administrative machinery or government.

4. Exponential growth and Cost benefit analysis (CBA)

Exponential growth occurs in any situation where the increase in some quantity is proportional to the amount currently present. The type of growth is common and the mathematics required to represent it is very simple. We will approach this sort of growth first as discrete, year-by-year it increases and then more usual way as a continuous growth function.

$$N_0 = \text{Initial amount} \quad ; \quad N_t = \text{Amount after t years}$$

$$r = \text{Growth rate (fraction per year)}$$

$$N1 = N0\ (1 + r)\ ;\ N_2 = N_1\ (1 + r_2) = N_0\ (1 + r)^2$$

$$N_t = (1 + r)^2$$

Cost benefit analysis (CBA) is a tool for of the modern financial analysis of any commercial analysis. The operation turns to be non-viable if it is in negative. But when CBA is in positive term, its viability is accepted. This means that in a given time, under given circumstances, if the CBA of pollution control measure is positive, such a pollution control measure is considered with a viable exercise and can be proceeded .

In fact integrated approach and urgent necessary are industrialization, resource utilization, food production, population and environmental pollution control. Then CBA should be used as guidelines.

1.7. ENVIRONMENTAL MANAGEMENT

It aims at the development of the environment for human benefit and preserve the maximum evolutionary potential of the biosphere. Standards are necessary for managing and maintaining the environment so that it will continue to be suitable for man and other species of the ecosystem. Environmental management has three following key concepts:

(*a*) System approach

It deals with a procedure that recognizes the relationship between natural and manmade system and the critical role of human factor.

(*b*) System analysis

It consists of the formulation, issue definition and part insight that can be used to find the solution of problems.

(*c*) System management

It consists of actual techniques of management for solving problems such as CAM/PERT, PUBS and others. Proper environmental management must provide for the continuous formulation and reformulation of social, economic and environmental actions by a way of built-in feed back system. For successful management of an environment restoration programme we have to plan conservation and management of the following resources:

(*i*) Land use planning and management; The total land area of the world is 13,128,341hectares; out of total land use of crop land is 1,477,877 hectares, permanent pasture is 3,322,943 and forest and wood land is 4,095,317 hectares. Other land covers an area of 4,232,737 hectares and wild area is 3,486,097 hectares. The total land carries a population density of 403/1000 hectares. The total land area of India 32,87,263 Sq. km. extending from Himalayan to tropical rainforests of the south. Only 62% of total land area is topographically useable. Some essential factors for land management are as follows:

- (*a*) Land may be classified according to the nature of soil, physical features, availability of water and storage, run off etc. We should take help of remote sensing methods for land classification and land map be prepared.
- (*b*) Changes from land used should be monitored and the intensity and frequency of natural hazard like cyclones, flood etc. should be anticipated.
- (*c*) The landscape and pollution load also need to be considered.

(*ii*) Water resource management: To maintain fresh water management is important as follows;

- (*a*) There is no misuse or wastage of water.
- (*b*) Pure water should be available to man for different purposes so water storage and distribution should be done in a scientific way.
- (*c*) Proper treatment of water should be done for drinking and cooking purposes.
- (*d*) Public awareness should be created against more water than necessary.

(*iii*) Soil management: Soil is a most important resource of food but results of global assessment of soil degradation sponsored by U.N.E.P. show that 1.2 billion hectares i.e. almost 11 % of the earth's vegetated surface have undergone moderate or worse soil degradation over the past fifty years because of human activity. As a result of this degradation there is declination of crops in number of countries. The immediate concerns for soil management are as follows:

(*a*) Practice of rotation crops and vegetables such as leguminous plants which add nitrogen in the soil.

(*b*) Soil erosion can be prevented by large scale-planting of trees and shrubs and the development of grasslands.

(*c*) Alkalinity of the soil can be removed adding gypsum, organic manures and fertilizers.

(*d*) Water-logging is avoided by sealing all points of leakage from water resources such as ponds, canals etc.

(*e*) Use of non-degradable fertilizers and pesticides should be avoided.

(*iv*) Mineral resources management: The following parameters should be considered for maintaining mineral resources:

(*a*) Appropriate technologies should be developed to recycle metals.

(*b*) Alternatives to fossil need to be found out.

(*c*) Research should be carried out to substitute some metals like gold, silver etc.

(*d*) Mining areas need to be reclaimed.

(*e*) Need reserves on the ocean floor and unexplored areas need to be searched for.

(*f*) Minimizing waste and new technologies to recover resources from waste.

(*g*) A data bank on the availability and expenditure of mineral resources should be maintained so that their use is regulated.

(*d*) Management for forests and wild life: Forests are renewable source and contribute in economic development. India has an area of 752.3 lakh hectare notified as forests ; out of this 406.1 lakh hectare area is classified as reserved and 215.1 lakh hectare as protected. It has been estimated that 11 % of India's total area is under forest cover.

The following actions should be taken for maintaining forest and wild life:

(*a*) Continuous monitoring of forest growth and depletion rate.

(*b*) Adoption of scientific technologies for forest growth and preservation of forest fire.

(*c*) Strictly stopping and enforcing the law for cutting any type of trees.

(*d*) Adopting tree plantation in large scale and to prepare social forestry to meet the requirement of fuel wood, fodder, timber etc.

(*e*) Hunting of any type wild animals and their babies should be banned.

(*f*) Awareness should be created among people about the necessity of forests for survival of human beings and wild animals.

1.8. ENVIRONMENTAL AUDIT

It is a management tool comprising a systematic, documented and periodic evaluation of environmental organization with the aim to safeguard environment by facilitating management control of environmental practices and assessing compliance with company policies.

For a smaller or medium industry the audit should be carried out at a regular interval. The internal audit should be more frequent which may be checked by external agency that would identify the efficiency of the internal audit. For a bigger industry it should be well planned. The report should be based on facts supported by the documentary evidences of site management and also should include action plan with specific responsibilities and dead lines. The advantages of environmental audit are as follows:

(*i*) Environmental audit is evaluation of the efficiency of resource utilization.

(*ii*) Identification of areas of risk.

(*iii*) Environmental liabilities.

(*iv*) Weakness of management system.

(*v*) Control of waste/pollution generation.

(*vi*) Cost reduction of corporate operation.

1.9. CAUSES OF ENVIRONMENTAL DEGRADATION IN INDIA

Reasons for environmental degradation in India are as follows:

1. Desertification

Desertification is due to human over exploitation of dry lands through over-cultivation, overgrazing, poor irrigation practices and deforestation. Increased desertification raises food demand and intensifies pressures It has found that every year one kilometer land of Rajasthan are going to be desert.

2. Loss of Forests

The forests are the richest biological zones which can provide a wide range of useful products in India. Due to increase in the rate of loss of forests there has been a wide range of effects of economic and environmental balance through increased erosion, floods landslides, silting of hydro-electricity facilities, irrigation systems reservoir and harbors.

3. Soil Erosion

Soil erosion and soil pollution is a serious concern in India. It is estimated that every year there is a loss of 600 million tones of soil resulting in a loss of agriculture productivity. Furthermore due to various reasons such as effluent from industries and domestic sewage directly falling on the soil cause the loss of productivity.

4. Depletion of Genetic Resources

Different species and sub-species of plants (Specially medicinal plants) and animals are estimated to be threatened with extinction in India which would have a on future agriculture, industry, science, human heath and welfare.

5. Water Pollution

Due to rapid growth of industrialization, open defecation in rural areas and domestic effluents of cities without treatment directly into ponds, rivers etc. cause pause threat to water pollution.

6. Climatic Change/Green House Effect

The problem of air pollution is now a serious concern due to acceleration of industrial tempo. Due to atmospheric pollution there is change of climate in different cities in India.

Carbon dioxide build-up leading to change is one of the key issues. Recent researches indicate that increasing concentration of CO_2 causes a warming trend leading to climate change in the next century similarly emissions of chemicals in the atmosphere makes another burning problems which makes a changes in climate i.e. green house effect. Change in climate affects agricultural production.

7. Acid Rain

Rain mixes with the pollutants specially sulphurdioxde and nitrogen dioxides in the atmosphere to produce acid rain. This rain will kill fishes, water life and corrode buildings, including some of India's most important ancient monuments. It may also damage forest and croplands and pose a substantially treat to health.

Legislative measures suggested by Tiwiri committee for protection of environment.

(1) Biosphere reserves: Government may consider comprehensive legislations to reserve biosphere specially genetic diversity in plants.

(2) Protection of grazing land: The states should be interested to make legislation to protect gazing land.

(3) Protection of endangered species: Indian legislation should be implemented to protect endangered species.

(4) Toxic substances control act: There should be legislation to ban sale toxic chemicals other than pesticides or judicial utilization of these compounds with proper protection.

(5) Scientific land use: Suitable legislation have to be made to prevent the growing abuse of land.

(6) Noise pollution prevention: There should be strict legislation and measures to prevent noise pollution.

(7) Protection of forests: There should be strict legislation to save the forests from greedy people.

QUESTIONS

1. What is environmental education ? What are the objectives of environmental education ? How colleges and universities help to spread environmental education?
2. What do you mean by ENVIS and LCA ? What are the activities of ENVIS ?
3. What is EIA and Environmental audit ? What are different options for EIA?
4. What is environmental management ? What are different types of environmental management ? What steps will you take for management and planning for forest and wild life ?
5. What are the causes of environmental degradation in India ? What are the suggestions of Twiri committee ?

CHAPTER 2

SOLID WASTE CHARACTERISTICS, COLLECTION, TRANSPORTATION AND HEALTH IMPACTS

In the twentieth century, due to industrial revolution and technology development, consumption patterns of the people, all over the globe, have changed. The use of natural resources and goods has increased manifold. Due to this, huge quantities of different types of solid wastes are produced every day creating an alarming problem of their disposal. It is now recognized that proactive management is required to deal with this problem, *i.e.,* it is required to reduce the generation of solid waste, effective collection of solid waste and utilization of solid waste rather than concentrating on disposal alone. Thus, solid waste management involves management of activities associated with generation, storage, collection, transfer and transport, reuse and recycling, processing and disposal which should be environmentally compatible, adopting to the principles of economy, aesthetics, and energy conservation. This chapter presents and describes different kinds of solid wastes.

2.1. TYPES AND SOURCES OF SOLID WASTES

Useless, cannot be used, not wanted—these are some of the dictionary meanings of waste. Generally readers are carried away by such concepts, as if greater portion of solid waste means municipal solid waste (MSW). Other than MSW, there is a substantial contribution in terms of industrial solid waste of varying composition and solid wastes from thermal power plants and agriculture related activities. It will be worthwhile to discuss a little bit about the origin of different types of solid wastes and their constituent components. A few words or terminology, very frequently being used, are refuge, trash, garbage, rubbish, etc. Refuge, has a broader meaning like waste and is used as its synonym. Trash is generally used for the most combustible components of throwaway materials (paper, rag, wood chips, toys, etc.)

Garbage means the fall-outs and throwaway from kitchen, market place, stores, ware houses, etc. and may contain various putrescible wastes. During summer the garbage amount is more when vegetable wastes are more abundant. It requires careful handling as it attracts and breeds flies and other insects. It also generates unpleasant odour due to rapid fermentation. Rubbish includes all non-putrescible wastes except ashes. It consists of both combustible and non-combustible substances such as cans, paper, brushes, metals, etc. It becomes a nuisance when scattered by wind or careless handling. Based on the source of contributors, four common categories of solid waste are:

1. Municipal waste.
2. Industrial waste.

3. Agriculture and Animal waste.
4. Hazardous waste.

2.1.1. Municipal Waste

Municipal solid waste (MSW) mainly consists of:

(*a*) Food wastes, commonly called garbage, are prone to decompose. They originate from food products of animal and vegetable origin, arising out of preparation, processing, handling, catering, and eating.

(*b*) Rubbish is combustible and non-combustible rejected materials other than those mentioned above. The combustible portion (trash) consists of paper, cardboard, textiles, plastics, rubber, etc. The non-combustible portion consists of glass, ceramics, metals, etc.

(*c*) Ashes and cinders originate mainly from coal, firewood, and burnt residues of other combustible materials.

(*d*) Construction and demolition wastes include wide varieties of materials, mostly non-combustible in nature. Civil works of construction, remodeling, repair works and demolition of building structures and others that include broken pieces of bricks, stones, plasters, dirt, sand, wooden articles, metal pieces, electrical parts, etc.

(*e*) Water treatment plant wastes are obtained from the water treatment plants in solid or semisolid form, such as resins, organic waste, inorganic waste, etc.

(*f*) Special wastes are uncommon materials accumulated from unpredictable and infrequent sources, *i.e.,* abandoned vehicles, dead animals, limbs, blood, etc. from hospitals; and that found from street sweepings.

A. Characteristics of MSW

The physical and chemical characteristics of MSW of typical Indian cities are presented in Tables 2.1 and 2.2. The variation of contents of organic and inert materials depending on the sources is significant. For example, MSW from hospitals (Kolkata) may contain 35% organic materials and 55% inert materials and rest other combustible. Whereas mixed residential and commercial MSW from the same metropolis may contain 60% organic, 20% inert materials and 19% other combustible materials. Metals and glass together constitute almost one percent of the total MSW of bigger Indian metropolis (Table 2.3).

With changing patterns of living style and human cultural activities, MSW composition is also changing over the years. It is noteworthy that plastic and paper components have increased and likely to maintain this pattern, whereas, glass is likely to decline in the coming years.

B. Properties of MSW

The properties of the solid wastes need to be studied for proper handling, selecting suitable equipment, collection, transport, storage, and treatment. Design of further treatment, recycling, and disposal can be gainfully planned based on this information. Properties of MSW mainly depend on :

(*a*) The components of the total MSW of a particular municipality. For example, a summary of garbage composition of four metropolises is presented in Table 2.3.

(*b*) The average and the range of particle sizes. A numerical estimate may range from

102-104 objects per ton for any random sample that may correspond to average particle size of 0.5 meter to 0.05 meters respectively (sand, grit and glass particles excluded). The particle size of the inert ingredients varies from 0.5 mm to 10 mm. The total number of particles also varies largely.

(*c*) A typical sample of large metropolis usually shows average moisture content of 14-15 % and the moisture content tends to increase with increase in food wastes.

(*d*) Components like food wastes, garden wastes and wood chips contribute to the higher densities of the major mass of MSW. Ranging from 150 to 300 kg/m^3, a typical MSW sample may exhibit average density of 200 kgs/m^3. Increase in dry and inert components, i.e., ashes and cinders, decreases the average density. This has great significance for the transport and storage aspect of the MSW.

Table-2.1: Physical characteristics of city refuse in Indian cities

Category	*Population (in lakhs)*	*Characteristics (by wt %)*							
		Paper	*Rubber*	*Metal & fine*	*Glass*	*Ash, earth*	*Plastic & Leather*	*Miscellaneous*	*Composite matter*
I	2	3.09	0.487	0.57	0.512	0.29	15.041	33.41	46.6
II	2-5	4.76	0.671	0.59	0.387	0.34	19.562	39.76	34.12
III	2-20	3.80	0.620	0.81	0.638	0.44	11.732	40.15	41.81
IV	20	7.07	0.866	0.86	1.031	0.76	15.783	41.69	31.69

Source: Reference 7. Nag (1992).

Table-2.2: Chemical characteristics of city refuse in Indian cities (by wt %)

Population (lakhs)	*Moisture*	*pH*	*Organic Matter*	*Carbon*	*Nitrogen*	*Phoshorous*	*Potash*	*C/N relation*	*Henry (Calorific) value BTU/V*
2	22.12	8.18	22.02	12.255	0.602	0.706	0.705	20.35	1442.21
2-5	25.05	8.16	22.51	12.506	0.611	0.715	0.734	20.47	1574.80
3-20	22.45	8.34	21.51	11.95	0.555	0.676	0.722	21.45	1560.00
< 20	31.18	7.68	27.57	15.316	0.584	0.590	0.678	22.24	2056.58

Source: References 7. Nag (1992)

Table-2.3: Garbage Composition of Four Indian Metropolises (by wt%)

Item	*Bombay*	*Calcutta*	*Delhi*	*Madras*
Paper	3.20	3.18	5.88	5.90
Metals	0.13	0.60	0.57	0.70
Glass	0.52	0.38	0.31	—
Textiles	3.26	3.60	3.56	7.07
Plastics & Leather	17.57	6.31	0.42	—
Bone	0.50	0.42	1.14	—

Stones	—	1.83	5.98	13.75
Coconut Shell	—	4.96	—	13.75
Earth & Ash	15.43	33.58	22.95	16.95
Ignited Coal	—	8.06	—	—
Fermentable	59.37	29.30	57.71	36.24

Source: Kolkata Municipal Corporation, 1998.

2.1.2 Industrial Wastes

They include the wastes produced during various industrial operations. Even though our discussion has more emphasized on typical MSW and not the major industrial wastes, one can not afford to overlook the contribution of some minor or small scale operations which are located within the municipal territories to meet the daily requirements of the residents. These are candle making, plywood manufacturing, bakeries, leather goods, rubber industries, pharmaceutical products, canned goods, laundry trades, dairy products and photographic products, etc. The spent solution and solid waste of these industries contains major organic constituents. Every company should have their own solid waste handling and treatment systems as otherwise they produce bad odour and cause problems to public health authorities.

2.1.3 Agriculture and Animal Wastes

The agriculture wastes are usually of plant origin. Plants that remain after harvesting are in huge quantities. India has the highest livestock population in the world. Animal wastes include the remains after slaughter and animal fascias, etc. A survey in Bombay has found that the animal waste (1500 tons per month) constitutes the largest share followed by mineral waste (1100 tons per month), and agriculture waste (550 tons per month).

2.1.4 Hazardous Wastes

Hazardous substances, depending on their quantity, concentration (physical or chemical), infectious characteristics, is of potential hazard to human health. They may cause or significantly contribute to an increase in mortality and to serious, irreversible or reversible but incapacitating illnesses. It will also affect the animal and plant lives on a short or long-term basis. Hazardous waste may include (*a*) radioactive substance (*b*) fuming, odorous, corrosive and toxic chemicals, and (*c*) biological wastes, combustibles, flammable and explosive wastes.

All the wastes and their treatment are discussed in details in chapter 3.

Collection

Two major aspects of MSW collections are:

1. Collection policy.
2. Collection method.

1. Collection policy

1. Collection policy has to be decided by each municipal corporate body or its equivalent municipal organization. The policy may be, depending on the decision of the body, to collect the wastes by the Corporation employees; through private contractual collection, or by community. Alternately, the municipal body may have a combination of systems mentioned above. Many advanced countries have categorized MSW, say, organic, glass and metal, paper and textile, etc. The waste producers have to put the waste into different bins/containers

marked for specific type of waste, as suggested by the Municipal Body. Irrespective of the above-mentioned policies of collection, four major factors affect the collection patterns:

(*a*) Climatic and seasonal variation

(*b*) Density of residential premises and population

(*c*) Nature of the street and city planning and

(*d*) Frequency of transporting the collected MSW to a specified workable storage or treatment sites.

During cold and dry season, foul odour formation from waste is least but during monsoon, the odour and the increased weight due to rain, create immediate problem. Flies, insects, rodents, stray animals and cattle that inflict from the locally collected waste create additional nuisance. In summer and rainy seasons, these may become potential sources for spreading diseases.

Bulk of MSW obviously depends on the congestion of residential areas. Total number of capita per unit area is higher in a metropolis where multistoried residential buildings are located. So, the contribution of refuse goes up due to larger number of total residents in that particular locality. Localities that have institutional or commercial office buildings, and schools produce.

MSW in larger quantities, mainly food wastes and paper scraps. Collection policies as described earlier cannot be the same in these two types of localities, namely, residential areas and office complexes.

Usually the newer parts of the planned cities, streets and street junctions have well defined dumping places for common MSW. A constructed holding or collection tank occupies a particular section of the existing space of the streets. However, the older parts of most cities and towns, this is absent. One observes, in both the cases, undesirable spillover or strewing of portion of the MSW on the streets. In India very rarely different containers for different types of MSW are provided for local collection of the same.

2. Collection Methods

In India, with the existing infrastructure facilities and manpower, many of the municipal authorities are able to collect MSW and transport it to a further site on daily basis. Very often, some localities of the metropolis have less frequent pick up than others. Conversely, in certain areas, the total mass and volume of MSW collected locally may be in large quantities, which is in excess than the frequency and quantity at which these are transported away, resulting in piling up of rotting, backlog MSW.

Collection of MSW, managed by a locally elected body or residents' coordination body, may pose a problem unless the transport is also managed by the same body.

Collection methods also need consideration on collection techniques and strategies. Very often, three main variations are adopted for residential or domestic MSW collection: (*a*) Backyard, (*b*) Set-back or Setout, and (*c*) Curbside.

(*a*) Backyard (Door to Door) collection: When collection is from house to house, the collectors will walk the short distances between houses and the vehicle will move slowly and at intervals. Though convenient for the householder, but large number of collectors are required and for the short distance of travel, the motor vehicle is ineffectively employed. It incurs heavy transmission wear and high fuel consumption. Handcarts and animal-carts are much more efficient as they operate at their optimum speed and no energy is used when they are stationary. Unpleasant incidence occurs due to variation in the deposit of MSW at different household site.

In tropical countries, particularly in hot and humid seasons, regularity and frequencies of pick up has to be maintained in order to minimize fouling and similar objectionable issues. The primary advantage of this system is the convenience to the homeowner. But the major disadvantages are (*i*) High cost due to requirement of more labourers and the cost will be low where the labor cost is low, (*ii*) Many home owners object to having the collectors enter their private property, and (*iii*) This concept or practice can not be implemented in big apartments and block houses or housing complexes. Mostly the second or the third choice is exercised.

(*b*) Curbside Collection: This is the largely practiced method both in developed and developing countries, exceptions are some communities with strong cultural and aesthetic values. The ugly site with the exposed and strewn MSW is objected to but an alternative or substitute becomes very expensive. The trash-trailer is hauled away at regular intervals by suitable transport vehicles or tractors. As a common practice, some where near the street corner or street crossing, sizable concrete structures (bin or reservoir) are maintained where house holders or their domestic aids deposit their domestic MSW daily or in regular frequencies either stuffed in sacks or carried by baskets. This ends up in careless throwing and littering the surroundings causing a very common foul and ugly scene at dumping sites. In high-density residential areas or slums, there is a common spillover phenomenon, which is beyond control. This is a common sight in market areas and certain localities in big metropolis.

The disadvantages of curbside collection are (*i*) Bins are turned over by goats or cattle, (*ii*) Bins sorted by scavengers or bins staled, and (*iii*) Failure of the householder to deposit MSW materials daily.

(*c*) Setback or Setout: This method is usually not so popular or frequently used. It is a compromise between the backyard and curbside method. In order to make the backyard collection more systematic each house owner put SW in a closed container at the door (or back-door) side and the collectors pick up and empty the container (can) and replaces the closed empty can at the door-side. The collector usually pushes a wheeled cart in which he dumps the waste. Finally the collector deposits a sizable collection of MSW at curbside for pickup by the transport vehicle.

In this method, collector may be required to do more than one task, or the homeowner may be required to do one of the tasks. This method has shown to be advantageous than the backyard method. In congested dwelling area, apartments, high rise buildings and housing estates, this method seems to be the best choice because individual door-to-door collection becomes prohibitive due to several reasons. An improvement on this method is that the densely populated housing community members employ manpower to collect household MSW and deposit it on a wheeled cart, ready to be hauled to the transport vehicle site. Alternatively, the individual house- aids or house-owners deposits their refuge directly into the large bin or wheeled cart placed at convenient corner. However, it is the cheapest method of collection. When the rate of waste generation is high and collection is frequent, very high labour productivity as per weight collection can be achieved.

The disadvantages of municipal collection are:

(*a*) Municipal sanitation departments are too susceptible to political interference. Excessive intervention on the part of public representatives may frustrate the sanitary officials and workers and may hamper the purpose for which the department was created.

(*b*) Municipalities try to economize the cost which reduces the systems' effectiveness.

(*c*) Labour is demotivated and may be inefficient.

2.2. TRANSPORTATION AND COSTING

Transportation is the most expensive part of MSW management. The transportation is involved movement between the operations of collection and depositing the MSW to the proper site of storage, final disposal, treatment and/or recycling. The transport of the locally collected MSW to a further site may be performed by three different methods: (*i*) Municipality's own transport system and staff members' (*ii*) Private contract (*iii*) Organized local body with the help of hired transport operators.

The first one obviously is the most expensive followed by the third one. The second one is usually not so popular due to lack of coordination of the local collection of MSW and the frequency of pick-ups. Hence labour and transport absorb the major part of operating cost of the solid wastes management services. It is usual for a city to employ between two to five workers for each 1000 population. Three workers per thousand populations may represent about 1% of the total national work force.

Transport is required on a scale of about 1 heavy vehicle/15000 population. The solid waste management services can absorb up to 1% of the gross national product and are one of the most expensive city services. Efficiency of systems and high labor productivity, therefore, are of vital importance.

The principal means of transportation of solid wastes may be motor vehicles, railroads and marine vessels. Pipeline and conveyer transportation systems have also been used, especially in some European cities. The transportation by motor vehicles should follow certain requirements as follows :

(*a*) Vehicles must be designed for highway long distance.

(*b*) Vehicle capacity must be such that allowable weight limits must not be exceeded.

(*c*) The vehicles must transport wastes at minimum cost and.

(*d*) The loading and unloading of wastes should be simple.

Railroad transportation of solid wastes is generally used in remote areas (including some hill areas), where highway travel is difficult. The process is not economical and is found only in few communities. The disposal of solid waste by dumping into sea is possible only in case of coastal cities. Care is taken to tarry the waste sufficient distance away (2 to 3 km from the beach) in barges and is dumped there. The waste may be washed ashore under tidal conditions. The method is very costly and is not used in India.

The use of pipeline transportation is a recent innovation. Studies have concluded that it has got some advantages and disadvantages. For long-term projects the operating cost of pipeline is less than that of any other transport system. But a pipeline is unable to transport large metal objects. The water used in slurring the refuse must be reclined in order to maintain the economy of the system. The cost of refuse transportation by conveyer system is quite high in relation to other methods. Conveyer equipment comes in limited sizes. They are subject to a high degree of wear and breakage. Fire is a potential hazard and its occurrence would be difficult to control. These disadvantages relate to currently available conveyer equipment.

The cost of solid waste collection depends on the following factors :

(*a*) Physical conditions such as community size and population density.

(*b*) Topography and length of haul to disposal site.

(*c*) The type of service rendered, including the frequency.

(*d*) The amount and type of refuse collected

(*e*) The point of pick-up, e.g., curbside versus back door.

(*f*) Prevailing wage rate of collection personal and worker.

(*g*) Equipment efficiency.

2.3. HEALTH IMPACTS

Among the entire probable hazards originating from the solid wastes, the main hazard is to the human health. Depending upon the category and characteristic of the solid waste, the health hazard may be of short term or long term. The agro-based solid waste may cause spontaneous fire during warmer seasons. During monsoon, rapid decomposition may cause odorous gases and may become breeding ground for various insects. The domestic and municipal solid waste may be properly treated in order to reduce all probable hazards. The solid wastes when separated and sorted out, into degradable and non-degradable, either at the source or during dumping, further reduces the risk of hazards and enhances the reuse or recycling process.

The main concern of the industrial solid waste is that the rain washings and leaching through solid wastes contaminate water resources. Depending on the nature and origin of the industrial solid wastes, the ratio of organic and non-organic substances varies. The organic materials are more degradable and become vehicle for the spread and inter-mixing of the more objectionable and hazardous components, even though present in smaller amounts. A detailed discussion on the gaseous and fluid materials, which may cause hazard and toxicity, is beyond the scope of this text. However, some of the gaseous and liquid contributing items are very common in association with solid waste. The concentration of such items, of course, will vary depending on the origin and nature of the solid waste.

Volatile compounds, e.g., ammonia, hydrogen sulfide and similar derivatives, acids of lower molecular weight, low molecular weight hydrocarbons, esters, and ethers are detectable along with oxides of nitrogen and sulphur. The domestic, cattle farm house and agro farmhouse wastes contribute gases similar to that of biogas, while dairy, slaughterhouse, tannery give out different odorous and foul gases of varying composition and concentration. The microbial degradation of animal tissues results in many different types of compounds of sulphur and nitrogen. The insecticides and pesticides are usually solids and their residues, contaminated in the solid waste of different resources, also contribute significantly to pollution in ecosystem.

The above compounds may belong to chlorinated hydrocarbons, aromatic derivatives, furans, sulphur and phosphorous products. They have different melting points and mostly insoluble in water, and exert high vapour pressure but have characteristic smell. In very low concentration, these compounds permeate the ambient atmosphere. Usually they react with skin and fine membranes of humans that causes irritation of the eyes and respiratory systems. These compounds get absorbed through different routes into the animal and human bodies and have very quick and strong reactions on the nervous systems and the ganglion nodes, affect the reflexes, cause nausea, vomiting, headache, respiratory, intestinal and skin problems.

Longer exposures to other foul gases i.e., NH_3, H_2S, etc., cause similar reaction to human beings. Dizziness, headache and breathing problems are very common. On longer exposure, the human being gets used to the same and common reflex mechanisms, becomes prone to more acute and chronic deformity and carcinogenic distress.

Liquid effluents associated with solid wastes are limited. from domestic, Livestock and municipal solid wastes usually contain 20% or more moisture in an average. Industrial solid wastes may contain hydrocarbons. Water either by sprinkling, quenching or flashing but mainly from rain washes the soluble and degradable part of the solid wastes in the dumps and mixes with other water bodies. Different salts of lead, mercury, cadmium, nickel, chromium, and arsenic find their way into organized water supply in the metropolis. Directly or indirectly these find wider access to all kinds of water bodies in suburban and rural areas. Contamination of potable water for cattle and human occur and easily go undetected. The source of many of the toxic and hazardous pollutants may be very diverse and sometimes unexpected. There may be more than one state and chemical formulation in which any of the pollutant may exist in the effluent (solid, liquid or gas), i.e. Pb (+1, +2), Cr (+3, +6) etc. Each has specific ecological impact, separately as well as in common. Early monitoring and detection can prevent further exposure to the pollutant. Once contamination is exhibited alleviation is rather difficult.

EXAMPLES

1. *Municipal solid waste contains organic and inorganic material. When analyzed by the combustion method, 0.20 gm of an organic substance yielded (i) 0.157 gm of carbon dioxide and 0.11 gm of water (ii) 74.6 ml of nitrogen gas at N.T.P. Find the empirical formula of the substance.*

Solution: Calculation of percentage of elements:

Percentage of nitrogen (by difference) = 26.49

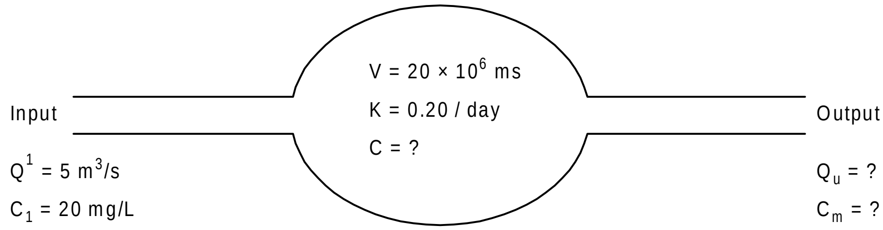
Calculation of Empirical formula:

	Percentage	*Atomic weight*	*Atomic ratio*	*HCF*	*Atoms present*
C	21.4	12	1.76	1.76/1.66	1
H	6.11	1	6.11	6.11/1.66	4
N	46.6	14	3.33	3.33/1.66	2
O	26.44	16	1.66	1.66/1.66	1

Hence the empirical formula of the compound is CH_4N_2O.

2. *In a pond with volume 20 × 10 m that is fed by a waste material with a flow rate of 5 m/s and pollution concentration equal to 20 mg N. In another pipe there is sewage fall at the rate of 0.2 m/s in the pond which has a concentration of 50 mg/1 and reaction rate coefficient 0.20/day. Find the steady state concentration in the lake.*

Solution: Let us consider the pollution is completely mixed in pond as the concentration of the mixture is Cm.



$$\begin{aligned}
\text{Input rate} &= Q_I C_I + Q_m\ C_m \\
&= (5 \times 20 + 0.2 \times 50) \times 10^3\ \text{L/m}^3 \\
&= (100 + 10) \times 10^3 \\
&= 110 \times 10^4\ \text{mg/S} \\
\text{Output rate} &= Q_u\ C_u \\
&= (Q_I + Q_m)\ C \\
&= (5 + 0.2)\ \text{m}^3\text{/S} \times \text{Cmg/L} \times 10^3\ \text{L/m}^3 \\
&= 5.2 \times 10^3\ \text{Cmg/S} \\
\text{Decay rate} &= KCV = 0.20 \times d \times C\ \text{mg/L} \times 10 \times 10^6 \text{m}^3 \times 10^3\ \text{L/m} \times 24\ \text{hr/d} \\
&\quad \times 3600\ \text{S/hr} \\
&= 23.1 \times 10^3\ C\ \text{mg/S}
\end{aligned}$$

Therefore,

$$\begin{aligned}
5.2 \times 10^3 C + 23.1 \times 10^3 C &= 11 \times 10^4 \\
28.3\ C \times 10^3 &= 11 \times 10^4 \\
C &= 3.89\ \text{mg/L}
\end{aligned}$$

3. *A city of population 5 lakhs with a per capita demand of 250 liters / day is to be supplied water after disinfecting with a chlorine dosage of 0.7 ppm. If bleaching powder is 40 % available chlorine is used. Find the yearly requirement of bleaching powder .*

Solution:

$$Q = 500000 \times 250 = 125 \times 10^6\ \text{L/day}$$

Dosage of bleaching powder with 40% chlorine = 0.7/0.4 = 1.75 mg/L

$$\begin{aligned}
\text{Bleaching powder required} &= 125 \text{ x } 106 \text{ x } 75 \\
&= 218.7\ \text{Kg/day} \\
\text{Yearly requirement of bleaching powder} &= 30 \text{ x } 12 \text{ x } 218.7 \\
&= 78732\ \text{Kg /year}
\end{aligned}$$

4. *A truck collects 500 Kg/m^3 of solid waste in a Bombay city and a dump time of 5.0 minutes. In order to ensure once a pick up the truck collects the solid wastes from 250 locations per day. The disposal site is 8 km away from the collection site. Each stop typically has four cans containing 5 Kg each. About 10 percent of the stops are backyard pickups. Assume that two trips per day will be made to the disposal site. The mean density of solid waste is 10^2 Kg/m^3 and mean time per collection stop plus mean time to reach next stop (tp) is 0.0253 hour. Find out the size of the truck needed for solid disposal. Decay time is 15 minutes, Unloading time at disposal site = 6 minutes, Off route time (B) = 0.50, Average haul speed = 25km/h.*

Solution: According to Government analysis of refuse collection and sanitary land fill Disposal (USA Technical Bulletin no. 8, page 61, 1952)

The truck capacity is given by

$$V_T = \frac{V_P * H * 2X}{r * t_p * N_d * S}(2t_d - t_u) - (B / N_d)$$

where

V_T = Volume of solid waste carried per truck by truck at a mean density D_T, m^3

V_P = Volume of solid waste per pick up location, m^3/stop

r = Compaction ratio

tp = Mean time per collection stop plus the mean time to reach the next stop, hr

H = Length of working day, hr

Nd = Number of trips to the disposal site/day

X = One-way distance to disposal site, Km

S = Average haul speed to and from disposal site, Km/hr

td = One-way delay time, hr/trip

tu = Unloading time at disposal site, hr/trip

B = Off route time per day, hr

Generally truck costs include the depreciation of initial capital investment plus the operating and maintenance which is given as follows

The volume per pick up VP = (4 cans) * (5Kg/can) * (0.19 m^3)/(10^2 Kg/m^3)

Haul distances (S) = 2 × 8 16 Km

The compaction ratio is determined from the density

r = 500 Kg/m^3 / 10^2 Kg/m^3 = 4.90

VT = (1.53) (4–0.64-0.5-0.1–.0.25) = (1.53) (2.51) = 3.84 m

QUESTIONS

1. Differentiate between garbage, rubbish, refuse and trash based on their composition and source.
2. What are the different types of solid wastes produced? What are different characteristics of Municipal solid waste?
3. Compare the advantages and disadvantages of collection methods of Municipal solid wastes.
4. What are the methods of transporting solid wastes? What are the factors on which transporting costs depend?
5. What are hazardous wastes? What are its impacts on health?

CHAPTER 3

TREATMENT OF SOLID WASTES

3.0. INTRODUCTION

At all levels of human developments as well as the industrial revolution create environmental problems as pollution in air, water pollution and solid waste disposal. It is unfair to classify solid waste problem as a single part problem to the environment, rather this problem is transcend traditional environmental boundaries and contribute to air, water and land pollution.

In India 29 million tons of MSW is produced every year. It is due to concentration of very high population in urban areas and added new type of wastes from shops, institute and factories. The solid wastes provide an attractive habitat for disease vector (as flies and rodents). It requires long time for decomposition in usual course that may cause air pollution as well as water pollution. Therefore, there is a need for the treatment of solid wastes.

3.1. METHODS OF TREATMENT

There are nine methods of treatment of solid wastes: (A) Landfill method (B) Composting (C) Vermitechnology (D) Anaerobic digestion (E) Incineration (F) Pyrolysis (G) Catalytic hydrogenation of solid waste (H) Hazardous solid waste management and treatment.

3.1.1.(A) Landfill method

Landfill arises from the chemical changes brought about by bacteria and complete disposal of solid wastes by filling in the upper layer of the earth's mantle.

The advantages of a well planned and operated landfill are :

(*i*) It requires a relatively small capital investment.

(*ii*) It may reclaim fallow land.

(*iii*) It minimizes odour and fire nuisance, etc.

(*iv*) It denies access to the wastes to the flies that are already to the site.

The disadvantages are:

(*i*) It frequently requires longer and more costly hauls than other methods.

(*ii*) It requires more land than some other methods that makes it difficult to obtain suitable sites at reasonable cost in big cities.

(*iii*) Operational problems may occur during inclement weather, and

(*iv*) If proper action is not taken it causes health hazards as insects and rodents may breed.

(*v*) There is possibility of water moving through the system.

Important aspects in the design of land fills include : (*i*) Site selection (*ii*) Land filling (*iii*) Recovery of land fill gas (*iv*) Equipment requirements (*v*) Water pollution (*vi*) Control of hazards.

(*i*) Site selection: The types of sites being used for disposal are (*i*) Low laying land, (*ii*) Valleys, (*iii*) Mineral excavation, (*iv*) Areas involving reclamation (*v*) Flat land to build up future.

The selection of site for land fills should be based on obtaining large enough tracts of land located in areas which have soil characteristics that will minimize the possibility of ground water pollution. There should be access roads, which will be hard and wide enough to permit two way truck travel. The site may also have the facilities of equipment shelters storage sites for special wastes, electric, water and sanitary services.

(*ii*) Land filling : The three major methods of dumping are (*a*) Area filling (*b*) Trench filling (*c*) Depression filling.

(*a*) Area filling : In this process waste is spread to a thickness of 15-30 cm and a top dressing of moist earthen materials spread to avoid blowing of light materials by wind. Such layer continues to be deposited until a final height about 3 meters and the final cover materials are relatively thicker and heavier, say 4-5 cm. A compacting process is better for the future land use

(*b*) Trench filling: This method is better if the water level is low at the site of filling. The earthen trench materials are reused as cover materials.

(*c*) Depression filling: This method is applicable when natural and man-made depressions are not very useful for aquaculture or for other storage purpose. Selection of depression should be proceeded by a study of the geometry, hydrology, land geology and available cover material of the site.

As per Indian Municipal (Managing and Handling rules, 2000), there is the following criteria for land filling:

(*i*) The area of landfill site should be large enough to last for 20-25 years.

(*ii*) The site shall be at least 0.5 Km away from habitation clusters, forest areas, monuments, national park, wetlands and places of important cultural, historical or religious interest.

(*iii*) Land fill site should be at least 20 Km away from airport including airbase. Municipal authorities shall obtain approval of airport/airbase authorities prior to the setting up of the landfill site.

(*iv*) A 500 meter wide buffer zone of no-development be maintained around land fill site and shall be incorporated in the Town Planning Department's land-use plans.

Salvato (1989) recommends a formula for estimating annual volume required for land filling :

$$Vl.F = P^* \ E^*C \ / \ Dc$$

Where $Vl.F$ = Volume of landfill, m^3

P = Population

E = Ratio of cover (soil) to compact fill

C = Average mass of solid waste collected per capita per year, kg/person

Dc = Density of compacted fill kg/m^3

Ratio of cover (soil) to compacted fill

E = VLF + VC/VSW

Where VSW = Volume of solid waste, m^3

VC = Volume of cover, m^3

The density of the compacted fill is somewhat dependent upon the equipment use at the landfill site.

(*iii*) Recovery of landfill gas: Municipal solid waste are potential resources for recovery of land fill gas (mainly methane) and the average availability is about 5 liters per Kg per year. Four gases are formed such as hydrogen sulphide, carbon monoxide, carbon dioxide and methane. Though hydrogen sulphide gas is toxic it is found in small traces and its large concentration can be traced by its smell.

Carbon monoxide, present in large amount is diffused very slowly on the surface. Methane is diffused very slowly from the site and is present in higher concentration below the level at which ignition would occur.

Three main types of bacteria are found in landfill method (*i*) Saprogenic, the bacteria responsible for decomposition (*ii*) Zymogenic bacteria which are agents for fermentation (*iii*) Pathogenic, associated with human diseases.

Saprogenic and zymogenic are aerobic type bacteria for which oxygen is necessary. They are obligate and facultative anaerobes that can adjust to varying supplies of oxygen.

During first stage of decomposition aerobic bacteria are dominant but declines their activity as their work due less amount of oxygen and their work is taken by anaerobic and facultative bacteria.

During the decomposition of waste internal temperature of landfill rises as result of activities of aerobic bacteria, which are helpful of destruction of pathogen bacteria.

(*iv*) Equipments required: The equipment requirements for landfill include crawler and rubber-tied tractors, scrapers, compactors, drag lines and motor graders. The size and amount of equipments required will depend primarily on local site conditions, the size of the landfill operation and the method of operation. A covered shed should be provided for filed maintenance of the equipment. Telephone is also needed for emergencies.

(*v*) Water pollution : In landfill waste and the products of decomposition either by rain fall or ground water movement can adversely affect its utility. There is possibility of serious water pollution.

In order to avert water pollution, the lowest level of the landfill should be no less than ten feet above the expected level of the high water table. In addition, proper surface drainage should be designed and established in order to prevent water from washing through the rubbish and re-entering the existing water routes.

(*vi*) Control of hazards: Pathogens bacteria can be controlled by quickly covering the waste with a layer of soil at least 20-25 cm thickness. This serves both to isolate the waste and retain heat for destruction of pathogens. There it should not permit cans on the open surface as it will be helpful for breeding of mosquitoes during rainy season. Regular inspection should be required for rat infestation and if required anticoagulant poison should be used. Watering carts should be frequently used to reduce air-bome dust. Workers should always use gloves to protect them from dermatitis.

Landfills are brimming, and new sites are not likely to be easily found. For this reason there is an interest in conserving existing landfill space and in developing alternative methods of dealing with waste. The better option is composting for treatment of solid waste.

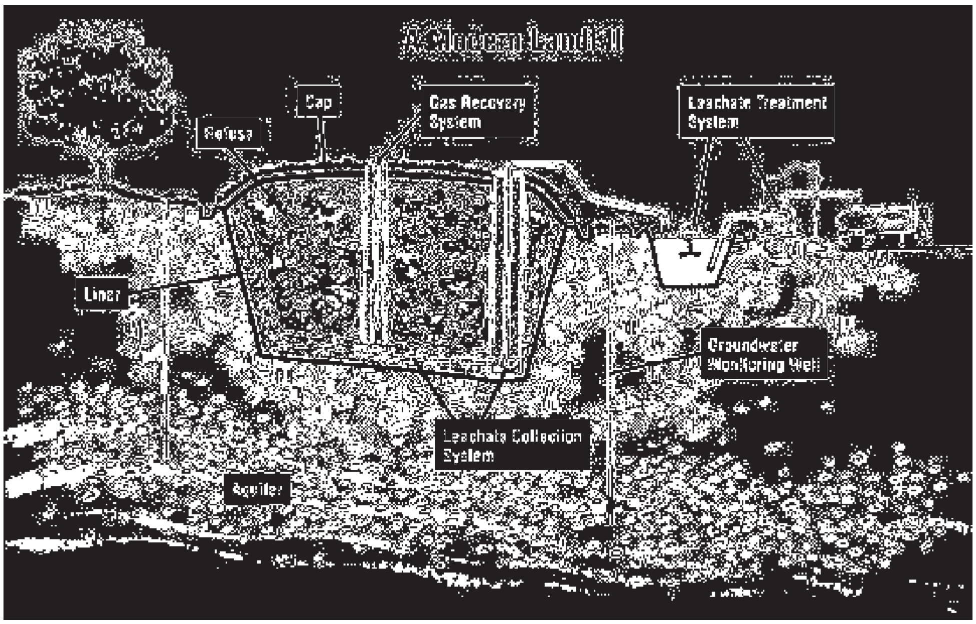


Fig 3.1. Landfill method

3.1.2. (B) Composting

It is an anaerobic microbial driven process that converts organic wastes into sanitary humus like material. This material can then be safely returned to the natural environment. This method is actually a low moisture, solid fermenting process. It leads to volume reduction of 50% of waste Using compost improves soil structure, texture and aeration and increases the soil's water-holding capacity. Compost loosens clay soils and helps sandy soils retain water. Adding compost improves soil fertility and stimulates healthy root development in plants. The organic matter provided in compost provides food for microorganisms, which keeps the soil in a healthy, balanced condition. It contains about 15% N_2, 1% P_2O_5, 0.8% K_2O, 30% C and 40% ash. Nitrogen, potassium, and phosphorus will be produced naturally by the feeding of microorganisms, so few if any soil amendments will need to be added. Compost does not present health hazards as heat developed during composting kills the pathogens and eggs of parasites. The primary aim of composting operating is to obtain final compost with a desirable product quality in a limited time period and within limited compost. The process is carried out by oxidizing the volatile matter in the biodegradable organic fraction of solid waste. Air acts as a source of oxygen and aerobic bacteria acts as a catalyst. The change occurring during the process may be represented as:

Biomass + O_2 (Aerobic/bacteria) $\longrightarrow$ CO_2 + H_2O + Organic manure

Compost includes the following steps:

(*i*) Facility deign: Selecting the right site is critical to many aspects of a composting operation, from materials transport and road access to neighborhood relations. From an environmental management perspective, the critical issues are soil type, slope, and the nature of the buffer between the site and surface or groundwater resources. If the soils are impermeable, groundwater is protected from nitrate pollution, but runoff is maximized which increases the BOD, phosphorus, and pathogen threat to surface water. On the other hand, highly permeable soils reduce the runoff potential but may allow excessive nitrate infiltration to groundwater. Intermediate soil types may be best for sites, which are operated on the native soil. For some large facilities, or those handling challenging waste materials, a working surface of gravel, compacted sand, oiled stone or even asphalt or concrete may be appropriate.

(*ii*) Removal of non-compostable : The first step is to remove several components of refuse which are of no values such as cans, glass either by hand pricking or ferrous material by magnetic separator.

Almost any organic material is suitable for a composting. But there need a proper ratio of carbon-rich materials, or "browns," and nitrogen-rich materials, or "greens." Among the brown materials are dried leaves, straw, and wood chips. Nitrogen materials are fresh or green, such as grass clippings and kitchen refuse. Manure is one of the finest materials you can add to any compost pile. It contains large amounts of both nitrogen and beneficial microbes.

(*iii*) Grinding : The raw refuse is shredded by grinder to 4 to 5cm size prior placement to digester. Leaves represent a large percentage of total any garden waste. If they are grinded in a shredder/chipper they will decompose faster—an issue with larger leaves. Seeding with partially decomposed solid waste to the extent about 1 to 5 percent by weight can reduce composting time.

(*iv*) Compost materials: Almost any organic material is suitable for a composting . Raw materials should normally be blended to approximately 35:50 (by weight) carbon to nitrogen ratio by weight. The ratio between these key elements is based on microbial biomass and energy requirements. Inadequate nitrogen (a high C:N ratio) results in limited microbial biomass and slow decomposition, while excess nitrogen (a low C:N ratio) is likely to leave the composting system as either ammonia (odour) or nitrate (water pollution). In nitrogen limited system microorganisms efficiently assimilate nitrate, ammonia and other nitrogen compounds from the aqueous phase of the compost, thus limiting the pollution threat.

For composting a proper ratio of carbon-rich materials, or "browns," and nitrogen-rich materials, or "greens." is mixed. Among the brown materials are dried leaves, straw, and wood chips. Nitrogen materials are fresh or green, such as grass clippings and kitchen refuse. Grass clippings break down quickly and contain as much nitrogen as manure but it should be avoided as grass clippings that contain pesticide or herbicide residue, unless a steady rain has washed the residue from the grass blades.

Kitchen refuse includes melon rinds, carrot peelings, tea bags, apple cores, banana peels which can successfully compost all forms of kitchen waste. However, meat, meat products, dairy products, and high-fat foods like salad dressings and peanut butter, can present problems. Meat scraps and the rest will decompose eventually but will smell bad and attract pests. Egg shells are a wonderful addition, but decompose slowly, so should be crushed.

The other important factor to consider when creating a composting mixture is water content. From a microbial standpoint, optimal water content should be 40 to 60% range. This moisture content is a balance between water and air filled pore space, allowing adequate moisture for decomposition as well as airflow for oxygen supply. The ideal water content will vary somewhat with particle size and density, and fine, dense organic substrates should be drier if adequate aeration is to be assured. Excess water, in addition to increasing the odor potential via anaerobic decomposition, will increase the runoff and leachate potential of a composting pile during rainfall .

(*v*) The phases of composting: In the process of composting, microorganisms break down organic matter and produce carbon dioxide, water, heat, and humus, the relatively stable organic end product. Under optimal conditions, composting proceeds through three phases:

(*a*) the mesophilic, or moderate-temperature phase, which lasts for a couple of days,

(*b*) the thermophilic, or high-temperature phase, which can last from a few days to several months, and finally

(*c*) a several-month cooling and maturation phase. Different communities of microorganisms predominate during the various composting phases.

Initial decomposition is carried out by mesophilic microorganisms, which rapidly break down the soluble, readily degradable compounds. The heat they produce causes the compost temperature to rapidly rise. As the temperature rises above about 40°C, the mesophilic microorganisms become less competitive and are replaced by others that are thermophilic, or heat-loving. At temperatures of 55°C and above, many microorganisms that are human or plant pathogens are destroyed. Because temperatures over about 65°C kill many forms of microbes and limit the rate of decomposition, compost managers use aeration and mixing to keep the temperature below this point. During the thermophilic phase, high temperatures accelerate the breakdown of proteins, fats, and complex carbohydrates like cellulose and hemi cellulose, the major structural molecules in plants. As the supply of these high-energy compounds becomes exhausted, the compost temperature gradually decreases and mesophilic microorganisms once again take over for the final phase of "curing" or maturation of the remaining organic matter.

(*vi*) Placement: Air circulation is an important element in a compost pile. Most of the organisms that decompose organic matter are aerobic—they need air to survive. Air with at least 50 percent of the initial oxygen concentration should reach all parts of the composting material for optimum results.

The rate can be estimated using the relationship by $W0_2 + 0.07 \times 10^{31}$ T where $W0_2$ is equal to the rate of oxygen consumption in mg O_2/h/g of initial volatile matter and T is equal to the temperature in ^{0}C.

Open files or windows (2m to 3m wide at the bottom) are placed on the ground on a paved area or shallow pits. The windows or piles are turned at such intervals that aerobic conditions are maintained. This may be every 2 or 3 days if moisture content is very high or a total of three to four times within 15 to 21 days composting period. Heat released during composting is equal to the difference of energy content of the material at the beginning and end of the process. The degree of decomposition can be estimated by measuring the reduction in the organic matter present using the COD (Chemical Oxygen Demand) test.

3.1.4. (C) Vermitechnology

Waste biomass from domestic, agriculture, urban and industrial sources is the main cause of organic pollution in developing countries which can be used for vermitechnology. It has the following advantages:

(*i*) Vermitechnology is a natural and eco-friendly process (*ii*) Vermitechnology facility can be designed and operated to minimize environmental impacts by controlling odors and bio aerosols (*iii*) It can replace high-cost inorganic fertilizers in developing countries (*iv*) It can improve soil quality by supplying humus forming organic materials. It can supply essential nutrients (apart from nitrogen, phosphorus and potassium that were drawn from soil through vegetation) (*v*) By a reduction of the leaching of nutrients and helping in the slow process (*vi*) Many community organic wastes generated from agricultural and forest activities, food processing industry, household activity and natural vegetation can be recycled into a vermitechnolgy. Thus, a single composting facility can handle a wide variety of organic resources. It can abatement of pollution through organic agriculture (*viii*) It can increase in the water retention capacity by increasing the humus content.

(*i*) Vermitechnology Process

Preparation and Loading: Vermitechnology or vermicompost can be practiced in small scale under indoor environment or in commercial scale under outdoor environment. The land topography should be at elevated or uplands to avoid water logging. The compost infrastructure should be developed under shade in a covered area to avoid. Vermitechnology can be done in earthen pits, concrete tanks, and plastic/ wooden crates or in tin containers.

For establishing a small unit at home scale or in a courtyard, a regular flow of organic wastes like kitchen waste, crop waste, animal waste etc. may be available. Generally, a container/box/bin made of wood/tin/plastics or two or three chambered containers can be used for vermitechnology depending on the amount of wastes generated in a family.

Usually, in multi chambered bin, composting is done alternatively following “by filling one and making vacant other” policy. The wooden bins are preferred because it provides better insulation against adverse temperature. The size and number of container depends on quantity of waste material generated per day. The height of the bin should not be more than 15-18 inches. Holes of 1/4th inch diameter made in the body of the container will ensure better aeration and drainage of excess water. A gunny bag or a lid to conserve moisture and avoid light for better activity of worm as worm functions against sunlight and prefers dark condition should cover the container.

Before putting household waste in the container, a layer of coconut coir/leaf mould/peat moss/banana stem peels of biodegradable in nature should be placed as first layer of 3-4 inch in thickness as vermibed. Thereafter, the household waste particularly kitchen waste can be added continuously in layers. Earthworm can consume all kind of household wastes like yard waste, tea bags, vegetable and fruit waste, pulverized egg shells etc. Waste like garlic and onion scales, citrus foods, bones, meats, dairy products and other household chemicals like metals, plastic, glass, soap, insecticide etc may be avoided. The efficiency of composting can be improved by reducing particle size and increasing surface area of the waste. Therefore, waste material may be dumped after grinding or blending. A good mixture preferably equals proportion, of brown (dry and dead organic waste like straw, weeds etc) and greens (fresh plant or kitchen waste materials) would be best for balanced nutrition to earthworm. On an average, a container of size 2 feet in width, 3 feet in length and 12 inch in depth can accommodate 1 kg of earthworm (approximately 2000 adults) which can recycle minimum half a kg of organic waste in a day.

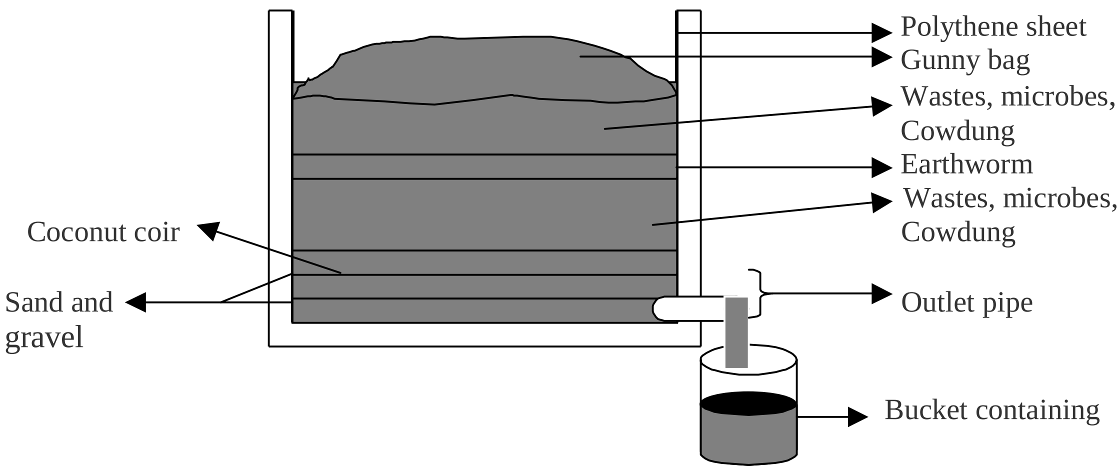


Fig. 3.2. Schematic structure of compost unit.

(*ii*) Commercial unit

Commercial unit can be developed on land surface by digging series of pits. The pit size can be of 10-12 feet in length, 3-4 feet in width and 1-1.5 feet in depth. Depending on topography the pit can be made below or above the land surface. A gentle slope is provided for collection of lecheate (vermiwash). There should be a provision of hole at the end of the pit for collection of vermiwash. A layout should be made providing series of pits (20-25 numbers) arranged in two rows face to face connection with a common channel. For collection of lecheate a slope of 0.5-1% in each pit is provided. The bottom of the pit can be lined with either polythene collected in a common tank. A number of such units can be made as per the availability of raw material and targeted production. Therefore, the layout of the vermicompost unit is important for providing slope both within the pit as well as in the channel so that the vermiwash from the entire system is collected at a common point in a chamber.

The site of commercial unit of vermitechnology should be selected based on availability of raw material in an area. In Eastern India the raw materials available plenty are: paddy straw, vegetable wastes, wastes from other cereals, pulses, oil seed crops, garden waste, waste generated in aquatic bodies (water hyacinth) and food processing industry. A sequence of operations is generally performed for vermitechnology before the materials are loaded in the pit. After collection, the raw materials are chopped or crushed or cut into small pieces for increasing surface area and thereby hastening the decomposition process. Another important raw material for earthworm feed is cow dung. For production of quality feed of earthworm, intermixed materials would be an ideal proposition depending on availability of the raw material. It has been observed that minimum 20% of the cow dung would be required in a mixture and maximum may be 80%. Some waste materials like bran of wheat, rice, pulse and kitchen waste are more ideal as feed material. Therefore, any combinations of feed materials can be prepared depending on availability of the raw material.

For hastening the decomposition process the cellulolytic and lignolytic fungus cultures are added at the rate of 500 cc/t of material and mixed thoroughly. The mixed materials can be allowed for pre decomposition for 10-15 days before putting in bed or can be directly placed in bed. While loading, the depth of loaded material in the bed should be 1-1.5 feet at a desired moisture content ranging from 70-80 % depending on raw material. A thin layer (1-2 inch) of pure cow dung of 7-10 days old may be placed on the mixed materials as a starter food to earthworm. After checking the temperature inside the bed the earthworm should be released at the rate of minimum 5000 numbers per bed. If the temperature inside bed is more than ambient temperature earthworm should not be released till temperature attains normal. The mixed material can also be placed in 2-3 installments adding about 4-6 inch layer at a time and release the earthworm in desired number till it attains a depth of about 1-1.5 ft. The worm starts consuming the waste material and moves downward and upward so that the entire material are consumed uniformly and subsequently leave vermicast. During process of vermicomposting an ideal environmental condition should exist with respect to moisture (60-80%), temperature (25-30° C), optimum air volume and a pH level towards neutral. At temperature drop below 10°C in the bed the worm will be less active and show low mobility and food consumption. Under such circumstances the earthworm community will remain in a favorable zone in the bed. Thus, the composting process will be slow and uniform. If temperature attains 5°C or less the adult worm may stop producing cocoons and the growth rate of baby earthworm will be reduced.

During composting, the earthworms produce cocoons that hatches and produce baby earthworm. Thus they multiply and increase the population. A regular management practice of watering requires for maintaining a desired level of moisture in the bed. This can be achieved by practicing sprinkler irrigation system with major quantity of water. During winter and summer, under extreme cold or hot climate, adequate measure to be taken to maintain desired temperature in the bed by using certain insulating material like gunny bag, paddy straw, wooden material etc.

(*iii*) Maturity and Harvesting

When the vermicompost starts maturing show a definite change in physical appearance of compost material. At maturity the material will be soft, spongy, dark brown in color with earthy odor (no foul smell). At this point the watering can be stopped. The maturity can also be judged by C: N ratio, BOD, nitrate-N, VFA (volatile fatty acids) and ratio of reducing sugars etc.

After harvesting of vermicompost, earthworms can be separated either by manually or by screening through a net of 2 mm in size. However, the later process of earthworm separation is more convenient and economical than the former one. After separation the cocoons and baby earthworm may remain with vermicompost. After earthworm separation the moisture is brought to 20-25 % level before bagging. During dry season the vermicompost gets dried under open sun while, during rainy season, drying under open condition become difficult. At IIT, Kharagpur an innovative earthworm separator cum vermicompost drier is designed and developed. The harvested vermicompost is spread on a screen where the earthworm gets separated and remains above the screen, while the vermicompost moves downwards through a series of plates. During the movement hot air blows with air temperature of about 50° C to bring down the moisture content of compost to a desired level. Finally, the dried compost falls on a conveyor belt, which is bagged, in the same unit. The capacity of the machine is 100 kg/hr.

(*iv*) Vermiwash

Besides production of solid vermicompost, another product i.e. liquid manure or vermiwash is obtained in composting process. During watering of compost beds the excess water percolate through the compost material and is collected in a tank. All the soluble nutrients, enzymes, humic acid and hormones are washed through the body of the earthworm and vermicompost, which is a rich fertilizer material, used as liquid manure. From each vermibed minimum 100 liters of vermiwash can be harvested per year. Vermiwash is generally used as a foliar spray to the crops and also in water bodies in fish farming for increasing production of phytoplankton and zooplankton.

Table 1. Composition of Vermicompost and Vermiwash

Parameters	*Vermicompost*	*Vermiwash*
pH	6.9	6.9
N %	1.60	0.0046
P %	0.98	0.0025
K %	1.10	0.063
0.C %	14.1	—
Cu ppm	38.0	0.117
Zn ppm	180	0.132
Ca ppm	2760	786
Mg ppm	4100	328
Fe ppm	11200	0.151
Mn ppm	1290	213

(*v*) Effect on soil properties

Soil biological components is favorably influenced by the addition of compost. The organic substance feeder type of earthworm seems to be great promoters of crop production by boring, perforating and loosening the soil, by consuming organic wastes and by releasing excreta as worm casts. Their body exudates improve the water holding capacity of soil and promotes in establishing beneficial microorganisms in soil. Addition of vermicompost replenish the organic matter content of soil and increase the availability of moisture to the plant and thus reduce the number of irrigation needs. In clay soil, the addiction of vermicompost increases the permeability to water and air, which in turn increase the infiltration rate and reduce surface runoff. The nutrient rich vermicompost supplies all necessary macro and micronutrients to the plant system.

3.1.5. (D) Anaerobic digestion

Using the process microbial degradation of organic waste promotes fermentation of gases and soluble salts and finally to utilize the organic matter as the fertilizer. The process involves four groups of bacteria in the digested slurry as follows :

(*i*) The hydrolytic bacteria catabolize the carbohydrates, proteins, lipids etc. contained in the biomass to fatty acids, H_2 and CO_2.

(*ii*) Hydrogen-producing acetogenic bacteria catabolize certain fatty acids and some neutral end products to acetate, CO_2 and H_2.

(*iii*) Homoacetogenic bacteria synthesize acetate using H_2, CO_2 and formate.

(*iv*) In the final phase, called the methanogenic phase, methanogenic bacteria cleave acetate methane and CO_2. Water acts as an oxidizing agent in methane formation. Thus water acts upon enzymes, itself breaking to form hydrogen and oxygen. Hydrogen is used by microorganisms to reduce CO_2 to CH_4, while oxygen oxidizes the decarbonized to form acid. Thus methane forming bacteria plays an important role in circulation substances and energy turnover in nature. They absorb CO, CO_2 and H_2 to give hydrocarbon, methane and synthesis of its own cell substances.

In practice, anaerobic digestion of MSW is carried out by segregating the non-biodegradable and the biodegradable materials. This may do manually or mechanically. The smaller pieces of inorganic like clay, sand may be removed by washing the biomass with water. The washed material is then shredded such a size that will not interfere with mixing and may be more amenable to bacterial action. The shredded biomass is then mixed with sufficient quantity of water and slurry is fed in to a digester system.

If necessary nutrients like nitrogen, phosphorus and potassium have to be added to the digester. The hydraulic residue time in the digester system depends on the following:

(*i*) Digester type (*ii*) Operating temperature (*iii*) Feed slurry consistency.

Wash time is in the range of 3 to 4 days. Destruction of volatile solid wastes varies from about 60-80 percent and can be used for estimating process. Gas production is 8 t0 12 ft^3/ lb of volatile solids destroyed (CH_4 = 60 percent, CO_2 = 40 per cent).

During the anaerobic digestion a gas containing mainly CH_4, and CO_2 are produced. The gas is called biogas which is used for generation of electricity or fuel. The residual biomass comes out of the digester is form of a slurry, which is separated into a sludge, which is used as manure and a stream of waste water. A portion of water may be recycled and the remaining portion may be discharged. The operating temperature may be ambient temperature to 60 ^{0}C. In most of the digesters are single stages, where all the reactions mentioned take place. Two stage digesters are in operation where in the first stage, the hydrolysis and acidogenic take place. While in the second phase of digester, the methanogenesis reaction takes place. Residence time is of about 7 days. The technical problems of the system are as :

(*i*) When low solid content slurry is used in a digester, relatively large quantity of water is required. Disposal of a large amount of wastewater may be a problem.

(*ii*) Gas production from unheated digester becomes low in winter.

(*iii*) To maintain digesters at a temperature higher then the ambient its contents are to be heated. This gives rise to some difficulties as the heat exchanger tends to get fouled easily.

3.1.6. (E) Incineration

This process was practiced for the long time to reduce solid waste and lower transporting costs to disposal site and accommodating the wastes for a greater number of people. The two main disadvantages of the process are (*i*) Capital, equipments and operating costs are very high (*ii*) Possibility of high pollution in air.

The advantages of this process is that

(*i*) Land required per ton of solid waste is less compared to that required land fill (less than one third).

(*ii*) Lower transportation costs to disposal site.

(*iii*) As high heat is produced many pathogenic disposal residues are best disposed by incineration (specially hospital residues).

(*iv*) In USA at ocean side, Longs island it has been developed power recovery during incineration.

(*v*) In the process ashes left over in the combustion chamber can be used for fertilizer, aggregates and materials recovery.

There are two types of incinerators (*i*) Batch type (*ii*) Continuous type.

(*i*) Batch type: It is unsuitable for urban area but are used for in the smaller surrounding communities. The process promotes inadequate combustion due to lack of uniform burning temperature. As a result there is heavy output of particular matter, optimal volume reduction and an unstable residue. It is very difficult to control economically emission of particulates.

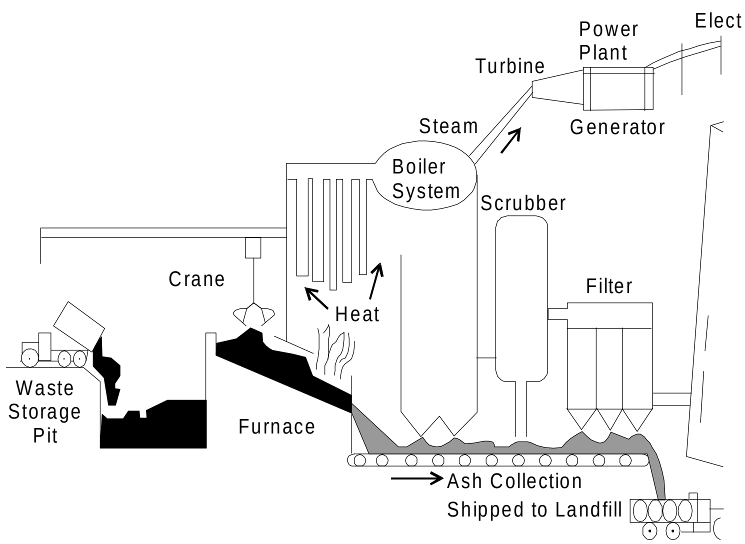


Fig. 3.3 Incineration plant with pollution control system.

(*ii*) Continuous type: In that process incinerator attends a uniform combustion temperature range and yields a stable residue. Volume of solids is achieved in a well-deigned incinerator to one third of its total waste with controlled temperature range 760-1000^o C. It has been found that particulates emissions from incinerators are found 18 to 20 percent that can be successfully controlled by wet scrubber or electrostatic precipitator. Recently waste heat can be utilized for steam generation, electricity or desalination of seawater. In that process storage bins depend on the furnace capacity, storage requirements, collection schedule and truck-discharge methods. Furnace grates are used to move wastes through furnace. Traveling, reciprocating, rocker arm and borrel grates have been used successfully. Burning rate 60 to 65 lb/ft^3/hr has been adopted as a generally allowable for standard firing. Refractory made combustion chamber are generally used.

Heat recovery system is used by two boiler section: convection and economizer.

As incinerators produce air pollution, nuisance of dust and noise pollution it is necessary to overcome this negative feeling and to improve its design and technology to make worthy for future generation.

3.1.7. (F) Pyrolysis

Solid wastes generated from municipal, domestic or industries are either disposed in land fill or incineration processes but these are being restriction due to air pollution or the availability of lands. Pyrolysis is a form of incineration that chemically decomposes organic materials by heat in the absence of oxygen. Pyrolysis typically occurs under pressure and at operating temperatures above 430°C. In practice, it is not possible to achieve a completely oxygen-free atmosphere. Because some oxygen is present in any pyrolysis system, a small amount of oxidation occurs. If volatile or semi-volatile materials are present in the waste, thermal desorption will also occur. Organic materials are transformed into gases, small quantities of liquid, and a solid residue containing carbon and ash. The off-gases may also be treated in a secondary thermal oxidation unit. Particulate removal equipment is also required.

Pyrolysis destroys semi-volatile organic compounds, fuels and pesticides in soil. The process is applicable for the treatment of organics from refinery wastes, coal tar wastes, creosote-contaminated soils, hydrocarbons, and volatile organic compounds.

Several types of pyrolysis units are available, including the rotary kiln, rotary hearth furnace, or fluidized bed furnace. These units are similar to incinerators except that they operate at lower temperatures and with less air supply. Combustion takes place in three stages:

(*i*) Drying: Moisture must be driven from the solid waste with heat so that it can be made hot enough to break up into its combustible components and burn.

(*ii*) Pyrolysiis : The volatile matter in the feed is converted to combustible gas or liquid. Part of the gas or liquid is combusted within the furnace to provide required heat.

Automatic control regulates air supply to maintain air temperature in the furnace.

(*iii*) Gasification : In some pyrolysis operations the fixed carbon left after pyrolysis is gasified to drive additional energy. Fixed carbon in that portion of combustible content of the feed remaining after the volatile matter has been distilled off.

A molten salt process may also be used for waste pyrolysis. In molten-salt oxidation (MSO), combustible waste is oxidized in a bath of molten salts (at 500-950°C). There is no direct flame, and this prevents many of the problems associated with incineration. Shredded solid waste is injected with air under the surface of a molten salt bath. Hot gases rise through the molten salt bath. The salt, being alkaline, scrubs acids from the gases. The heat of the molten salt degrades and melts the waste material. Because the salt bath is liquid, it also removes some particles in the gas. By-products are retained in the melt. Gases exiting the salt bath are treated by an emission clean up system before discharge to the atmosphere. Spent molten salt is tapped from the reactor, cooled and placed in a landfill.

The advantages of pyrolysis process are as follows:

(*i*) Due to less amount of air being required in pyrolysis unit, the exhaust gas handling system is smaller than an incinerator.

(*ii*) It is easier to control the temperature than incinerator.

(*iii*) The operating cost may be lower in a pyrolysis furnace than incinerator especially if exhaust gas temperature is 1400^{o} C.

(*iv*) Hearth area of sludge handling capacity in pyrolysis can be higher than incinerator

(*v*) Residual product may be used for waste water treatment for removal of organics or an aggregate for road preparation.

Disadvantages of the process:

(*i*) Due to presence of reduced organic compounds in the pyrolysis exhaust gases, the corrosivity is higher than incinerator.

(*ii*) It has been observed that the combustible fraction in the residue can reach high levels due to incomplete reaction. This might cause some ultimate disposal problems.

(*iii*) Due to controlled oxidizing atmosphere to be maintained in the furnace, more control is required than incinerator.

(*iv*) There is high content of CO gas than incinerator.

There is development of waste treatment by pyrolysis known as Plasma pyrolysis technology. In that process there is thermal disintegration of carbonaceous materials into fragments of compounds in an oxygen-starved environment. Plasma pyrolysis (also called plasma gasification) exploits the thermo chemical properties of plasma. The particle kinetic energy in the form of heat is used for decomposing chemicals. The total process is as follows:

The system consists of feeder, primary and secondary chambers, scrubber and induced draft fan mounted on a common movable platform The double port feeding mechanism is easy to operate and is charged with inert gas to prevent air venting into the hot zone. Fish mouth door has been provided with a cover of heat resistant material, which do not allow heat to enter. A plasma torch is mounted on the circular end well. The torch is aligned in such a way that waste materials fall into the hot zone of the plasma arc. The torch cathode and anode are cooled by forced water flow. In addition, auxiliary cooling of anode with air has been incorporated in the plasmas torch. The waste induced into the extended hot zone of the primary chamber is pyrolysed. The pyrolysis producer gas contains CO and hydrogen along with hydrocarbons and is combustible. This is ignited inside the secondary chamber. The exhaust gas is scrubbed and released into the atmosphere is almost colourless. There are following operational advantages.

(*i*) Compactness (*ii*) It can fully be automated (*iii*) It can be located in the hospital building or other commercial places for heat recovery. (*iv*) No segregation required (*v*) It has above 95 % volume reduction.

3.1.8 (G) Catalytic hydrogenation of solid wastes

At this time the common methods of waste disposal in India are landfill, incineration and composting which have resulted either in low calorific value fuels or production of non-saleable commodities. Hence, there is a need to concentrate on newly developed techniques such as catalytic hydrogenation where the waste can be efficiently processed into high heating value fuel oil. The process has the following advantages:

(*i*) The relevant technology is available in the field of coal pyrolysis to guide reactor design and material selection.

(*ii*) The product fuel oil could be stored and used when required for external purposes.

(*iii*) Gas volumes are considerable less then those produced by conventional incinerators and consequently gas cleaning costs are lower. Air pollution standards can be maintained at low cost.

(*iv*) The char obtained is a storable and transportable fuel. In a mixture with sewage sludge it can be as a fertilizer. As the char has a large volume, it shows promise for use as a substitute for activated carbon.

(*v*) The solid residue (ash) obtained is inert, sterile and provides for a satisfactory filling material. The solid residue occupies a volume only 10% or less of the original volume of the waste.

(*vi*) There is efficient recycle of raw materials. Iron, aluminum, tin and glass can be recovered.

(*vii*) When the system is operated properly, there is no air or water pollution.

(*viii*) The process shows the potential for profitability.

Research has been done on catalytic hydrogenation solid waste conversion for a number of years. But Nag has developed technology for the catalytic hydrogenation of municipal solid waste that will help in long term benefits of the process and social obligation in avoiding pollution control.

Design of the total process : In that process ferrous material is separated from the waste by a magnetic separator; this prevents damage of shredder machine which consists of large hammer mills to crush the incoming material. The size classification of particles after reduction is achieved by means of an electrically operated rotating wire screen (mesh size opening 0.05 cm). The bigger particles after separation are recycled to the shredder machine and the fine particles are fed to the slurry preparation tank. In this tank nickel catalyst as nickel hydroxide and recycle carrier oil are mixed well with solid waste by an agitator.

Nickel hydroxide catalyst is prepared by the reaction of ammonia on a saturated solution of nickel nitrate. The mixture is boiled to remove excess ammonia and is then filtered. Nickel is chosen because in an ultimate process it can be removed magnetically and recycled.

The slurry is sent to the furnace through a pump where the slurry is heated to 450-460°C by oil available in the product of the process. The slurry is then pumped to a continuously stirred tank reactor (CSTR) operating at 70-80 Kg./cm^2 pressure and temperature 450-460°C. The agitation speed is maintained between 70-80 rpm.

The detailed design of reactor is shown in Fig 3.4. The use of low vapor pressure oil carrier permits operation temperature of the water. Compressed hydrogen gas (70-80 kg./cm^2 pressure and temperature 150-160°C) is introduced in the reactor. Since the reaction conditions are essentially those of the water gas generation and shift reaction, about 50 per cent of the hydrogen requirements of the process are met by generation of hydrogen in situ. The organic wastes decompose at the high temperatures to oil soluble fragments which migrate to the catalyst in the slurry for hydrogenation. Thus, the oil functions are not only as a transport and reaction medium for the solids but also plays a key role in the following reaction.

$$4C_6H_{10}O_5 + 12H_2 = \underset{\text{Oil}}{(C_6H_{14} + C_{12}H_{26})} + 4CO + 2CO_2 + 12H_2O$$

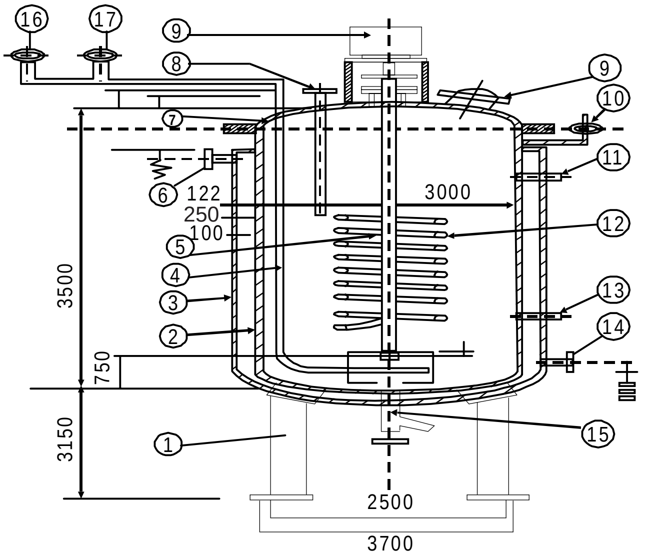


Fig. 3.4 Design of a CSTR for Catalytic hydrogenation

(1) Supporting legs (2) Reactor vessel (3) Steam jacket (4) Hydrogen Inlet (5) Agitator (6)Reactors inlet (7) Reactor vessel cover (8) Thermo wall (9) Agitator motor with gear unit (10) Manhole (11) Liquid level controller (12) Cooling coil (13) Temperature control socket (14) Condensate outlet (15) Product outlet (16) pressure gauge (17) Flow meter

The volatile product passes through a heat exchanger where heat exchange takes place between recycled carrier oil and the product from CSTR.

The partially cooled slurry is fed into the knock-out pot, where gas-slurry separation takes place. The product gases from the top of the knock-out pot are sent to the hydrogen plant for further processing. The slurry from the knock-out pot is passed through a recycle oil cooler and fed to a settler tank Where the slurry streams are separated according to densities. The product oil, having the higher density, remains at the bottom and is divided in to two streams, recycle stream and product stream. The recycle stream is sent to the slurry preparation tank and product stream is sent to the product oil storage tank.

Char, catalyst and water taken out from the bottom of the settler tank are passed through a magnetic separator which separates out the nickel catalyst for recycle to the slurry preparation tank. After catalyst separation, the char and water are sent to the settling tank where char and water are separated out.

The product gases obtained from the knock-out pot, are compressed (35-40 kg./cm^2) and are fed to a reformer after mixing with superheated steam. The reforming reacting takes at 700-740°C temperature in the presence of nickel catalyst and heat is supplied to the reformer by combustion of a fuel oil/air mixture. The reformed gas is fed to a heat exchanger where it exchanges heat with boiling feed water and temperature of the gas is reduced to 355-360°C.

The gas from the reformer is fed to a shift converter containing iron oxide catalyst where carbon monoxide reacts with steam to form carbon dioxide and hydrogen.

Converted gas is cooled by heat exchange and enters at the bottom of a column for CO_2 removal by contact with potassium carbonate in presence of steam at a temperature of 60-80°C. The spent solution from the absorption column is regenerated by heating to 110°C and is again for absorption.

The produced water contains impurities and has an unpleasant phenolic odour. Treatment with activated carbon column is an effective method for water purification ; after treatment, the water is colourless, odorless and has a pH around 6 to 7.

Economic viability of that process

Let us assume that 1000 tons of organic/day is fed to the reactor.

Total organic in the municipal solid waste (paper, Plastic, total compostable) totals 48.97 tons; total inorganic in the municipal solid waste (metals, glass, and ash fines) total 36.62 tons; and rest (14.41 tons is moisture).

Consider that 2 % organic material is lost with in organics. Therefore total organic required before unit operation is 1020 tons.

$$\text{Inorganic per 1020 tons organic feed} = \frac{36.62 \times 1020}{48.97} = 762.76 \text{ tons}$$

$$\text{Moisture content} = \frac{14.41 \times 1020}{48.97} = 300.14 \text{ tons}$$

Total municipal solid waste required/day = (1020 + 762.76 + 300.14 tons) = 2082.9 tons, 2.3 tons of catalyst and 3000 tons of carrier oil are used per day. Therefore from the material balance, the gaseous products obtained from the reactor and hydrogen plant are :

Reactor plant	*Hydrogen plant*
(Output /day)	(Output/day)
(*a*) H_2 – 72.5 tons	CO_2 – 470.62 tons
(*b*) CO – 105.2 tons	H_2 – 116.52 tons
(*c*) CH_4 – 1.8 tons	
(*d*) CO_2 – 75.0 tons	
(*e*) C_2H_6 – 71.5 tons	
(*f*) C_3H_8 – 7.9 tons	

Overall reactor energy balance : Input (Kcals/day)

Heating value of solid waste	= 38.62×10^9
Sensible heat of solid feed at 455°C	= 1.39×10^9
Heating value of hydrogen	= 3.81×10^9
Sensible heat of hydrogen	= 0.082×10^9
Total	43.832×10^9 Kcals

Out put (Kcals/day)

Heating value of production gas	= 3.92×10^9
Sensible heat of product gas at 175 °C	= 0.09×10^9
Heating value of product oil	= 36.4×10^9
Sensible heat by product oil	= 0.83×10^9

Heating value of char $= 2.13 \times 10^9$

Total $= 43.37 \times 10^9$ Kcals

Cost Estimation

Direct Production Cost :

Item	Cost $\times 10^7$ (Rupees)
(*a*) Cost of catalyst (2.3 tons) and carrier oil (3000 tons)	0.575
(*b*) Utilities :	
Cost of power (3.06×10^7 Kwh)	1.7
Cost for D.M. water	0.063
Cost for process water	0.125
(*c*) Operating labor and supervisory	0.5
(*d*) Cost of maintenance and repair	2.7
(*e*) Operating supplies	0.28
(*f*) Laboratory changes	0.1
Total	5.953×10^7

Therefore, total direct production cost/year = Rs. 5.953×10^7

Fixed changes

(*a*) Depreciation	
Machinery and equipment	1.70
Building and yard	0.5
(*b*) Local taxes	
(1% of fixed capital investment)	0.93
(*c*) Insurance	
(1% of fixed capital investment)	0.93
(*d*) Rent (1% value of land purchased	0.12
Total fixed changes/year	Rs. 4.18×10^7

Plant overhead cost :

Plant overhead cost (for medical, service, safety, and promotion), generally 40% of the operating labor and maintenance. Operating labor and maintenance/year

$= \text{Rs. } (0.5 + 2.7) \times 10^7$

$= \text{Rs. } 3.7 \times 10^7$

Therefore, plant overhead $= \text{Rs. } 3.7 \times 10^7 \times 0.4$

$= \text{Rs. } 1.48 \times 10^7$

General expense :

Item	Cost $\times 10^7$ (rupees)
(*a*) Administrative cost	3.45
(*b*) Distribution and selling cost	0.5
(*c*) Research and Development	0.5
Total general expenses/year	Rs. 4.45×10^7

Now, manufacturing cost/year = Direct production cost + Fixed charges + Overhead Plant cost

= Rs. $(5.953 + 4.18 + 1.48) \times 10^7$

= Rs. 11.613×10^7

Therefore, total production cost/year = Manufacturing cost + General expenses

= Rs. $(11.613 + 4.48) \times 10^7$

= Rs. 16.053×10^7

Calculation on net profit:

Price of fuel oil/ton = Rs. 5,500

Therefore, total income/year = Rs. $5{,}500 \times 330 \times 229.36$

= Rs. 41.6×10^7

Let income tax 40% of the gross earning

Hence, net income = Rs. 16.64×10^7

Therefore, product cost/ton of fuel oil $= \dfrac{\text{Rs.}16.64 \times 10^7}{330 \times 229.36} = \text{Rs.,,}193.19$

Profitability analysis:

Payout period : Payout period or cash recovery period is defined as minimum length of time necessary to recover the original capital investment and is calculated as follows :

Payout period (no interest charge) :

$$= \frac{\text{Depreciable fixed capital investment}}{\text{Average profit / year + Average depreciation / year}}$$

Salvage values for machinery, equipment, building and year

= Rs. $[(22.34 + 2.9 + 6.92 + 2.234) \times 0.05] \times 10^7$ + $[(6.48 + 2.234) \times 0.03]\ 10^7$

= Rs. $(1.72 + 0.262) \times 10^7$

= Rs. 1.92×10^7

Therefore, depreciable fixed capital investment

= Rs. $[92.27 - (1.982 + 1.34)] \times 10^7$

= Rs. $88{,}948 \times 10^7$

$$\text{Therefore, payment period} = \frac{\text{Depreciable fixed capital investment}}{\text{Average profit / year + Depreciation / year}}$$

$$= \frac{88.948 \times 10^7}{(16.64 + 2.056) \times 10^7} = 5 \text{ years}$$

The economics for the above mentioned system has to be worked out on individual basis and depends to a great extent on the location and cost of various input in each case.

3.1.9. (H) Hazardous solid waste management and treatment

The industries or research institutes who have the facilities for collection , storage , treatment and disposal of such wastes shall apply to the State Pollution Control Board for the grant of authorization of any of the activities. Any person importing hazardous waste shall maintain the records and shall be open for inspection by State Pollution Control Board / the Ministry of Environment.. The common methods for treatment of hazardous wastes are as follows:

(*a*) Cyanide waste: This waste is commonly destroyed by oxidizing agents such as ozone, ozone plus ultra violet light, sodium or calcium hypochlorite, hydrogen peroxide which process to choose will depend to large extent, on the type of materials to be treated and the facilities are available. The problem is that some wastes contain metals such as cobalt, nickel and iron that form highly stable complex cyanides that are oxidized extremely slow even in the presence of large stoichiometric excess of oxidant.

(*b*) Organic waste: Waste containing organic wastes require some special treatments such as changing of pH to precipitate amines and organic acids which then can be removed by filtration and recycled or disposed off. Carbons may have adsorbed toxic organic compounds such as polycyclic aromatics, amines nitriles and mercaptans.

(*c*) Toxic elements : Different techniques are needed for removing different toxic elements. Nag et al. removed8 arsenic (III) and chromium (VI) by $FeSO_4$ activated saw dust bed from industrial solid waste in which removal of arsenic 90 % and chromium 97%. There is other method for removing arsenic to oxidize it to the pentavalent state by adding excess of ferric salt and co precipitate it with ferric hydroxide by adding an alkali. The method is very useful for co precipitation of molybdenum, selenium and vanadium. Mercury can be converted to the divalent state and precipitated with a slight excess of sodium sulphide.

Spent catalysts containing hazardous metals can be often reactivated by solvent stripping, heat treatment, gaseous oxidation or reduction or combination of both the processes.

(*d*) Radioactive materials : There are two main types for disposal of radio active materials.

(*i*) Containment : Here the waste is kept in a shielded container and is allowed to place remote places so that wastes may decay after a long period of time Sometimes solidification and immobilization of the waste which may be buried in underground stainless steal or in deep sea water.

(*ii*) Dispersal in which very low radioactive substances may be diluted and disposed in marine water.

Very systematic process should be taken for handling hazardous waste treatment and also follow the recommended Government rules as follows:

(*a*) Every container of hazardous chemical shall be clearly marked to identify the contains of the container, the name and address of the manufacturer and the physical, chemical and toxicological data.

(*b*) Any person importing the hazardous chemical shall maintain the records of the chemicals and shall be opened for inspection by the concerned authority of the State or Ministry of Environment and Forests.

(*c*) An occupier shall prepare and keep upto date an onsite and off site emergency plan. There should be provision during major accident of the person and immediately inform the District Emergency Authority.

(*d*) Every occupier generating hazardous waste should have the facilities for treatment, transport, storage and disposal of such wastes

QUESTIONS

1. What are the different methods for treatment of solid wastes ? What are the advantages and disadvantages of Land fill method?
2. Discuss design aspects of Land fill method.

   Why control of hazards is important in Landfill method ?
3. What are the different steps of anaerobic digestion ? What are the advantages of vermicompost technology ?
4. What is the process difference between Incineration and Pyrolysis technology ?

   Discuss different processes of Pyrolysis for solid waste treatment.
5. What are the advantages of catalytic hydrogenation of solid waste ? Discuss the process in details.

CHAPTER 4

RECOVERY RECYCLING AND REUSE

4.0. INTRODUCTION

In the wake of rapidly depleting natural resources and the health hazards caused by the huge amount of wastes produced, recovery and reuse have become inevitable in the present scenario. The synthetic pathways of nature are overloaded. Another important point to note is that the nature recycling periods are very long compared with the human life span and the society is interested in recycling on a time scale which is comparable 'with an individuals' lifetime. It is clear that new methods of waste reclamation and reuse must be developed.

Energy costs are rising, making energy recovery more attractive and more economical, and the disposal cost will rise as social pressure for environmentally-sound waste disposal increase making recovery a better alternative. Moreover, the industrial incentives for using secondary materials will also increase to the extent that air and water pollution control regulations are strengthened. In this liberalization era, as the competition is increasing recycling will be a strategic tool for competitive advantage as it reduces the cost inputs and enhances the profit margin. Recycling also adds to sustainable development as it leads to lesser use of nature resources and it can also be used as a label to promote the acceptability of the product.

The amount of wastes generated each year is staggering. No one really knows how much waste humans generate, but much of it originates from the developed countries.

Estimates of the amount of solid waste generated by the United States range from 6 to 10 billion tons a year. Indian municipal solid waste differs markedly with respect to the composition and the properties as compared to western countries. It has lower amount of metal (0.64 %), paper (0.81 %) and plastics (0.62 %) but is rich in inorganic materials due to the presence of ash. It also has high density and moisture content. Hence the method which can be applied in developed nations cannot be entirely applied to other regions say India, in the case of waste utilization. These aspects must be taken into consideration before designing waste treatment and utilization techniques for India.

Recycling industry is already well established and the process depends on the following factors:

(*a*) Recovered material value.

(*b*) Processing plant location that determines the collection costs for waste material's and the distribution cost for the recovered product.

(*c*) Concentration of recoverable material.

(*d*) Quantity of waste arising.

(*e*) Regularity of waste arising.

(*f*) Recovered process route options.

(*g*) Recovered material options.

(*h*) Financially contribution from waste producers.

4.1. REUSE OF WASTES

The basic objectives of waste utilization are :

(*i*) To recover materials which can be further used such as silver from photographic plate ; hydrocarbon and catalysts from petrochemical residues ; glycerin from soap factories ; sulphur from hydrogen sulphide.

(*ii*) Substitution of materials such as use titanium dioxide instead of lead; use carborundum instead of silica ; use bauxite flux instead of fluorspar.

(*iii*) Process change and equipment modification such as burning of coal by fluidized bed combustion to reduce sulphurdioxide emission ; flow rate modifications to reduce dust generations in rotary kilns.

(*iv*) Reuse of materials to recover heat energy such as heat value from incineration of solid wastes : biogas from digestion unit ; water used in cooling and conditioning system

(*v*) Financial returns can also be obtained from the residues of some industries such as proteins from slaughter house waste ; vermicomposting manure from hatcheries; food wastes from canteens.

For proper study and application of how and what to recover from the solid waste, it is necessary to classify them into various convenient categories. As explained in Chapter 2, the solid wastes are typically classified into the following types.

4.1.1. Municipal solid wastes

(*a*) Food wastes (*b*) Rubbish and Dirt (*c*) Demolition and construction wastes.

4.1.2. Agriculture and Animal wastes

4.1.3 Industrial wastes

4.1.4. Other wastes

4.1.1. Municipal solid wastes

Today the recovery and reuse from huge amount of municipal wastes produced have become must for health hazards posed by the wastes and economic benefit. The various ways to achieve the wastes utilization from different type of wastes are discussed below :

(*a*) Food wastes: Indian municipal wastes, which chiefly contain food wastes, are dense (260-500 kg/cu.m) with a high moisture content of around 50 % even in dry session and hence, are not very much combustible. Therefore, out of the chemical and biological processes in vogue the latter is preferred in India. Biological methods such as aerobic anaerobic and vermiculture methods are follows :

(*i*) Aerobic digestion: It is a process of converting the organic constituents of the wastes and other products like proteins alcohol, cellulose, etc. into humus soil. Humus improves the wastes retention capacity of the soil, makes the soil less prone to pH changes. It also provides valuable nutrients needed for plant growth. At present, around 10 % of the MSW collected in

India is composted. The net disposal cost of solid waste though aerobic digestion is around Rs. 60-80 per ton, i.e., around 10 times lesser then the incineration costs. The detail description of the process is discussed in chapter 3.

(*ii*) Anaerobic digestion : It is decomposition of food wastes by the bacteria and actinimocytes in an atmosphere which lacks in oxygen. This process primarily yields methane, an eco-friendly and excellent fuel which finds numerous applications in both domestic and industrial fields. The digested slurry is a good fertilizer too. This is one of the few methods which not only leads to total pollution control but is also economical. Anaerobic digestion has also been found to remove the COD up to 90% and also to facilitate the co-disposition of kitchen wastes, garbage and sewerage to recover the bio-gas and high quality organic manure. The total treatment of the process is discussed in chapter 3.

(*iii*) Vermitechnology : It is one of the cleanest and cheapest methods of disposing off the food scraps. Earthworms consume the food waste and produce excreta. This excreta is referred to as vermicaste. The earthworm castings are excellent source of nutrients. These worms aerate the soil and the final compost can be used as a fertilizer. The earthworms themselves are a source of pro-biotic food for poultry and fishery. During vermitechnology of food waste about 2000 worms are added to per meter of the top surface of a dump. Suitable arrangement has to be made for mutual aeration of the pits continents. They should have a moisture content about 50 %. If necessary water has to be added, it takes about 60 days to complete a batch. On completion of a batch the material is taken out of the pits and sieved to separate converted biomass, non-biodegradable matter and worms from vermitechnology. Dead worms and excess worms produced during the process form a bye-product. After suitable treatment it may be used as a fish feed or poultry feed.

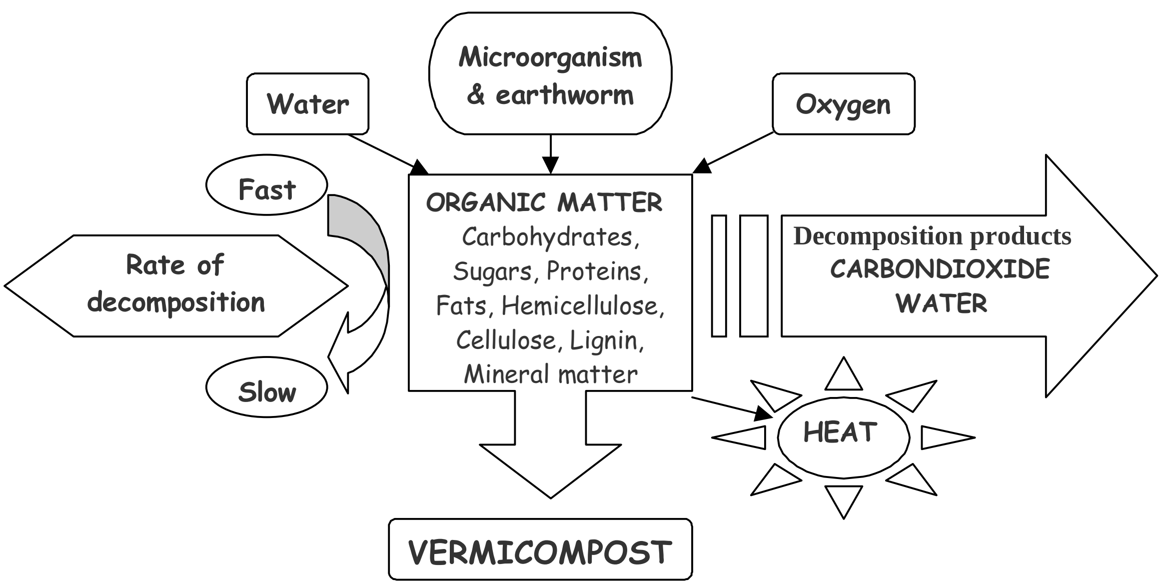


Fig. 4.1. Vermicompost Process

Food wastes themselves can be used as fuels in pellet or shredded from power generation as their calorific value is comparable to other solid fuels. Food wastes along with other MSW are frequently disposed off through sanitary landfills in most of the cities in India.

(*iv*) Hydropulping : The process is used in hospitals, colleges and offices. Hydropulping is a technique whereby the wastes primarily paper and food are macerated with water and transported to a central facility for dewatering and compassion of bailing. After the wastes are dewatered, they are removed from premises either land fill, anaerobic digestion or incinerated. The advantages of this process that it minimizes the dusty conditions with solid waste collection and it reduces the labour cost for cleaning. The handling of the waste is efficient.

The disadvantage of the process that it requires large quantities of water to make the system operable and the effluent water requires biological treatment and other physical treatment before discharge.

(*v*) Hog feeding : The feeding of food wastes collecting from restaurants and hotels to hogs has been practiced for many years. The process is profitable to farmers and owner of restaurants as these types of wastes are most difficult to handle in sanitary manner and is responsible for the majority of nuisance and associated with refuse programme. Garbage from hotels and restaurants is much higher in nutritive value. Each hog can eat about 10 kg of garbage per day and will gain about 0.5 kg in weight per day.

(*b*) Rubbish and Dirt : These wastes consist of combustibles like paper, paper-board, and non-combustibles like metals, glass, ceramic, dirt, etc. Paper constitutes the largest single category material in urban waste and it is estimated that two-third of the paper and paper board in the urban waste is recoverable by producing cellulose fiber from it. The remaining combustible matter can be processed into pellets or shreds and can be used for power generation through incineration. There are three Refuse Derived Fuel (RDF) manufacturing units in India-one each at Mumbai, Bangalore and Delhi. It is a novel idea but has not received much popularity. Moreover, it is difficult to have any control over the pollution due to the burning of these fuels. While burning, it is likely to be treated as a standard fuel rather then a waste which needs more attention. Chemical conversion like pyrolysis can produce valuable organic compound from the rubbish. The recovery of rags is one of the oldest recycling operations. The cleaned rags or cloth fibers from the industries can be processed to yield explosive compounds like cellulose-acetate and cellulose-nitrate. Although glass is not a scarce or valuable resource, probably, more effort has gone into the recycling of then in to the reclamation of any other material. The remaining part of non-combustible wastes can be used for landfills and strengthening of roads.

(*c*) Demolition and Construction wastes : The amount produced of this class of wastes can be estimated by the licenses given for new constructions, and the demolitions or ordered by the concerned municipal authorities. Useful materials like iron and steel can be salvaged from the demolition wastes quite easily. The other materials which include concrete, bricks, stones, etc., can be used for soil stabilization, embankments and in rail road constructions.

4.1.2. Agriculture and animal wastes

Agriculture wastes are usually of plant origin. Plants that remain after harvesting are in huge quantities. In India agricultural residue annually follows as crop residue/by products 1600.5 lakh tones ; fruit and vegetable wastes/residues 0.3 lakh tones and forest residues/by products 0.175 lakh tones, which can be utilized for the essential resources such as fertilizer, fodder, fuel and food.

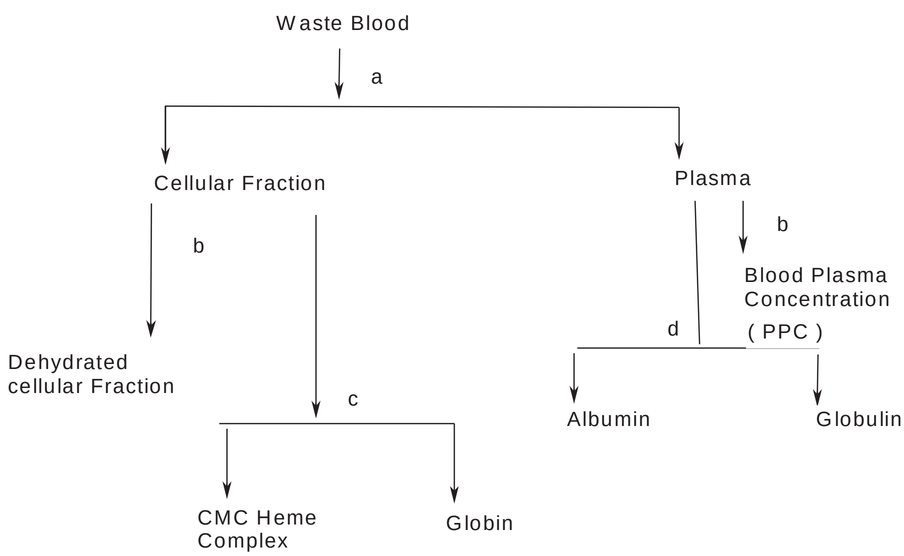
India has the highest livestock population in the world. Animal wastes include the remains after slaughter and animal fascias, etc. From municipality survey in Mumbai has found that the animal wastes (1500 tons per month) constitute the largest share followed by mineral wastes (1100 tons per month) and agriculture waste (550 tons per month). In India fish and marine wastes/residues are 0.5 lakh tons per annum which has the plant nutrient value in thousand tons (N_2 3.4 ; P_2O_5 2.9 ; K_2O 0.5).

In slaughterhouse waste blood can be utilized to get different types of pharmaceutical grade proteins, which we separated as follows :

Collect blood from slaughter house after just killing of animals and added immediately an anticoagulant sodium citrate solution that final concentration was 0.33% (w/v).

Centrifuge non coagulated blood (5000 g, 10°C for 15 minutes to separate the plasma and blood corpuscles separately. Dry both the fractions were dried under cold condition to get plasma protein concentrate and cellular fraction.

Separate the plasma after centrifugation, dilute with an equal volume of a 0.85% NaCl solution and mix with a saturated ammonium sulphate solution. Centrifuge the precipitated globulins and wash with acetone. To the supernatant add 1 liter 0.5 M acetic acid followed by saturated ammonium sulphate solution to salt out the albumins. Dialyze both albumin and globulin fractions and make freeze-dried. For deconjugation of hemoglobin and decolouration of globin and carboxymethyl cellulose (CMC) which offers a good recovery of globin and permits the utilization of both the globin and complex–heme as food ingredients. Resuspend



(*a*) centrifugation, (*b*) freeze drying, (*c*) mixed with CMC followed by centrifugation, (*d*) salt fraction.

Fig. 4.2 Proteins from waste blood

the cellular fraction in distilled water following agitation for hemolysis. Complete acidification with 1 N HCl and carboxymethyl cellulose in the solution. Centrifuge the mixture at 5000 g at 10°C for 20 minute and collect the precipitate and wash with distilled water to obtain CMC–heme complex. Adjust the supernatant containing the globin to its isoelectric pH and isolate the precipitate by centrifugation and freezes dried.

Esterase and lipase can be obtained from slaughterhouse waste liver and lipase in the following way :

Exercise Pig pancreas in the slaughterhouse immediately after the death of the animal and place in ice. Remove the tissue as quickly as possible and cut the pancreas into small pieces, homogenize in chloroform butanol mixtures at different ratio. Decant each treatment with chloroform–butanol of the liquid phase. Then wash it with acetone and finally by ether. Filter the suspension under vacuum on Whatmann No 1 paper and dry the last extraction under vacuum. Store the resulting powder for several months at –20° without detectable inactivation. Perform all subsequent steps of the purification were performed at 0-4°C.

Extract lipase by suspending the dilapidated powder for 1 hr in 0.1 M Tris-HCl buffer (pH 9.0). After centrifugation fractionate the clear extract with ammonium sulfate and dissolve the lipase rich sediment in Tris-buffer and treat with butanol and solid ammonium sulfate to move the part residual part of the lipid from the extract. Agitate the mixture l hr and then centrifuge for 20 min at 10,000 rpm. Collect the protein containing cream situated at the butanol-water interface and suspend in buffer. Dialyze the suspension was twice for 8 hr against buffer and was centrifuged for 30 min. The clear solution thus obtained is completely free of lipids and ready for further utilization. Thus esterase and lipase enzymes can be extracted from pancreases and liver of slaughted animals which can be used for preparation different pharmaceutical drugs, food emulsifiers, esters synthesis etc.

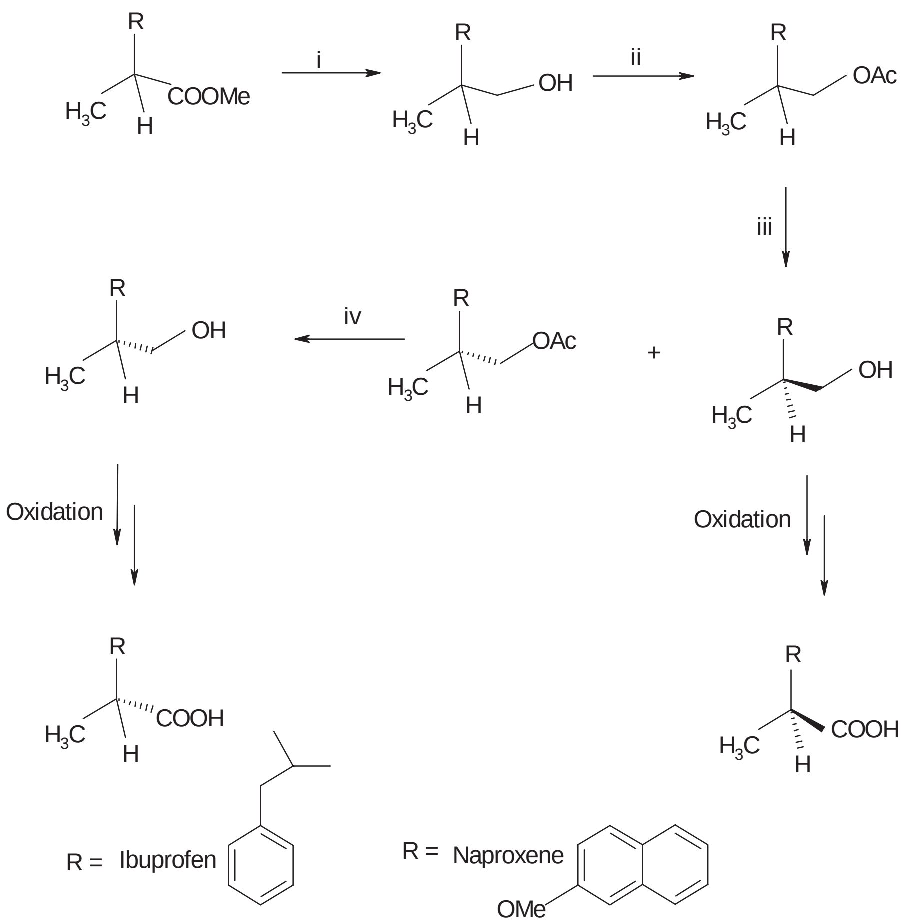
Nag and Basak et. al. used these enzymes for preparation of different drugs, flavor etc. One example for preparation of chiral anti-inflammatory drugs is as follows (Fig. 4.3) :

The wastes of slaughter house such as bones, pieces of meat, catgut, stomach etc. are processed to make fish or chicken feed. Bones, horns and hooves are used in the art and handicraft industry. Animal faces after anaerobic treatment to produce biogas and slurry which is used as fertilizer.

4.1.3. Industrial waste reuse

The best method for any type of industrial waste treatment is to recycle or to recover the pollutants from the waste. The recovery and recycling the wastes ensures the conservation of the environmental resources, reduces the cost of production, creates opportunity for employment, besides considerably eliminating the load of pollution. In fact, nothing is waste rather the waste of today is the resource of tomorrow. Some of the industrially recovered products from the wastes are described below.

5 million tons of press mud is produced from sugar and paper industries in India. Good quality compost can be prepared using press mud and distillery spent wash in 1:2 ratio by heap method within two months. This compost can be added to both the alkaline and acidic soils to improve their properties. Furfural may be obtained as recovery product from the sugar wastes, containing molasses and bagasse. Oxalic acid is obtained from oxidation of molasses sugar press mud. Many useful pharmaceutical ingredients, viz. tocopherol and lecithin are obtained from rice bran. Sodium silicate is obtained as bye-product from paddy husk. Bromelain is prepared from pine-apple waste. Saw dust, a product from timber industry can be utilized in manufacturing active carbon and moulding powder. Red mud from aluminum can be used to make colored



(i) $NaBH_4$/MeOH, (ii) Ac_2O/Et_3N/DMAP/CH_2Cl_2, (iii) PPL/Acetone/Buffer pH 7.8
(iv) PLE/Acetone/Buffer pH 7.8

Fig. 4.3. Synthesis of Anti-inflammatory Drugs

composition for concrete with heavy product, or in manufacturing bricks, and floor tiles. Fly-ash, a waste product, obtained in huge quantity from thermal power station, may be utilized for manufacture of fly-ash brick, clay fly-ash bricks. Mica waste could profitably be utilized for making insulating bricks and mica paints. Other recovery materials from industrial wastes such as iron dust from steel industry; fluorides from aluminum industry, pulp from paper mill effluent and cardboard from waste paper have marketable value.

4.1.4. Other wastes

The huge amount of plastics being discarded daily around the world and the difficulty in their degradation, call for extensive study of the ways to utilize these mountain of plastics. In the developed countries like USA, UK, Canada and Japan, where progress is measured in terms of industrial growth and quite often is considered as an yard of its development, use of advanced plastic materials has been considered as an index of its development. The capita consumption of plastic per annum in USA is 95 Kgs, as compared to Korea & Japan which stands at 30 Kgs, followed by China at 18 Kgs. Indonesia 7 Kgs and India at 3.5 Kgs. However, use of plastics has skyrocketed to more then 80 million tons a year in recent times and are being used in designing composites and hitch industrial components. Plastics products being comparatively cheaper hit the market rapidly nevertheless help poor in many ways, not only as a substitute for some of its basic needs but also as a commodity for a living. Thus plastic products have a greater impetus in modern society, its economy and have changed the life style of lower class, middle class and upper class families equally well. The situation has aggravated further because of depletion of forest and mineral resources and absence of an alternate natural source of energy. However plastics do a good service to the humanity in helping to preserve natural and forest resources.

The highly successful use of plastic materials in automobile and engineering industries as well as in household appliances and more so in one time disposable packaging materials has raised the concern of the environmentalists and ecologists because the litter it generates every day. The question is how to tackle the problem of polymer waste disposal?

Recycling which is as follows can control plastics pollution :

(*i*) Segregation of polymer wastes in to commodity and specialty plastics.

(*ii*) Reactive processing by melt mixing technique with each other in a processing equipment in presence as well as in absence of catalysts compatibilizers to form new materials. Analyzing the recycled polymers and blends for its technical properties, thermal properties environmental stability and processing characteristics. Fine threads or ropes can be prepared from used polythene covers.

(*iii*) Compression moulding and injection moulding of the plastic materials to value added products such as plastic containers can be made into pads or panels after proper melting and moulding.

(*iv*) Blending with amorphous rubbers to make thermoplastic elastomers.

(*v*) Tailor made green products for railways, automobile industry and agriculture.

Plastics, because of their organic composition, can be used for power generation through incineration, after suitable pre-processing.

Due to increase in automobiles and two-wheelers, the number of tyres discarded per year is also increasing. Ground tyres can be used as substitutes for asphalt for road laying and to produce recycled rubber. Tyres can be heated to recover steel (from radials) and bitumen, each tyre has organic matter whose fuel value is equivalent to nearly 2.5 gallons of petroleum. This makes the prospects of power generation from the TDF (Tyre Derived Fuel). The combustion process has been found to produce less ash then coal burning and has lower emissions then high-sulphur coal. The scrapped tyres can be used to strengthen the soil and also to increase the shock absorbing capacity in various civil engineering structure like bunds, walls of tanks, coastal structures like groins, jetties, break water, etc.

QUESTIONS

1. What are the basic objects of reuse of wastes ? What is Hydropulping process ?
2. What are the different constituents present in Municipal solid waste ? What is the common treatment of food waste ?
3. What is the common treatment of Agricultural and Animal wastes ? Discuss Aerobic digestion.
4. What are the common industrial reuses ? How used plastic materials can be recycled ?
5. How rubbish and dirt can be reused ? What is Hog feeding ?

CHAPTER 5

EVALUATION AND SELECTION OF FACILITIES FOR SOLID WASTE MANAGEMENT

5.1. INTRODUCTION

Proactive management and green sustainability aims at making the solid waste management a profit making activity by creating awareness among the people to minimize the waste and to increase the reuse, by using the waste for recycling, for power generation, and for bio-manure production, etc. However, the equipment is required for various operations such as vehicles for transporting the solid waste, incineration plants, recycling and power generation plants, etc., though the proactive management may reduce the number and size of the equipment required. There are several alternative types of equipment available for each activity. It is therefore necessary to identify the appropriate one before procuring it. Therefore, it is necessary to evaluate these alternative equipments for their techno-economic factors as well as the social factors. This chapter describes the economic analysis of the alternatives with some examples.

5.2. ECONOMIC ANALYSIS

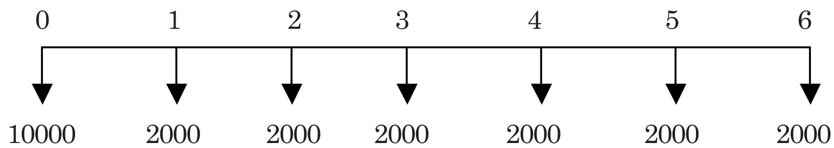
This is a common approach used by all the entrepreneurs while selecting the technology/ equipment. This is based on the time value of many, i.e., the money earns interest over a period of time and therefore, the amount of money today will not be same after a month. Due to this an investor invests his money only if the interest rate is attractive enough to him. This interest rate is called the minimum attractive rate of return (MARR). Another presumption is that the equipment has a finite life, and deteriorates over time. Its value decreases overtime and becomes useless after a period of time or after its life. Therefore the amount invested is to be recovered with in its lifetime.

While comparing the alternatives, only the cost factors are considered or the costs and revenues are considered. In the former, the alternative that gives the least cost is chosen where as in the later, the one with the largest net revenue is chosen. Generally, the data collected is in an aggregate form.

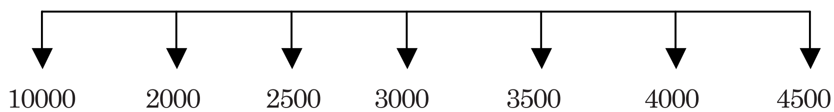
The following are the popular methods of economic analysis.

5.2.1 Discounted cash flow method (DCF)

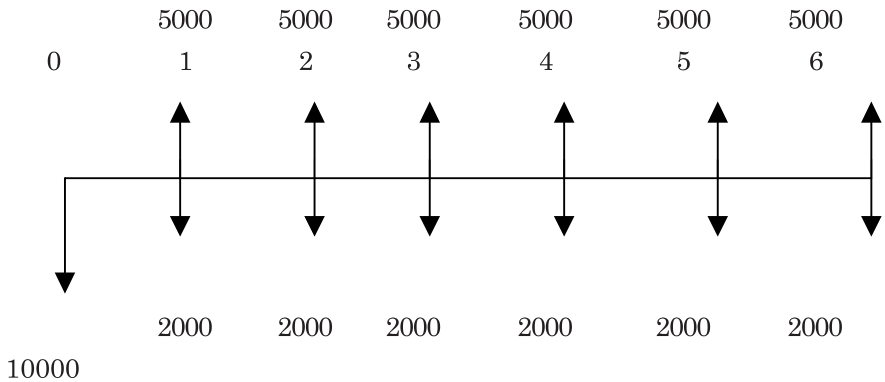
The cash flow represents, in an aggregate form, the cost and/or revenue figures over a period of time, say in years. The data is generally obtained on year-basis, but it is not uncommon to obtain the data on half-yearly, quarterly, or monthly basis. Fig 6.1 shows a typical cash flow diagram.



(*a*) Cost cash flows only



(*b*) Cost that is increasing every year by a certain gradient.



(*c*) cash flow series showing costs and revenues.

Fig. 5.1: Different cash flow series.

The cash flow depicts the expenditure on procuring and maintaining equipment or technology and/or its revenues. As the initial capital and maintenance costs are negative cash flows, they are shown with the downward arrow, where as the revenues are shown with the upward arrow. Another presumption of these cash flows is that the total aggregate transaction occurs at the end of the period. For example, maintenance expenditure may occur at various times in a year, but, the total maintenance expenditure is considered to have been paid only at the end of the year. If the period is taken less than a year, say 3 months, then the expenditure during those three months only considered to have occurred at the end of the three month period. Using DCF, the analysis is carried out with the following measures.

(*a*) Present worth

(*b*) Annual worth

(*c*) Future worth and

(*d*) Internal Rate of Return (IRR).

The first three measures, determined based/on DCF, are interchangeable and therefore provide the same result. It can be found obvious by observing the algorithm given to determine them.

Procedure for DCF Analysis

(1) List out the alternatives and estimate the time horizon or life of each alternative (say, n periods).

(2) Obtain the cash flow, the initial investment which is taken as occurred at the end of the zeroth period or at the beginning of the first period, and the costs and revenues during each period for the first alternative.

(3) Determine the minimum alternative rate of return (MARR) or the interest rate to be paid on the investment. This may be the Banks' lending rate at that time or rate at which the capital is raised through debentures, etc. It should also include other express related to borrowing the money such as processing fee.

(1) Determine the appropriate measure, i.e., present worth, annual worth, future worth, or IRR.

(2) Determine the measure using the following mathematical expressions:

Let P = the initial investment that has occurred at the end of the zeroth period.

A = the net annual expenditure/revenue that has occurred at the end of each period from first period to nth period. This is same for every period if the expenditure/ revenue is uniform throughout the time horizon.

A_1.... . An = The net annual expenditure/revenue of each period.

Present worth $$\text{P.W} = -\text{P} + / - \text{A}\left[\frac{(1+i)^n - 1}{1+(1+i)}\right] \qquad \text{...(1)}$$

Where i is the minimum attractive rate of return, and n is the planning horizon (number of periods.)

Given the present worth, the uniform equivalent annual worth can be determined by

$$\text{A} = -\text{P}\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \qquad \text{...(2)}$$

This is obviously the uniform equivalent annual cost.

The present worth of a future cash flow can be expressed as $P = F/(l + i)$

Where F is the one time cash flow at the end of the 9th period, and P, i, and n are as defined earlier.

Similarly the uniform equivalent annual worth of a future sum is expressed as

$$A = F\ [i(l + i)^n] \ /\ (1 + i)^n\ [(1 + i)^n - 1]$$

After simplification,

$$A = F\ i/[(1 + i)^n - 1] \qquad \text{... (4)}$$

The future worths of the present cash flow and the uniform equivalent annual cash flows are expressed as

$$F = P\ (1 + I)^n \qquad \text{... (5)}$$

$$F = A\ [(1 + I)^n - 1]/i \qquad \text{... (6)}$$

These equations are rewritten as

$$P = A\ (P/A,\ i,\ n) \qquad \text{...(7)}$$

i.e., $[(1 + i)^{n-1}]/i\ (1 + i)^n$ is termed as $(P/A,\ i,\ n)$ and is called the uniform series present worth factor. Similarly,

$$A = P\,(A/P,\ i,\ n) \qquad ...(8)$$

$$P = F\,(P/F,\ i,\ n) \qquad ...(9)$$

$$A = F\,(A/F,\ \mathrm{i},\ n) \qquad ...(10)$$

$$F = P\,(F/P,\ i,\ n) \qquad ...(11)$$

$$F = A\,(F/A,\ i,\ n) \qquad ...(12)$$

Where [A/P, i, n] is the capital recovery factor, i.e., the invested capital P is recovered in equal amounts of A; (P/F, i, n) is called present worth factor; (A/F, i, n) is called the sinking fund factor, as a fund F is established to accumulate through the collection of uniform equal payments; (F/P, i, n) is the compound amount factor; and (F/A, i, n) is the uniform series compound amount factor. These factors for various values i and n are determined and tabulated to facilitate the easy evaluation of alternatives.

Problem 5.1: *The collection and transportation of solid waste in a city is being planned. The following alternatives are considered:*

1. *Big compactor*
2. *Mini compactor*
3. *Small tipper*
4. *Mitsubishi tipper*

Table 5.1. Details of the Vehicles

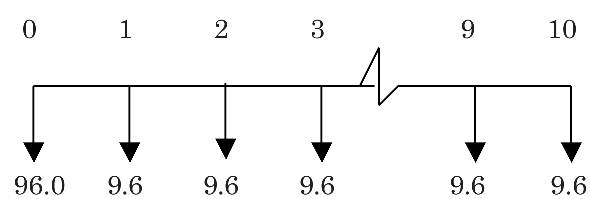
S. No.	*Name of the Vehicle*	*Initial Cost in lakh(Rs.)*	*Capacity in tons*	*Maintenance per year (lakh Rs.)*
1	Big Compactor	12.0	20	1.2
2	Big Tipper	7.02	15	1.75
3	Mini Compactor	7.4	10	0.55
4	Small Tipper	5.0	6	0.22

Solution. The details of the vehicles are given in Table 5.1. Solid waste to be handled every day is about 150 tons. Therefore, the number vehicles of each type required and the total cost are shown below.

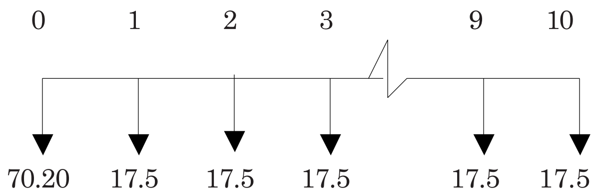
1	Big Compactor	150/20»8	96.00	9.6
2	Big Tipper	10	70.20	17.5
3	Mini Compactor	15	111.00	8.25
4	Small Tipper	150/6»25	125.00	5.5

The cash flows of the alternatives can be shown below. An equal life of 10 years with zero salvage value and an MARR of 15 % are assumed.

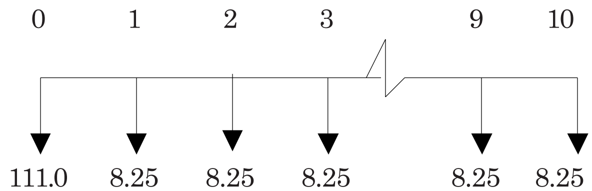
(*a*)



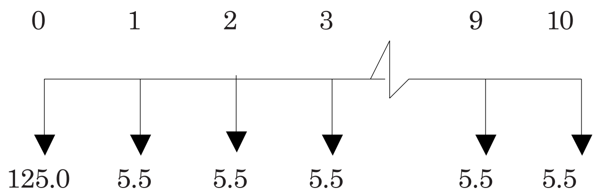
(*b*)



(*c*)



(*d*)



The investments or expenditures are shown downward with a negative sign and the revenues or gains are shown upwards with a positive sign. However, in the cash flows shown above, there are only investments and therefore, the negative sign is not shown. The present worth values are given below:

PW (a) = 96 + 9.6 (P/A, 15, 10) = 96 + 9.6C5.0187 = Rs 144.17952 lakhs.

PW (b) = 70.20 + 17.5 (P/A, 15, 10) = 70.20 + 17.5C5.0187 = 157.82725 lakhs.

PW (c) = 111 + 8.25 (P/A, 15, 10) = 111 + 8.25 C 5.0187 = 152.404275 lakhs

PW (d) = 125 + 5.5 (P/A, 15, 10) = 125 + 5.5 C5.0187 = 152.60285 lakhs

Here the alternative (*a*), i.e., procuring 10 numbers of big compactors is the most economic alternative. Determining the uniform equivalent annual worth or the future worth of these cash flows can obtain the same result.

AW (a) = 9.6 + 96 (A/P, 15, 10) = 9.6 + 96C0.19925 = 28.728 lakhs

AW (b) = 17.5 + 70.2 (A/P, 15, 10) = 17.5 + 70.2C0.19925 = 31.48735 lakhs

AW (c) = 8.25 + 111(A/P, 15, 10) = 8.25 + 111C0.19925 = 30.36675 lakhs

AW(d) = 5.5 + 125 (A/P, 15, 10) = 5.5 + 125C0.19925 = 30.40625 lakhs

The future worth of the alternatives are

FW(a) = 96C(F/P, 15, 10) + 9.6C(F/A, 15, 10) = 96C4.0455 + 9.6C20.303

= 583.2768 lakhs

FW(b) = 70.2C4.0455 + 17.5C20.303 = 639.2966 lakhs.

FW(c) = 111C4.0455 + 8.25C 20.303 = 616.55025 lakhs.

FW(d) = 125C4.0455 + 5.5C20.303 = 617.354 lakhs

The least value is obtained with alternative (*a*) in both the cases. Therefore, using any one of these three measures is sufficient as all the three measures will give the same solution.

This analysis can be utilized for any equipment or treatment process required such as incineration equipment by collecting the appropriate data. The initial cost can be collected from the vendors of the equipment. It should include the price of the equipment, packing and forwarding, and installation costs. The annual maintenance costs can be collected from the existing users. Otherwise, the costs such as manpower required and their salaries, electricity consumption and the charges, preventive maintenance schedule and the costs involved, the lubricating oils required, etc., have to be determined/estimated and by summing them up, the annual maintenance costs can be estimated. It is necessary to take every care so that the costs are neither inflated nor deflated. One has to be careful while analyzing the vendor's quotation regarding the terms and conditions given.

5.2.2 Analysis of Alternatives with unequal lives

Many a time, the alternative equipment, that are available, may not have equal life. For example, the big compactor may have a useful life of 15 years where as small compactors useful life may be of 10 years.

If DCF is analyzed for their life, i.e., big compactor for 15 years and small compactor for 10 years, the comparison may become erroneous. It is preferred to compare the alternatives based on the same life span, i.e., the same planning horizon. When the alternatives have unequal lives, planning horizon is selected in the following ways:

(1) Least common multiple of the lives of alternatives

(2) Longest life among all

(3) Shorter life among all

Least common multiple (LCM) method is not feasible in many cases. If the lives of two alternatives are 15 and 10 years, then the LCM is 30 years. That is to analyze the cash flows, it has assumed that the first one is repeated twice and the second one thrice. If the lives are 15 years and 8 years, LCM is 120 years, i.e., the cash flow of the first alternative has to be repeated for every 8 years and that of the second one for every 15 years during the 120 years. This not only becomes cumbersome but at times meaning less. Therefore, it is not generally used unless the LCM is nearer to the actual lives.

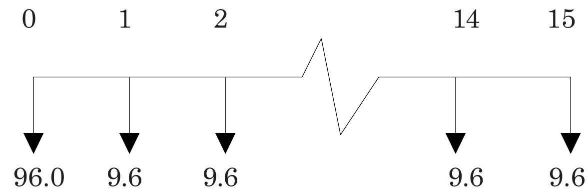
Among the other two methods, any one can be chosen. In the longest life method, the alternative with lesser life is assumed to have repeated till the end of the planning horizon. In the case of the 15 year and 10 year lives of alternatives, the second one is repeated and is assumed to have disposed after 5 years with a salvage value. It means, for the second alternative, its salvage value after 5 years has to be collected/estimated. In the least life method, the salvage value of the alternative with longer life at the end of the planning horizon has to be collected/estimated. Once the cash flows are thus developed for all alternatives over the chosen planning horizon, the present worth/uniform equivalent annual worth/future worth analysis is made.

Problem 5.2 : *Considering the problem given in example 5.1, let the lives of alternatives are as follows:*

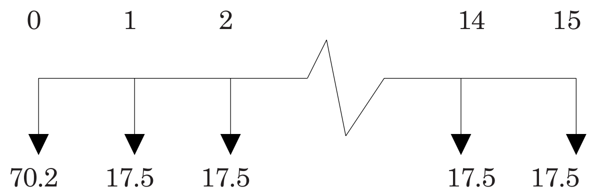
Sl No.	*Description*	*Life*	*Salvage Value after*	
			5 years	*10 years*
1.	*Big Compactor*	*15 years*	*8*	*4*
2.	*Big Tipper*	*15 years*	*4*	*2*
3.	*Mini Compactor*	*10 years*	*3*	*–*
4.	*Small Tipper*	*10 years*	*2*	*–*

(*i*) Using the longest life method, planning horizon is 15 years and the cash flows are:

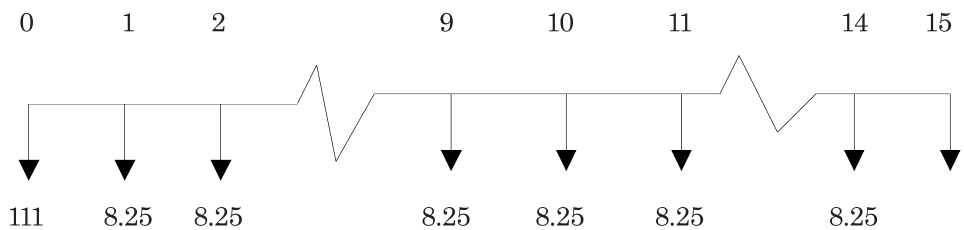
(*a*)



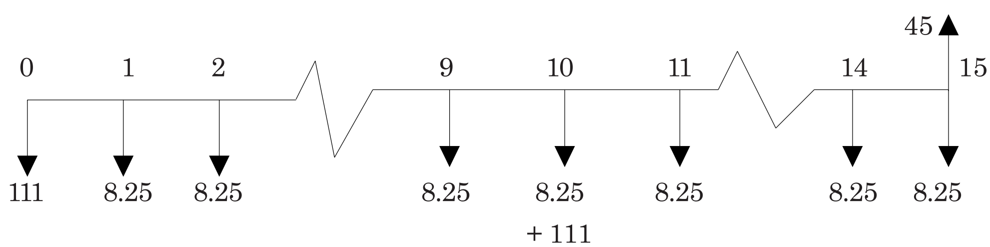
(*b*)



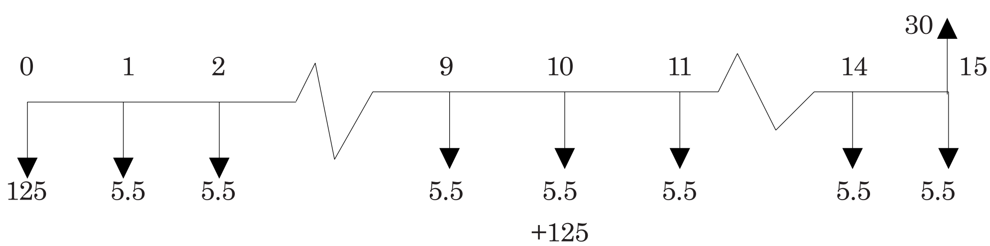
(*c*)



(*d*)



(*e*)



The present worths of the alternatives, assuming salvage values for the alternatives *c* and *d* are 45 and 30 lakh rupees respectively, are

PW(*a*) = 96 + 9.6 (P/A, 15, 15) = 96 + 9.6 C5.8473 = Rs.152.13 lakhs

PW(*b*) = 70.2+17.5 (P/A,15,15) = 70.2 + 17.5C5.8473 = 70.2 + 102.33
= Rs.172.53 lakhs

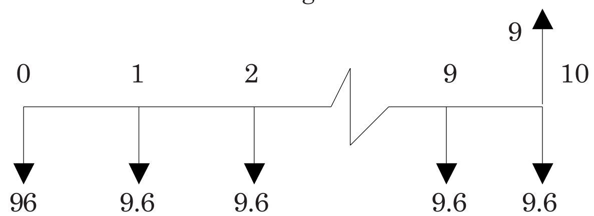
PW(c) = 111 + 111 (P/F, 15, 10) + 8.25 (P/A, 15, 15) – 45 (P/F, 15, 15)
= Rs. 181.1433 lakhs

PW(*d*) = 125 + 125(P/F, 15, 10) + 5.5 (P/A, 15, 15) –30 (P/F, 15, 15) = Rs.184.37 lakhs.

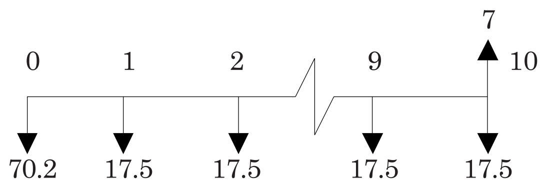
The alternative (*a*), i.e., the purchase big compactors provide an economic solution in this situation.

(*ii*) The least life method: Using the least life method the cash flows are

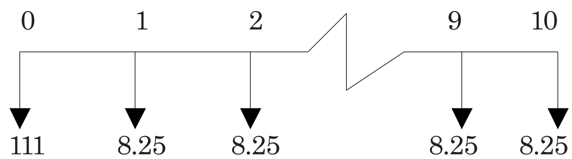
(*a*)



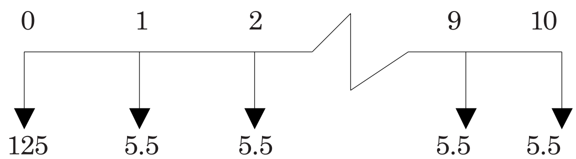
(b)



(*c*)



(*d*)



The present worths are

PW (*a*) = 96 + 9.6 (P/A, 15, 10) – 9 (P/F, 15, 10) = Rs.141.95481 lakhs.

PW (*b*) = 70.2 + 17.5(P/A, 15, 10) – 7(P/F, 15, 10) = Rs.156.29692 lakhs.

PW (*c*) = 111 + 8.25 (P/A, 15, 10) = Rs.152.404275 lakhs.

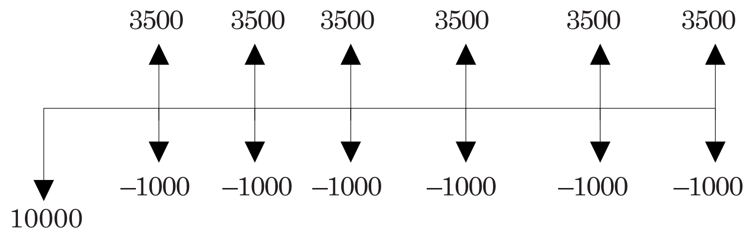
PW(*d*) = 125 + 5.5 (P/A, 15, 10) = Rs.152.6 lakhs.

This analysis makes the alternative (a) as the most economic.

The above analysis shows that the solution is consistent but it is true only for this case. The solution may differ with the life, i.e., planning horizon, considered and the cash flows.

5.2.3 Internal Rate of Return (IRR)

IRR is another measure that is useful to evaluate alternatives with the help of the cash flows. IRR is a value in percentage that gives a relative yield of different investments, i.e., different alternatives. One advantage of using IRR as a measure is that it does not require the MARR to be stated. IRR is determined by equating the present worth or uniform equivalent annual worth of cash flow to zero and solve for the interest rate. Suppose the cash flow of an investment is as follows:



The above cash flow shows the expenditure as well as revenue. Therefore, the expenditure is shown explicitly with a negative sign.

Determine i such that PW (revenue or receipts) = PW (Expenditure/disbursements), i.e., Net PW = PW (revenue or receipts) – PW (Expenditure/disbursements).

The i so calculated is the i^*. For the cash flow shown above, taking the life (n) as 5 years,

$$PW = -10000 - 1000\ (P/A,\ i,\ 5) + 3500\ (P/A,\ i,\ 5).$$

It can also be written as

$$PW = -10000 + 2500(P/A,\ i^*,\ 5) = 0.$$

That is, $(P/A,\ i^*,\ 5) = 10000 \div 2500 = 4$

Refer to the interest factors tables, for the (P/A, i, n) factor and note down the interest rate which gives a value of 4 or near 4 with the life of 5 years. We obtain, from the tables,

$$P/A,\ 7,\ 5 = 4.1001$$
$$P/A,\ 8,\ 5 = 3.9926$$

By interpolating

$$i^* = 7 + 4.1001 - 4 \div 4.1001 - 3.9926$$
$$= 7 + 0.1001 \div 0.1075$$
$$= 7 + 0.9312 = 7.9312\ \%$$

Similarly, IRR of each alternative is determined and the one that gives largest IRR is chosen.

Problem: 5.3 : *In problem 5.1, the gains to the Urban administration is in terms of the savings in hire charges other wise to be paid to the private contractors. Let the savings are as follows:*

Type	*Big compactor*	*Big Tipper*	*Mini Compactor*	*Small Tipper*
Savings in Rs. Lakh	*3.0*	*2.5*	*1.4*	*1.25*

Determine the best alternative using IRR method:

Solution: First alternative

(*a*) $96 + 9.6\ (P/A,\ i^*,\ 10) = 3.0 \times 8(P/A,\ i^*,\ 10)$

Therefore, $(P/A,\ i^*,10) = 96 \div (24 - 9.6) = 6.67$

If $i = 8,\ (P/A,\ i,\ 10) = 6.71$

$i = 7,\ (P/A,\ i,10) = 6.4176$

By interpolation,

$$i^*_a = 8.17\%$$

Similarly,

$$i^*_b = 1.44\%$$

$$i^*_c = 2.603\%$$

$$i^*_d = 15.99 \approx 16\%$$

From this analysis, it is evident that the alternative (*d*) gives highest rate of return and therefore to be chosen. Discounted cash flow methods are useful and reliable if the data obtained is correct. Any error in the data may lead to erroneous decisions. Also, the interest rate or the MARR is another factor that has to be chosen appropriately. The entire analysis depends on the accuracy of these data. Also between the present worth method and the IRR methods, the emphasis that one places is important for decision making. One may be interested on present worth of the investment given an MARR, and another may be interested in the likely returns. Accordingly, they may choose the method to be used.

5.2.4 Cost-Benefit Analysis

Cost Benefit Analysis or Benefit—cost Analysis is defined as a method of estimating the costs and losses as well as the gains and benefits, both qualitative and quantitative, in monetary terms and analyzing them for decision making. It also uses the discounted cash flow methods. The analysis generally expresses the value or index of an alternative interest of Benefit to Cost ratio (B/C ratio) or the difference of Benefits over Costs (B-C).

It is possible to estimate the quantitative factors such as the maintenance cost of the vehicles/incinerators, to estimate the costs/ benefits, hiring cost of the vehicle, etc., but it is difficult to estimate the monetary value of the qualitative factors such as the suffering of the people due to pollution. Use of such qualitative factors makes it difficult to use the Benefit-Cost analysis technique. However, several means and ways are developed by the social scientists to estimate their value in monetary terms that can be utilized to give approximate values, if not exact values.

For example the aggregate benefits and costs for a wastewater treatment plant are

The total costs = Rs 2,00,000; The total benefit = Rs 3,50,000

(Pollution taxes penalties to be paid if effluents are released without treatment).

Benefit – Cost Ratio or B/C = 3.5/2.0 = 1.75

Benefits and costs may be estimated as aggregated amounts as shown above or they can also be expressed as cash flows over a life cycle or over a planning horizon. The present worth analysis can be used to aggregate the cash flows of benefits and costs in order to determine B/C Ratio. It is well explained by the following problem.

Problem 5.4 : *Take the problem given in 5.3. Let the MARR is 15%. Determine the Benefit-Cost ratio of each alternative.*

Solution : Considering the costs and benefits separately, the present worths are determined. For Alternative (*a*) PW (costs) = 96 + 9.6 (P/A, 15, 10) = Rs. 144.17952 lakhs.

PW (benefits) = 24 (P/A, 15, 10) = Rs. 120.4488 lakhs.

Benefit – Cost Ratio BCR = PW (benefits)/PW (costs) = 0.8354

Similarly, BCR (b) = [25 (P/A, 15, 10)]/[70.2 + 17.5 (P/A, 15, 10)]

= 125.4675/158.2725 = 0.793

BCR (c) = [21 (P/A, 15, 10)]/[111 + 8.25 (P/A, 15, 10)]

= 105.3927/152.4043 = 0.6915

BCR (d) = [31.25 (P/A, 15, 10)]/[125 + 5.5 (P/A, 15, 10)]

= 156.8344/152.6029 = 1.0277

Considering the Benefit – Cost ratio, alternative (d) is preferred.

QUESTIONS

1. What is discounting ? What is its role in evaluation of alternative sites ?
2. What are the criteria for comparison of alternatives ?
3. How do you compare alternatives with unequal lives. Explain with an example.
4. Explain the terms interest, depreciation, purchase discount, and life of an asset. How they affect the choice of alternative ?
5. A town, which is recently growing in population, wishes to mechanize its solid waste disposal. It has gone for open tenders for supply of machinery. The quotations reveal the following data. Suggest the best choice.

Quotation \ Criteria	*Price (Rs. Lakhs)*	*Life*	*Operating expenditure (Rs. Lakh) per annum*
A	2.0	15	0.5
B	1.5	10	0.6
C	2.25	10	0.3

CHAPTER 6

SOLID WASTE MANAGEMENT PLANNING, MONITORING AND CONTROL

6.1. INTRODUCTION

Planning is fundamentally deciding the future course of action. It is deciding in advance what to do, how to do it, when to do it and who to do it. These decisions must be based on the purpose, knowledge, and forecast.

Several new planning components must be considered, and environmental protection programmes must incorporate new time perspectives. The general characteristics of future environmental plans should be:

(*i*) Relevant with regard to being able to fulfill established environmental objectives.

(*ii*) Operational cost effective on a regional and global scale implying reallocation of environmental investments beyond national and regional borders, and

(*iii*) Realistic with regard to feasibility.

It is important to guarantee everybody's right to be part of the planning process. Multi-dimensional environmental issues need additional experts representing various sections of the society such as business sector, employees, and general public. The experts in the related fields such as environmental engineers, management analysts, economists, etc., shall provide the necessary knowledge to develop an optimum work plan. They have to be brought to a single platform to form a group so that the environmental issues can be addressed in their totality. Infact, a planning team for a particular geographic area can be formed with representatives suggested above so that a comprehensive environmental management plan can be prepared and implemented with out any over emphasis on any specific aspect. It also makes implementation easy as all concerned parties are involved in the planning.

Generally, planning presupposes that there exists alternative courses of action to perform an activity and it chooses the appropriate one. Planning logically precedes all other functions of management, such as organizing, implementing, and controlling. Planning is unique in that it establishes the objectives necessary for all the group effort. Plans are also useful as control device. Without planning, the activities cannot be controlled because in the absence of a plan, there is no way to tell whether the activity is going on in the right direction or not. Plans thus become the standards for control. Any planning process involves the following steps:

(*i*) Specifying Objectives: The first step in planning is stating the objectives, as clearly as possible, without any vagueness. It shall indicate what is to be achieved.

(*ii*) Identifying alternatives: To achieve an objective, there can be several possible ways. All such alternative ways of performing the activity shall be identified and listed.

(*iii*) Evaluating alternatives: Among the alternatives identified, it is to be decided which is the best way of performing the activity. They may be evaluated for their efficiency, economy, complexity etc. using mathematical analysis, economic analysis, simulation, etc.

(*iv*) Selecting a course of action: Often, the evaluation may not be prescriptive but descriptive. The evaluation may only describe what happens with each alternative action and may present scenarios or results of the system once a particular alternative is chosen. It is to the decision maker now to decide upon the specific alternative course for implementation considering the other tangible/non-tangible factors which are not considered in the evaluation.

(*v*) Formulating derivative plans: Once the alternative is chosen, action plans have to be prepared in detail. It is required to state when and how to acquire the necessary resources, where the activity will be taken up, who will perform the activity, what time it takes, i.e. detailed schedule has to be prepared. Deciding on who will perform the activities lead to the design of an organization as discussed in chapter 7.

Another aspect that has to be considered in environmental planning is the democratization i.e., to involve groups and individuals such that they own and take responsibility. In some countries, Public hearings are held to explain the concerned public about the happenings and the environmental and health affects. The effort has to go beyond that to involve the public during various stages of environmental management. It leads to active public participation and effective implementation of the environmental plans in addition to providing social justice.

It is important to guarantee everybody's right to be part of the planning process. Multi-dimensional environmental issues need additional experts representing various sections of the society such as business sector, employees, and general public. The experts in the related fields such as environmental engineers, management analysts, economists, etc., shall provide the necessary knowledge to develop an optimum work plan. They have to be brought to a single platform to form a group so that the environmental issues can be addressed in their totality. Infact, a planning team for a particular geographic area can be formed with representatives suggested above so that a comprehensive environmental management plan can be prepared and implemented with out any over emphasis on any specific aspect. It also makes implementation easy as all concerned parties are involved in the planning.

6.2. PLANNING FOR SOLID WASTE MANAGEMENT

In the preparation of Solid Waste Management Plan (SWMP), one has to follow the steps of planning process described above.

6.2.1. Objectives of SWMP

Objectives of an EMP may be :

(*a*) To reduce air pollution to the permissible limits.

(*b*) To provide treatment facility for liquid effluent before leaving them to drain, stream etc.

(*c*) To reclimate the land disturbed by mining, etc.

These objectives vary based on the type of industry and location. It is necessary to conduct an environmental impact analysis study to understand the various impacts of the project/activity and the severity of the impacts. For example, the objectives for a mining industry are:

(*i*) To preclude or reduce the discharge of toxic and objectionable effluent into surface water bodies, ground water aquifers or usable lands to a minimum. Whenever possible, reuse of wastewater should be practiced.

(*ii*) To treat the effluent to conform to the standard laid down by the Central and State Pollution Control Boards before discharge.

(*iii*) To prevent the formation of acid mine drainage at source.

(*iv*) To dilute acid mine drainage to an acceptable effluent quality.

(*v*) To identify an appropriate site for disposal of over burden and mine wastes so that.

(*vi*) The site is a secure and impervious base (adverse environmental impacts, and also the economic and effective rehabilitation of the closed mine site to a productive after use)

(*vii*) To minimize emission of dust (suspended *b*). It ensures minimum leaching effects due to natural precipitation (*c*) It is far away from natural waste courses.

(*vi*) To prepare the land use plans to minimize the particulate matter), and gaseous pollutants such as sulphurdioxide, nitrogen oxides.

(*viii*) to abate the noise and vibration.

(*ix*) to alleviate the subsidence damage and to prevent land slides.

(*x*) To minimize the loss of flora and fauna and to ensure their rehabilitation.

6.2.2. Identification of Alternatives

Once the objectives are stated, alternative course of action available, to achieving the objectives, have to be identified. When there are multiple objectives, each seeking a different type of action, as in the case of mining environment, alternative courses of action for each objective have to be listed. The exhaustive list of alternatives have to be obtained through literature survey, expert opinion, catalogues and from such other sources. For example, the alternatives available to control acid mine drainage are modified mining methods, sealing of mine or part after closure, surface reclamation, water diversion, control of ground water flow, etc. Where as the methods available for prevention of dust emission are spray the face with water before drilling, use dust arrestor during drilling use water-ampoule stemming spray the face with water-wetting agent, spray water during loading and transportation, etc.

The exhaustive list of alternative can be obtained through content analysis, i.e., by scanning through the various literature, catalogues and from other sources and by synthesizing from it, or by group judgmental techniques such as expert opinion, Nominal group technique, Delphi method, etc.

Content analysis is a more thorough method then the literature survey. The books, journal articles, monographs, reports, etc and any other published available material is scanned through carefully for its appropriateness and utility for the problem under study and the material is noted down from each source. Of late, the audio and video tapes, and CDs also can be added to the source wherein the researcher listens to the material and notes down the relevant part. The collected material is then scrutinized and synthesized before drawing conclusions. The content analysis is mostly qualitative analysis concerning the general message of the existing documents. For simplicity and ease, the material is also scanned and analyzed based on some chosen characteristics.

Judgmental techniques take the help of experts and elicit the expert knowledge from them. Such knowledge is then synthesized and used to draw the inferences and conclusions. These include simple technique like Brain Storming (BS) to the complex to a common place and allowing them to write down freely their ideas and then short listing them for use.

Expert opinion differs in the opinions are taken through questionnaire or personal discussion. Even for the personal discussion, it is desirable that the researcher prepares a questionnaire so that he will seek uniform in formation from everybody. The questionnaire also helps the researcher to be specific to the topic rather than discuss arbitrarily. It also acts as guide to the researcher to put the expert on the track whenever he deviates from the topic.

Nominal group technique (NGT) similar to Brain Storming in the experts are called to a place but it differs with it in that the NGT is a more constructive approach unlike the open approach of BS. Here the problem is clearly defined and also the experts are guided in what the conclusions are :

In the questionnaire survey, a set of questions are prepared and sent to the persons for their responses. It may take a long time as one has to wait for the responses. It is also necessary to administer the questionnaire for a large number to make the responses valid. This method is useful to take the opinions of a large number of people, say customers, and not from the experts, who may be very few.

In contrast, the Delphi method is used to get the opinions of the experts. Here the questionnaire is sent back to the respondents after quantifying and analyzing their responses. The scores of the respondent and the overall scores of all the respondents will be sent so that the respondent can have an opportunity to review his earlier responses. The first round of questionnaire will be an open-ended one based on which the second round of questionnaire, which in more structure, is prepared. The exercise beyond the fourth round. The third and fourth round questionnaires are same as that of the second round. The exercise is repeated only to reduce the gap among the opinions and to arrive at near consensus. If there is consensus among the experts in the second itself, the further round are not required. This is also a tie taking method.

These alternatives can be obtained through content analysis, i.e., by scanning through the various literature and by synthesizing from it, or by group judgmental techniques such as Nominal group technique, Delphi method, etc. An exhaustive list alternative has to be prepared. A preliminary evaluation for their feasibility can be done through expert opinion. The alternatives that are feasible have to be short listed for further analysis.

6.2.3. Evaluation of Alternatives

The alternatives thus listed may or may not be mutually exclusive. They have to be first made mutually exclusive by making the combinations of alternatives, which are not mutually exclusive. In some cases, the individual or pure method may be an alternative and at the same time it, in combination with another may become another alternative. For example, use dust arrestor during drilling and spray face with water before drilling can be taken as two individual alternatives and their combinations as a third alternative. Whereas, spray face with water before drilling and spray face with water-wetting agent mixture are mutually exclusive and their combination has no meaning.

Once the mutually exclusive alternatives are listed, they have to be tested to see how far they can fulfill the said objectives. For evaluation of these methods, and to determine their effectiveness, one can use simple mathematical models to complex simulation methods, such as system dynamics. Many a time, the method used depends on the knowledge and preference of the evaluator. However, depending on the time available and importance, one can choose any method simple to complex. The results of such evaluation should lead to comparison and to draw the inferences so that a better alternative can be chosen for the purpose. A case is illustrated in detail in Chapter 7.

Once a method is chosen, then again several ways of performing that method may exist. For example, different types/models of dust arrestor are available. Which one is to be procured and used is again another decision to be taken. For this, the alternatives have to be analyzed for effectiveness and economy. Techno economic feasibility study or multi-criteria evaluation methods have to be used to choose that particular technology/equipment. Sometimes, the methods and the equipment may have to be evaluated together. The economic analysis of the alternatives is discussed in detail in chapter 7. In the similar way, alternatives have to be listed and evaluated for each subject.

6.2.4. Selecting a course of action

Once, the alternatives are evaluated and comparatively better alternatives are listed, it may be necessary to further verify which one has to be adopted. That is, some factors, such as time required to procure, difficulty in maintenance and obtaining spare parts when necessary, etc., may not be considered in the previous evaluation using mathematical/simulation models. The environmental manager may consider all such tangible and intangible factors before arriving at a decision. Only after considering all such factors, he has to select a course of action.

6.2.5. Formulating Derivative Plans

This is a very crucial stage of planning process. It prepares the implementation plans once the course of action is selected, it has to be decided who will procure the equipment, procedure to be adopted, who should install and commission the equipment, who should take care of the day-to-day running of the equipment, etc. there should be clearly defined documentation in this respect leaving no chance for ambiguity. These plans are useful for the control process as shown in the next section. It is also desirable to draw the schedule for the activities planned on using the technique like Gantt chart which will be useful for the management to see how far the planned activity is completed. The management can look into in at regular intervals and guide the personnel accordingly. These derivative plans, thus, become operational level plans and will be a guidance for carrying out the activities as well as monitoring and control.

6.3. CONTROL

Controlling is a vital function in any management. Uncontrolled systems go bizarre and ultimately lead to a disaster. Even the markets have to be controlled as the laissez-faire type of systems hard proved to be mutually distracting for both producers and customers and even for traders. Even in this liberalization era, the country like USA that associates liberalization most has imposed some controls on its markets.

In fact, controlling is not a restricting activity. It is a process of helping the system to go in the right path, i.e., in the chosen and planned path. Marie (1987) defined the control function as the process that measures the current performance and guides it toward some predetermined goal. The essence of control lies in checking existing actions against some desired result determined in the planning process. Infact, control function provides with a feed back to the system In terms of the gap between the action and the plan or between the achieved result and the anticipated result. The control function is expressed by a block diagram and is shown in Fig. 6.1.

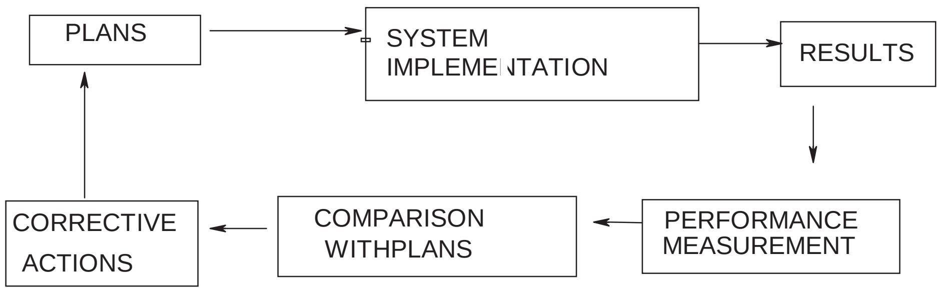


Fig. 6.1 Feed back Control System

6.3.1. Control Process

Therefore, control process consists of the following elements :

1. Plans. Plans are expressed in terms of objectives, predetermined goals desired result etc. or desired results, etc., Plans become the premises to verify whether the system is going in the right direction or not and whether it is achieving the required result or not. The verification may also include in addition to the measurable goals/results, the time perspective, i.e., whether they are achieved with in the required time or not. In fact it is also possible to verify the individuals performance if the action plans are prepared for each individual in detail.
2. Results of the activity or means of measuring the outcome of the activity: It depends on the type of activity to be measured. It may be simply 'yes' or 'no' if the measurement is to determine whether a person has carried out the set activity or not. It may be a number if the out come is in terms of quantity of products. Depending on the characteristic to be measured, It has to be decided, in the planning stage itself, when to be measured and how to measure.
3. Means of campaigning the outcome: Plans or predetermined goals become the means to compare the outcome of the activity. It is necessary therefore to state the goals or desired events or there should value in the same units as that of the outcome or results of the activity. It is therefore the planning become a premises for controlling.
4. Modifications or Corrective actions: Once, the comparison of the actual to the desired in made, one has to determine whether any modifications/corrective actions are necessary. When the output/result is not up to the threshold set, one has to take corrective action. While taking a corrective action, it has to be decided first whether the threshold/goal set is achievable or not with the existing environment. There may be inherent limitations of the process, equipment or manpower. If so the goal has to be reset to represent the feasible and achievable target. otherwise, one has to find out the bottleneck by going through the entire system in detail. Once the bottleneck(s) is identified the corrective actions that are possible have

to be listed. They have to be evaluated for their effectiveness and the alternatives are ranked based on their utility and effectiveness. Now, it is up to the manager to consider any other tangible/non tangible factors that could not be included in evaluation to choose the alternative corrective action for implementation.

6.3.2. Monitoring

Monitoring is vital to implement any effective policy and it applies to the solid waste management also. Here, monitoring not only helps to put the system on track but also useful to set the new standards and to derive new plans and policies. Without accurate and systematic information about the state and changes in the solid waste scenario, it is impossible to set the targets and to direct policy to meet them. This information base will be built upon the results of monitoring.

Monitoring is also required not only to know whether the planned activities are performed but also to know the changes that are occurring. In either case, it is necessary to identify the measurable and their units. In the first case, the measures may be the amount of solid waste handled per day, the solid waste status at the collection centers, i.e. fully recovered or partially removed , number of workers on duty in each area on daily basis, etc. In the second case, the measures may be increased in solid waste generation—monthwise with January data as basis, new types of wastes being dumped, status of hazardous waste, if any, etc.

To carry out the monitoring activity, the frequency, the characteristics, the person to measure, the instruments to be used and the methods of communications have to be specified. The location, the characteristics to be monitored at each station, the instruments, the personnel, etc. have to be stated clearly if number of each stations are required. The schedule may also include the day and time of monitoring, in addition to the above parameters.

In the case of environmental management, the threshold limits of pollutants in the atmosphere become the automatic goals/desired limits. Therefore, planning must include all these limits say SPM, NO_x, SO_x, etc., for air, BOD, COD, SS, DO, etc., for water, quantity and quality of solid waste, noise, etc. Their threshold limits have to be set. It is then necessary to monitor by taking the samples of air, water etc. to test the incidence of pollutants as the set time and in the set frequency in the example. The environmental manager must have way of checking whether the samples as per schedule are collected and are tested as per the norms provided in the law. Though, many industries see this activity as a cost center, it is now being realized that it can be turned into a profit center by undertaking productive and reusing recycling policies.

Therefore, monitoring and control are more important in environment management in not only providing clean environment to the employees as well as general public but also to reduce the cost of the material input and cost of the process.

6.4 SOLID WASTE MANAGEMENT AUDIT

As is discussed earlier in this chapter, a clear and detailed plan will remove ambiguity and will increase efficiency in the monitoring activity. Data collected through such systematic planning will also make environmental audit an easy task and no separate data collection is necessary. In another way, one can also take into consideration the requirements of environmental audit while designing the Environmental Management Plans (EMPS) and the factors/characteristics to be monitored. It is also necessary to specify to assign the tasks to specify persons including the task of supervising whether monitoring is performed as schedule or not. Such a detailed plan will envisage high performance.

Government of India, in its Environmental Protection Act (Amendment) 1992, has categorically stated that every industry has to submit the "Environmental Audit Report" for every financial year ending March 31st. This is different from the Financial Audit in the sense that the Financial Audit has to be performed by a qualified, professional, and external auditor. Where as for Environmental Audit, there is no such rule. The company itself has to prepare an Environmental Audit Report and has to submit to the Government.

Therefore, the companies, after coming into existence as per law, have an obligation to maintain the clean environment. The industries failing to take steps for preventing environmental degradation have to face legal action. If such legal actions against management are to be prevented, a critical review of such industries are to be undertaken at regular intervals, say, once in a year. Such a review and the report thereof form the purpose of the Environmental Audit. The form given in Table 6.1 is the format to be filled up by the industry and to be submitted to the Government.

Though the company personnel can make the audit internally, they can also engage a consultant to prepare the same. Mouli (1996) gave details steps to be followed in conducting such an environmental audit exercise. He divided it into four phases namely, pre-audit phase, site visit phase, report preparation phase and follow up phase. The main activities during the pre-audit phase are :

(*i*) Send a pre-visit questionnaire seeking the details of pollutant emitted control equipment used, waste water treatment details, etc. to the company.

(*ii*) Define audit scope and responsibilities of audit team.

(*iii*) Develop check lists, and

(*iv*) Review audit protocols.

The activities during the site visit phase include :

(*i*) Visit the premises, particularly to pollution control locations and sample collection locations,

(*ii*) Pre-audit discussion with management,

(*iii*) Impact the facilities as per checklists,

(*iv*) Collect samples in required numbers,

(*v*) Evaluate the results and

(*vi*) Post-audit discussion with the management.

The report will give a bird's eye view of the solid waste management scenario for all concerned the municipal council, the authorities, the public, the social organization, pollution control boards, environmental ministry etc.

Table 6.1

Form V : Environmental Audit Report for the financial year ending the 31st March

---

PART A

(*i*) Name and address of the owner/occupier of the industry, operation or process.

(*ii*) Date of the last environmental audit report submitted.

PART B

(*i*) Water consumption m^3/d Process cooling domestic

Name of products	Water consumption per unit of product	
	during the previous financial year	during the current financial year
(1)	(2)	
(1)		
(2)		
(3)		

(*ii*) Raw material consumption

Name of raw materials	Name of products	Consumption of raw material per unit of out put	
		during the financial year	during the financial year
(1)			

PART C

Pollution Generated (Parameters as specified in the consistent issued)		
(*i*) Pollutants	Quantity of pollution generated	Percentage of variation from prescribed standards with reasons
(*a*) Water		
(1)		
(2)		
(3)		
(*b*) Air		
(1)		
(2)		
(3)		

PART D

Hazardous Wastes [as specified under Hazardous Wastes (Management and Handling) rules, 1989]

Hazardous Wasters	Total Quantity (Kg)	
	during the previous financial year	during the current financial year
(*a*) From process		
(*b*) From Pollution control facilities		

PART E

Solids Wastes		
Total Quantity (Kg)		
	During the previous financial year	During the current financial year
(*a*) From process		
(*b*) From Pollution control facilities		
(*c*) Quantity recycled or re-utilized.		

PART F

Please specify the characteristics (in terms of concentration and quantum) of Hazardous as well as solid wastes and indicate disposal practice adopted for both these categories of wastes.

PART G

Impact of pollution control measures on conservation of natural resources and consequently on the cost of production.

PART H

Additional investment proposal for environmental protection including abatement of pollution.

PART I

Any other particulars in respect of environment protection and abatement of pollution.

The report preparation phase will consist mainly the preparation of the audit report. First a draft report is prepared, the draft report is review for legal compliances, report contents are discussed with the management and then, the final report is prepared. During last phase, i.e., follow-up phase, corrective steps to be carried out, listed action plan so prepared based on the corrective steps to be taken to improve the efficiency of pollution control systems.

QUESTIONS

1. Explain the steps in environmental planning process.
2. State and explain three important characteristics of planning process.
3. Explain the important steps in sequential Plan.
4. Explain the Environmental management Plan for its constituents and the steps of preparation.
5. Planning and Control are the Siamese twins. Explain ?
6. Explain the control function with the help of a block diagram.
7. Describe the elements of control process.
8. Differentiate Monitoring and Audit. Give the detailed procedure of Environmental Audit.

CHAPTER 7

ORGANIZATIONAL DESIGN FOR SOLID WASTE MANAGEMENT

6.1. INTRODUCTION

Whenever an activity is planned, some personnel are required to implement the plans and perform the said activities. This is true for any type of activity, be it in manufacturing in an industry, service in a government organization, or any other allied activity. The people together, who are at a place to perform common activities or achieve common goals, are referred as organization and their arrangement in a hierarchy, based on their roles, is called as organization chart. However, the roles of each person has to be specified in carrying out the activities, that include their duties, responsibilities, authority, accountability, etc. The design of these specifics, in addition to the roles, is called the organizational design. In solid waste management also, organizational design and other issues play an important role in the effectiveness of implementation of the plans and achievement of goals.

7.1 ORGANIZATIONAL DESIGN

The tasks involved in an organizational design are :

(*a*) Identification of activities.

(*b*) Formation of hierarchy of the activities by exploding a major activity into sub-activities.

(*c*) Identification of roles people should play.

(*d*) Formation of the designations.

(*e*) Defining the duties, responsibilities and authority of the persons at each designation.

(*f*) Arranging them in the form of a hierarchy thus defining the accountability and authority.

Many organizations fail to achieve their goals because of poor and unscientific organizational design. They do not specify the roles, and have no clear hierarchy. Responsibilities are not clearly and explicitly stated. Such a situation leads to chaos and anarchy. Every body blames every other person for the lapses and always tries to avoid decision making by passing on the paper either to the superior or to the subordinate. The success of any department, in achieving its goals depends upon the appropriate and scientific organizational design.

Many a time, it is taken for granted thinking that the system, existing already, will take care by itself but it may result in under achievement. When it is realized that the goals are not achieved and the achievements are far behind the plans, the blame goes to some individuals, mostly the lower level employees, for the failure, but hardly the organization structure and their roles are looked into. This further complicates the issue, develops mutual non-confidence in various levels of employees and leads to more inefficiency.

In order to avoid such a situation, to allow smooth functioning of the organization, to avoid mis-trust among employees and to make the system efficient. It is necessary that the organization is clearly structured and designed. This is also applicable, more so, to the solid waste management in our country as it involves several manual operations. It is worthwhile to recall the four principles of organizing, namely:

(*i*) Unity of command

(*ii*) Scalar Principle or chain of command,

(*iii*) Exception principle, and

(*iv*) Span of control.

The principle of unity of command means that an employee must receive command/order/work assignments from only one person. If multiple people are giving independent orders to the same person, he will be in a confusion which work he has to do. It may ultimately lead to chaos in a complex organization.

The scalar principle states that the order should flow in the line and no over looking of an intermediate authority should be allowed. For example, in a 3 level structure, Engineer-Supervisor-analyst, if engineer gives commands directly to the analyst over looking the supervisor, and at the same time, supervisor is also giving different commands to the analyst, it becomes difficult for the analyst to work and also the relations between the engineer and the supervisor will strain. Therefore, it is desirable that the engineer always communicates with the analyst through the supervisor or with the knowledge of the supervisor.

The principle of exception, says that a lower level employee should take only those exceptional issues to his immediate higher authority for decision-making and all the remaining decisions must be made by him only. This would be reducing the unnecessary load on higher authorities, and also minimizes the delay in decision-making. It is obviously necessary to formulate which of the decisions can be taken at lower level and which are those exceptional issues to be taken to the higher authority. The delegation is also important in this respect. In the absence of this clarity, there is every possibility that all the decisions are taken by the higher authority only or the conflicts may arise about the domain of decision-making.

Span of Control is the term used for the number of people that can be supervised by a person, i.e., how many subordinates one can manage. This differs from task to task. Only after making a thorough analysis of the nature of work, it is possible to define the span. In the loading and unloading jobs, one supervisor may be assigned for every fifty people or so, whereas, in an incineration or effluent treatment plant, a supervisor may be required for every 10 or 15 people. If the task performed by all the employees is similar, more number of persons can be assigned to a supervisor, whereas, if tasks performed are different for every person, less number of persons have to be assigned.

7.2. MONITORING AND CONTROLLING ROLES

Another major issue pertaining to organizing is the non-performance or under-performance of the tasks. Regular or frequent monitoring is required in order to see whether the tasks are performed as designed or not. Therefore, the monitoring and controlling roles have to be explicitly incorporated in the organizational design, so that the regular feedback reaches the authorities in time and in the required format. The personnel to measure the task completion rate/performing rate, and to give feedback to the concerned authorities have to be specified while designing the roles and preparing the organization manual.

7.3 AUTHORITY TO TAKE CORRECTIVE MEASURES

It is not sufficient just to know the way the solid waste management activities are being performed. It is also necessary to compare with the action plans. For example, a group of sanitary workers are assigned to lift the solid waste everyday from three locations. Supervisor might have observed that they are not removing fully and leaving a part of it. This may lead to stinking and cause protests from the surrounding residents. If the supervisor ignores, the solid waste builds up slowly and within a week, entire area may be polluted. He should have the authority to take corrective measures, and he should also be informed of that along with the support from higher authorities in facing the situations that may arise due to his decision. He may have assigned more people, may make the vehicle to make more trips, etc., if he found that it is necessary. Organizational design must be taken into consideration these tasks explicitly.

7.4 COMMUNICATION IN THE ORGANIZATION

One may find that the system is not working as planned. But a senior level manager may show his ignorance of the situation. One may hear him saying, "no body informed me". At the same time, his subordinate may say, "I was not told to inform such a situation also". It means that a communication gap exists here. A subordinate should be given clear and written guidelines of what to communicate, how to communicate, when to communicate, and to whom to communicate.

(*a*) What to communicate

The dilemma of what to communicate will always stay unless the company prepares some specific guidelines. As is discussed in the "exception principle", though only the exceptional issues, that require the higher level decision making, have to be put forth before the superior, it is also necessary to put a note for information of the decisions, which are not of routine nature, taken at the lower level to the superior so that he will be aware of what is happening in his jurisdiction. In other words, keep the superior informed of the developments/decisions in the section even though the authority to take such decisions lies with the subordinate.

(*b*) How to communicate

Many an information that has to be communicated may be of similar nature. It is always better if a format is developed and used. It is preferable to prepare the formats in which such a feedback can be communicated. The formats must be well designed, leaving scope for any comments/suggestions by the supervisor. They should contain the essential information that may be required for the higher authorities to perceive how the system is functioning, but at the same time, it should not be unnecessarily lengthy. When it is such lengthy information, people tend to ignore completely as it may require long time to get the glimpse of the report and to understand the vital information. In such a case, the report will not serve its purpose though the preparing personnel spent a large time. If the format is regarding the corrective actions already taken, the provision has to be made to provide with the details of the issue(s) also in addition to the actions taken. This brings the uniformity in communication, and removes the vagueness in communicating.

(*c*) When to communicate

The best time to communicate is when the event occurred or when the corrective action is taken. However, weekly or monthly reports can also be sent in the given formats. Here also, there should be clear guidelines in this regard.

(*d*) To whom to communicate

This may seem to be obvious that one has to communicate to his immediate superior. But many a time, it may not be sufficient. A matter may be related to other departments such as personnel department, finance department, etc., also. In such a case, in addition to giving the report/information to the immediate superior, a copy has to be sent to the concerned departments/sections. Therefore, it is also necessary to develop guidelines on what type of issue has to be communicated to which department/section.

The experienced employees might have gained this knowledge over the years, but new entrants to the plant or to that particular section, may not be aware of it. It is, therefore, helpful to keep these aspects documented to the extent possible.

7.5 ORGANIZATION MANUAL

Like any other department in the plant, solid waste management department also should maintain its organization manual. It shall include the organization chart and the description of each role/designation, their duties, responsibilities, authorities, accountability, etc. The manual has to serve as a reference guide whenever any doubt occurs in the section as to whose duty a particular task is. It is also possible to omit a particular task that has arisen in implementation. When such a task arises, it is necessary to update the manual by including that task by assigning to the appropriate designated role.

It is observed that the small and medium level companies do not maintain any such manual. When the operations increase, the workload on the personnel increases and the differences about 'who should do what' will arise. One can always define the roles (or redefine them) for that particular situation but it is always better for the company to avoid such conflicts by defining the roles clearly while designing the organization.

Many a time new posts are created without giving proper thinking and without defining the role explicitly. This always leads to confusion and conflicts. For example, a pharmaceutical company having a manpower of about 100 has the following structure.

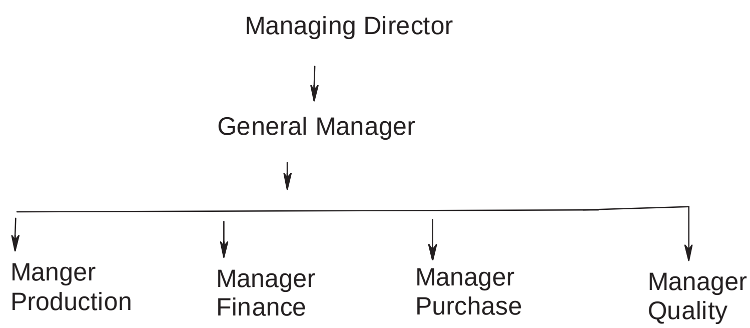


Fig. 7.1 Organization structure of the company before revision

The Managing Director felt that, as the operations of the Company are increasing, he should recruit a senior person to head the operations. He identified a person, who is a successful manager in another organization and recruited him as the Director. As this person is more experienced than the existing General Manager, the Director post was created in between the Managing Director and the General Manager. The managing director also recruited a Vice President (R & D) at the instance of the Director. The organization structure now has become the following structure:

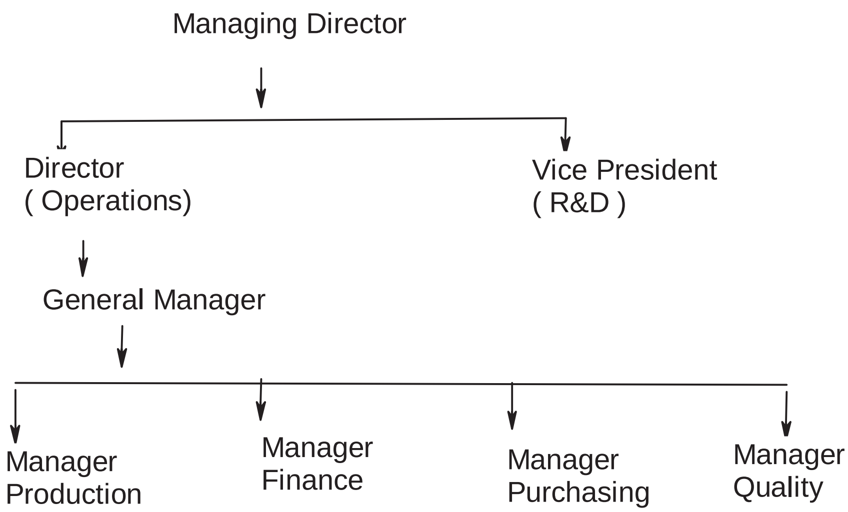


Fig. 7.2. Organization structure of the company after revision

Though the new roles are included, their duties and responsibilities are not clearly stated. The Director felt he is solely responsible for all operations and started communicating with the managers directly. The Managers, out of habit, use to go to General Manager for assistance and for reporting. In the process, the General Manager advises them as he thinks it right. This has led to confusion in the organization and to conflict between the Director and the General Manager. The matter has reached the managing director by means of complaints and accusations. He has not taken any corrective action to define their roles-scope, authority, responsibility, etc. Therefore, the conflict continued leading to chaos in the Company. The Managing Director could not decide what to do. General Manager was with him for a long time and proved successful in his organization. Therefore, he does not want to lose him. At the same time, as he invited the Director to join his organization it is embarrassing to tell him to quit. However after a few months, the Director left in disgust as he found that the Managing Director is not taking any action on the General Manager. Now again, the structure has become normal as the Vice President (R&D) also left as he found that there is no R&D works in the company.

Therefore, it is necessary to scientifically design and define the organizational roles to achieve the desired performance.

7.6 ORGANIZATIONAL STRUCTURE FOR SOLID WASTE MANAGEMENT

The structure depends upon the size of the city/town, the population in the city, the type of activities in the city/town, the types of solid waste to be moved and managed, the amount of solid waste, etc. The size of the city/town determines the no. of collection points distance to be moved where as the population and type of activities like businesses, industries (a particular city may have a large vegetable/fruit business which may produce large quantities of solid waste where as another city's major business may be cereals which produces lesser quantities relatively) determine the amount of solid waste generated, return, decides the frequency of the collection trips, type or mode of transport, manpower required, etc. In fact, this also provides the information on the type of treatment the solid waste requires, recyclable materials, and thereby the down wards activity to concert the solid waste management as a profit center rather than a cost center.

The data shows that in India, all recyclable materials are collected from the solved waste, not in an organized manner but by a large number people, particularly children, and sell them to the collection agents, who in turn supply to the industries. Therefore, the solid waste remaining is monthly biological and vegetable waste, which, in the opinion of the pickers, is not useful or resoluble. In fact, the remains after such collection by were pickers who decompose and lead to foul order and become growth centers for this and mosquitoes that affect the health of the surrounding people. It is this waste the authorities have to manage to provide clean environment to the populace.

Before taking up a case let us examine some organizational structures designed to manage solid waste. An urban cleaning management structure (Holmes, 1984) in Singapore is as shown below.

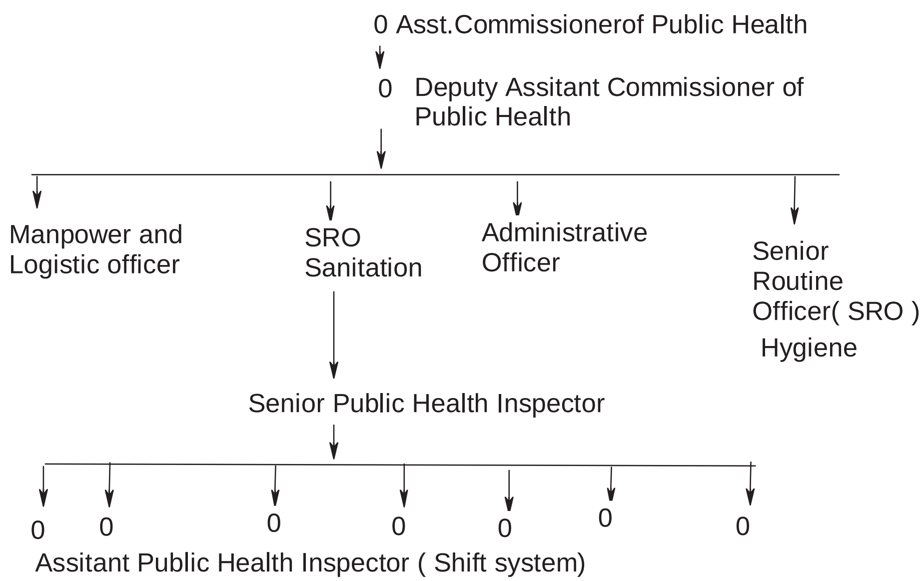


Fig. 7.3. Organizational Structure of an Urban Cleaning Management

The above structure have two vertical hierarchy roles, one as the top level, i.e., Assistant and Deputy Assistant Commissioners of public health, and two at the lower level, Public Health Inspector. Such hierarchic roles, many a time, become redundant as their duties and authority become similar. Moreover, it leads to conflict as the higher level officer tries to interact with second level subordinates by passing the immediate subordinate. That is Assistant Commissioner may send order directly to Sr.'s by passing Deputy Commissioner or SRO sanitation may send orders directly to Assistant inspectors by passing the senior inspector. This leads to conflict between Assistant Commissioner and Deputy Commissioner and between SRO and senior inspector. Therefore, it is always necessary to avoid such vertical roles in a line organization. Any superior should have more than one subordinate and superior-subordinate roles and must be clearly defined. As the superior deals with several subordinates, he may not tend to send orders directly to the next level subordinates. This vertical type of hierarchy where in a superior has only are subordinate.

Also violates the unity of command as the superior may by pass the immediate subordinate. This also brings chaos in the organization, as the subordinates do not know whom to follow. For example, if the Assistant Commissioner and Deputy Commissioner gives separate work assignments to SRO, he will be in a dilemma whose order to follow. Particularly when these orders are quite different, it leads to confusion and ambiguity and thereby the quality and the efficiency of the work suffer.

It is also observed from fig. 1 that the structure given is of only supervisory cadre. But the work will be performed by the skilled/semi-skilled /unskilled personnel. Their hierarchy is not shown. It is also important to design their hierarchy and to decide how many workers an assistant inspector can handle. This last level or last few levels, which are not shown in Fig. 1 are, may be crucial in achieving the set goals. In other words, Fig. 1 given an incomplete structure and if the authorities have not shown any interest to design the last level or last few levels. Then the entire work efficiency will suffer. It is therefore necessary to design all the levels and not to take any particular level for granted or over look it. In fact, it is at this last few levels one has to take into consideration the area or type of solid waste to assign the responsibilities. The work of Assistant public health inspectors has to be divided based on the area of collection, type of solid waste, etc. Their tasks may be inter changeable but have to be defined clearly and explicitly.

Let us examine another organization structure given in Nath (1984) and shown below.

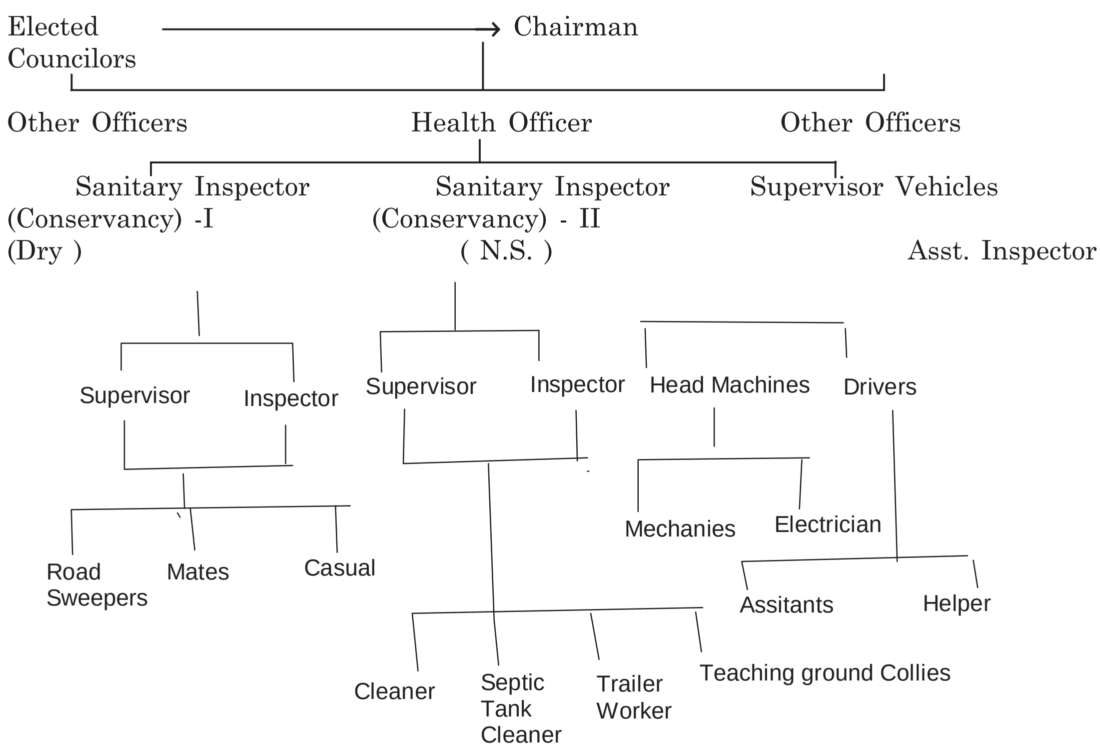


Fig. 7.4. Organization Structure-Case II

This is a better designed structure compared to the previous example. The two horizontal roles supervisors and inspectors—which seem to be not in order, can be taken as functional roles, i.e., supervisors from the line activity cleaning and collection work, say, assigning the jobs, etc., where as the inspectors takeover the function of control of their work. With a good understanding between these two roles, i.e., supervisors and inspectors, and with a well defined roles, the efficiency of the system will increase.

The third example shown below is an entirely different structure taken from Greco (1984).

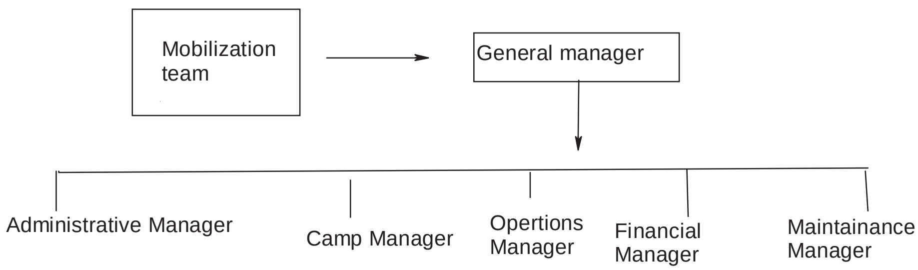


Fig. 7.5 Organization structure (GRECO)

It is observed that the structure shows only the top two levels of hierarchy. This is designed not to a municipal corporation , but to a private company which had undertaken a contact for solid waste collection & disposal, and cleaning operations. If a municipal corporation undertakes this activity without giving a contract, then separate financial manager and maintenance manager may not be required as the financial /accounts division of the municipality will take care of the cleaning operations also; and maintenance activity will be part of the maintenance activity of other vehicles/equipment. Even separate administration manager may not be required and at this level, camps manager and operations manager can be combined who will report to the Municipal Commissioner making "General manager" redundant. It is not desirable to blindly adopt any particular structure to another system. A thorough study has to be made of the activities, roles involved and a tailor-made structure has to be designed.

A case is demonstrated here in designing an organization structure for solid waste management of a metropolitan city. In doing so, the principles and practices of organizational design are also discussed.

7.7. DESCRIPTION OF THE CASE

The metropolitan city chosen here for discussion, is a fast growing city. The rapid unchecked increase in the population due to migration has already put the entire civic infrastructure under great stress giving rise to several water borne and food borne diseases.

The total estimated population of the city is about 45 lakhs. Taking average amount garbage generated per capita as 0.35 Kgs. per day per person the total garbage to be handled per day is in the order of 1580 tons. By the year 2000, the population is expected to reach 60 lakhs and the garbage generated per day to 2500 tons. Table 7.1 has shown the generation of garbage in the city.

TABLE 7.1: GARBAGE GENERATION

Sl. No.	*Category*	*9 lakh house holds*	*Garbage generated per day (approx) in tones*
1.	Domestic	380	1140
2.	Hotels, Restaurants, etc.	20	110
3.	Markets	360	80
4.	Hospitals	5	70
5.	Slaughter houses	35	20
6.	Recreation/Commercial Centers		100
7.	Others such as dairies, poultries etc.		60
			Total 1580

7.7.1. Collection of Garbage

Municipal council provided some dumping bins at various centers. But it is observed that neither in the domestic places nor in the market places, the waste is damped properly in the bins. It spreads all around. The bins also overflow when it is not removed for days together. The council has introduced a scheme of collecting domestic garbage through rickshaw pullers who will be paid by the citizens as Rs. 10/- per month per family. This scheme is introduced only in same parts of the city. Though the collection from individual homes is successful through this scheme, but the rickshaw pullers also dump the garbage in a central place of that area where from the municipal employees have to remove at to the dumping yard. Therefore, the situation becomes the same.

There is a large number of personnel, starting from the chief medical officer m six assistant medical officers m 52 sanitary supervisors, 350 sanitary jawans, and about 4300 workers. It has also a good number of vehicles about 170 in total. With the existing manpower and the fleet of vehicles, it must be able to handle the solid waste, i.e., transport the solid waste to the dumping yards. But it is reputed in the press that at many places the garbage is left to stink and cause problem.

A study of the city's solid waste management problem suggested adding another 60 v ehicles and to recruit about 1000 workers more. The expected increase in the cost is about Rs.20 cores initially and about 2.5 cores annually. It can be seen that all this additional expenditure can be saved if the organization is well designed and monitoring and following is made functioning.

7.7.2. Solid Waste Management Plan

Table 7.1. shows that the garbage to be moved per day is about 1580 tones, with the existing fleet of vehicles, each vehicle has to carry 10 tones per day, or it has to make only one trip per day. 10 % of the vehicles i.e. a bus, 15 trucks can be added to keep as stand by during the maintenance/breakdown of other vehicles. This necessitates division of the city into 150 areas, allocating one truck to each area. Manpower also can be planned to these 150 areas i.e., about 24 persons per area and accounting to 3600 personnel. The remaining 700 personnel will be utilized to provide weekly holiday for others as well as to substitute the staff on leave. The 24 workers will be divided into two teams and the area to be cleaned be year-marked for time. Similarly one jawan has to be assigned to each area and one supervisor should take care of this area. The 300 areas have to be grouped into 50 sub zones, each sub

zone containing 3 areas and will be under the control of sanitary supervisor. It means that each supervisor has to coordinate sixty sanitary jawans. These subzones have to be further clustered into 5 zones, one each under an Asst. Medical officer. The organization chart of the above can be depicted as follows.

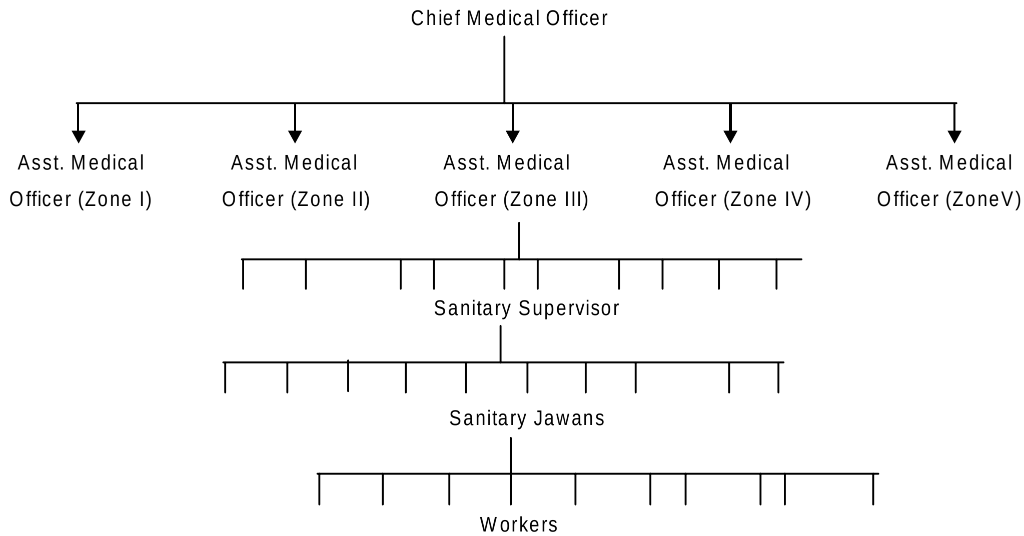


Fig. 7.6. Organization chart

The workers have to be assigned the work of lifting the garbage from the specified centers of the area. The scheme of rickshaw pullers has to be introduced throughout the city including markets. In order to coordinate and monitor their work, citizens 'committees have to be farmed. These committees also must monitor the work of sanitary jawans (SJs) and the workers and send the complaints/suggestions regularly to the supervisors. SJs, the workers and SSs (sanitary supervisors) have to be made accountable for only lapses in the movement of the waste.

This is a very feasible solution to the city only if the monitoring is introduced as part of the organization and implemented at all the levels.

The organization manual has to clearly specify the tasks and duties of each employee. Any non-performance of the task has to be dealt with immediately in order to increase the efficiency of the individuals as well as the system rather than only to punish the individuals.

A good organizational design only can really present the environmental degradation. The design, shown above, has taken into considering the existing employees without changing even their designations. However, when the organization is designed afresh for a city/town, where such a formal system does not exist, it is desirable that the design has to start from the lowest cadre, say, workers. It is that at that level, the work content and thereby the number of persons required has to be defined with specific job description. Then, the higher roles have to be designed as per the requirement.

7.8. THE FORMAT TO COLLECT THE DATA

It is required to collect the relevant necessary data form the city for which the organization for Solid Waste Management is to be designed. The format given below, as designed to obtain the data for the case is discussed above. This can be used for any similar study.

Data on Solid Waste Management

1. (*a*) Organization chart of the employees involved in domestic / market / industrial waste collection and disposal.
   (*b*) No. of employees designation wise.
2. Total Area of the city covered by MCH.
3. Whether categorized into divisions? If so, Number.
4. No. of collection points-division wise.
5. No. of disposal seats.
6. Vehicles/Equipment used in collection of :
   (*a*) Domestic refuse including sweepings.
   (*b*) Commercial refuse (market places, hotels, etc.).
   (*c*) Building waste (by demolition or otherwise).
   (*d*) Industrial waste rules, chemicals (solids), toxicants etc.
   (*e*) Special wastes, such as dead animals etc.
   (*f*) Hazardous waste, if any.
   (*g*) Any other category.
7. No. of House holds-division wise.
8. Size of population.
9. Amount of waste collected in tone/year or tone/month-division wise.
   (*a*) Domestic waste/ sweepings
   (*b*) Commercial waste
   (*c*) Building waste
   (*d*) Special waste
   (*e*) Industrial waste
   (*f*) Hazardous waste
   (*g*) Any other category (please specify).
10. Details of vehicles Equipment/Tools used.

Sl No.	*Type of Vehicle/ Equipment*	*Purchase cost*	*Maintenance cost/year required*	*No. or people*	*Capacity tone trip*	*Average Speed*
1.	2.	3.	4.	5.	6.	7

11. Total Budget of MCH for solid waste Management.
12. Break up of budget, say salaries, maintenance of vehicles/equipment, disposal costs, etc.
13. Solid waste generation estimates (Gross).

Sl No.	*1998-99*	*1999-2000*	*2000-2001*	*2001-2002*
(*a*)				
(*b*)				
(*c*)				
(*d*)				
(*e*)				
(*f*)				
(*g*)				

14. Solid waste generation estimates
    (*a*) Domestic per capitals per year.
    (*b*)
    (*c*)
    (*d*)
    (*e*)
15. Crew Assignments and schedules

Division 1	*Vehicles 2*	*Persons 3*	*No. of trips 4*	*Time per trip 5*	*Distance to be covered 6*	*No.of collection prints to be covered 7*	*No. of house serve 8*	*Amount collected into per day 9*

16. People participation, if any (local committees, voluntary organizations, youth associations, etc.).
17. Complaint redress system :
    (*a*) Mode of getting complaints.
    (*b*) Mode of redressal.
    (*c*) Feed back system, if any.
18. Disposal methods

Sl. No.	*Type of Disposal 1*	*No. of persons involved 2*	*Cost of operation 3*	*Initial Cost 4*	*Capacity in t/day 5*	*No. of Units*	*Indirect Costs land, poll with on etc.*
(*a*)							
(*b*)							
(*c*)							
(*d*)							

19. Special Taxes, if any.
20. Source of finance for solid waste management.
21. Special legislation, Rules and regulators, if any

Sl No.	*Name of Act/*	*Year of legislation*	*Year enfor-cement*	*Legislation Authority document*	*Enforcement authority*

22. Implementation and control difficulties, if any.
23. Future plans, if any proposed/considered/approved.
24. Expected Requirements
    (*a*) Man powers
    (*b*) Vehicles/Equipments
    (*c*) Tailor made Management into systems
    (*d*) Organization strategies
    (*e*) Peoples participation
    (*f*) Any other (please specify).

QUESTIONS

1. Briefly describe the activities involved in organizational design process.
2. What are the important principles of Organization and what they mean ?
3. What is Organization Manual and what are its contents ?
4. Design an organization structure for solid waste management of a metropolitan city. Give your assumptions and reasoning.
5. Environmental management emphasizes on public participation. How do you involve public in solid waste management ?

REFERENCES

1. Industrial Ecology by S. E. Mohan, Lewis Publishers, Washington, DC, 2002.
2. Research Methodology and Systems Analysis by P. R. Trivedi, IIEE Publisher, New Delhi, 2000.
3. Environmental Engineering by G. S. Pandey and G. C. Carney, Tata McGraw-Hill Publishing Company Limited, New Delhi, 1995.
4. Introduction to Environmental Engineering by Mackenze L. D. ; P Avid and A. Cornwall, McGraw Hill International Editions, UK, 1990.
5. Environmental Engineering and Sanitation by J.A. Salvats, Wiley, New York. 1979.
6. Solid Wastes, Engineering principles Managements Issues by G. Tchobanoglons, H. Therisen and R. Elision, McGraw Hill, New York, 1981.
7. Nag, A. Efficient Conversion of Calcutta Municipal Solid Waste into Fuel Oil by Catalytic Hydrogenation, Fuel Science and Technology International 10 (1), 117-138, 1992.
8. Nag, A. Utilization of Charred Sawdust as an adsorbent of dyes, toxic salts and oil from waste water. Institute of Chemical Engg. (Environmental, U. K) 73, 299-307, 1995.
9. Basak, A.; Nag, S.;. Mondal, S. and Nag, A. Chemo enzymatic synthesis of Anti-inflammatory drugs Tetrahedron Asymmetry, 8, 1401-03, 2000.
10. Rymshaw, E., Walter, M.F and Richard T.L. Agricultural Composting: Environmental Monitoring and Management Practices. Dept. of Ag. & Bio. Eng., Cornell University, Ithaca, NewYork,1992.
11. Atiyeh, R.M.; Subler, S., Edwards, C.A., Bachman, G. J.D. Metzger, J.D. and Shuster, W. Effects of vermicomposts and compost on plant growth in horticultural container media and soil, Pedobiologi*a*, 44: 579-590, 2000.
12. Agarwal, M. C. Environmental Pollution due to Surface Mining: Some Controls and Remedies, Indian Mining and Engineering Journal, 1, 13-18, 1984.
13. Ahmed, S.B., Input-Output Analysis in Environmental Modeling-Guest Editorial, IEEE Transactions on Systems, man and Cybernetics, l.3, 537-538, 1973.
14. Austin, L.M. and Burns, J.R. Management Science–An aid for Management Decision Making, Macmillan Publishing Company, New York, 1985.
15. Bisset, R. Methods for Environmental Impact Analysis: Recent Trends and Future Prospects, Journal of Environmental Management, 11, 1-17, 1980.

16. Bowonder, B. Environmental Changes in Developing countries: A Systems Perspective, Journal of Applied Systems Analysis, 14, 81-98, 1987.
17. Coates, V.T. Technology Assessment, Where it stands today ? Research Management, 16, 5, 257-272, 1973.
18. Davis, C.A. (1977), A Priority-tradeoff-scanning Approach to Evaluation in Environmental management, Journal of Environmental Management, 5, 259-273, 1977.
19. Martin, J., Principles of Database Management, Prentice-Hall of India Private Limited, New Delhi, 1976.

APPENDIX

MINISTRY OF ENVIRONMENT AND FORESTS NOTIFICATION

New Delhi, the 25th September, 2000

S.O. 908(E)—Whereas the draft of the Municipal Solid Wastes (Management and Handling) Rules, 1999 were published under the Notification of the Government of Indian in the Ministry of Environment and Forests number S.O. 783(E), dated, the 27th September, 1999 in the Gazettes of India, Part II, Section 3, sub-section (B) of the same date inviting objections and suggestions from the persons likely to be affected thereby, before the expiry of the period of sixty days from the date on which the copies of the Gazette containing the said notification are made available to the public;

And whereas copies of the said Gazette were made available to the public on the 5th October 1999;

And whereas the objections and suggestions received from the public in respect of the said draft rules have been duly considered by the Central Government;

Now, therefore, in exercise of the powers conferred by section, 3 6 and 25 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government hereby makes the following rules to regulate the management and handling of the municipal solid wastes, namely:-

1. Short title and commencement

   1. These rules may be called the Municipal Solid Wastes (Management and Handling) Rules, 2000.
   2. Save as otherwise provided in these rules, they shall come into force on the date of their publication in the Official Gazette.

2. Application

These rules shall apply to every municipal authority responsible for collection, segregation, storage, transportation, processing and disposal of municipal solid wastes.

3. Definitions

In these rules, unless the context otherwise required :

(*i*) "anaerobic digestion" means a controlled process involving microbial decomposition of organic matter in the absence of oxygen;

(*ii*) "authorization" means the consent given by the Board or Committee to the "operator of a facility";

(*iii*) "biodegradable substance" means a substance that can be degraded by micro-organisms;

(*iv*) "biomethanation" means a process which entails enzymatic decomposition of the organic matter by microbial action to produce methane rich biogas;

(*v*) "collection" means lifting and removal of solid wastes from collection points or any other location;

(*vi*) "composting" means a controlled process involving microbial decomposition of organic matter;

(*vii*) "demolition and construction waste" means wastes from building materials debris and rubble resulting from construction, re-modeling, repair and demolition operations;

(*viii*) "disposal" means final disposal of municipal solid wastes in terms of the specified measures to prevent contamination of ground-water, surface water and ambient air-quality;

(*ix*) "Form" means a Form appended to these rules;

(*x*) "generator of wastes" means persons or establishments generating municipal solid wastes;

(*xi*) "land filling" means disposal solid wastes on land in a facility designed with protective measures against pollution of ground water, surface water and air fugitive dust, wind-blown litter, bad odour, fire hazard, bird menace, pests or rodents, greenhouse gas emissions, slope instability and erosion;

(*xii*) "leachate" means liquid that seeps through solid wastes or other medium and has extracts of dissolved or suspended material from it;

(*xiii*) "lysimeter" is a device used to measure rate of movement of water through or from a soil layer or is used to collect percolated water for quality analysis;

(*xiv*) "municipal authority" means Municipal Corporation, Municipality, Nagar Palika, Nagar Nigam, Nagar Panchayath, Municipal Council including notified area committee (NAC) or any other local body constituted under the relevant statutes and, where the management and handling of municipal solid waste is entrusted to such agency.

(*xv*) "municipal solid waste" includes commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes;

(*xvi*) "operator of a facility" means a person who owns or operates a facility for collection, segregation, storage, transportation, processing and disposal of municipal solid wastes and also includes any other agency appointed as such by the municipal authority for the management and handling of municipal solid wastes in the respective areas;

(*xvii*) "pelletisation" means a process whereby pellets are prepared which are small cubes or cylindrical pieces made out of solid wastes and includes fuel pellets which are also referred as refuse derived fuel;

(*xviii*) "processing" means the process by which solid wastes are transformed into new or recycled products;

(*xix*) "recycling" means the process of transforming segregated solid wastes into raw materials for producing new products, which may or may not be similar to the original products;

(*xx*) "schedule" means a Schedule appended to these rules;

(*xxi*) "Segregation" means to separate the municipal solid wastes into the groups of organic, inorganic, recyclable and hazardous wastes;

(*xxii*) "State Board or the Committee" means the State Pollution Control Board of a State, or as the case may be, the Pollution Control Committee of a Union Territory;

(*xxiii*) "storage" means the temporary containment of municipal solid wastes in a manner so as to prevent littering, attraction to vectors, stray animals and excessive foul odour;

(*xxiv*) "transportation" means conveyance of municipal solid wastes from place to place hygienically through specially designed transport system so as to prevent foul odour, littering, unsightly conditions and accessibility to vectors; "vadose water" water which occurs between the ground, surface and the water table that is the unsaturated zone;

(*xxv*) "vermicomposting" is a process of using earthworms for conversion of bio-degradable wastes into compost.

4. Responsibility of Municipal Authority

(1) Every municipal authority shall, within the territorial area of the municipality, be responsible for the implementation of the provisions of these rules, and for any infrastructure development for collection, storage, segregation, transportation, processing and disposal of municipal solid wastes.

(2) The municipal authority or any operator of a facility shall make an application in Form-I, for grant of authorization for setting up waste processing and disposal facility including landfills from the State Board or the Committee in order to comply with the implementation programme laid down in Schedule-I.

(3) The municipal authority shall comply with these rules as per the implementation schedule laid down in Schedule-I.

(4) The municipal authority shall furnish its annual report in Form-II.

(*a*) to the Secretary-incharge of the Department of Urban Development of the Concerned State or as the case may be of the Union Territory, in case of a metropolitan city, or

(*b*) to the District Magistrate or the Deputy Commissioner concerned in case of all other towns and cities, with a copy to the State Board or the Committee on or before the 30th day of June every year.

5. Responsibility of the State Government and the Union Territory Administrations-

(*a*) The Secretary-in-charge of the department of Urban Development of the concerned State or the Union Territory, as the case may be, shall have the overall responsibility for the enforcement of the provisions of these rules in the metropolitan cities.

(*b*) The District Magistrate or the Deputy Commissioner of the concerned district shall have the overall responsibility for the enforcement of the provisions of these rules within the territorial limits of their jurisdiction.

6. Responsibility of the Central Pollution Control Board and the State Board or the Committees:

(*a*) The state Board or the Committee shall monitor the compliance of the standards regarding ground water, ambient air, leachate quality and the compost quality including incineration standards as specified under Schedules II, III and IV.

(*b*) The State Board or the Committee, after the receipt of application from the municipal authority or the operator of a facility in Form I, for grant of authorization for setting up waste processing and disposal facility including landfills, shall examine the proposal taking into consideration the views of other agencies like the State Urban Development Department, the Town and Country Planning Department, Air Port or Air Base Authority, the Ground Water Board or any such agency prior to issuing the authorization.

(*c*) The State Board or the Committee shall issue the authorization in Form-III to the municipal authority or an operator of a facility within forty-five days stipulating compliance criteria and standards as specified in Schedules II, III and IV including such other conditions, as may be necessary.

(*d*) The authorization shall be valid for a given period and after the validity is over, a fresh authorization shall be required.

(*e*) The Central Pollution Control Board shall co-ordinate with the State Boards and the Committees with particular reference to implementation and review of standards and guidelines and compilation of monitoring data.

7. Management of municipal solid wastes

(1) Any municipal solid waste generated in a city or a town, shall be managed and handled in accordance with the compliance criteria and the procedure laid down in Schedule-II.

(2) The waste processing and disposal facilities to be set up by the municipal authority on their own or through an operator of a facility shall meet the specifications and standards as specified in Schedules III and IV.

8. Annual Reports

(1) The State Boards and the Committees shall prepare and submit to the Central Pollution Control Board an annual report with regard to the implementation of these rules by the 15th of September every year in Form IV.

(2) The Central Pollution Control Board shall prepare the consolidated annual review report on management of municipal solid wastes and forward it to the Central Government along with its recommendations before the 15th of December every year.

9. Accident Reporting

When an accident occurs at any municipal solid wastes collection, segregation, storage, processing, treatment and disposal facility or landfill site or during the transportation of such wastes, the municipal authority shall forthwith report the accident in Form V to the Secretary in-charge of the Urban Development Department in metropolitan cities, and to District Collector or Deputy Commissioner in all other cases.

SCHEDULE - I
[See Rule 4(2) and (3)]
Implementation Schedule

S.l. No.	Compliance Criteria	Schedule
1.	Setting up of waste processing and disposal facilities	By 31.12.2003 or earlier
2.	Monitoring the performance of waste processing and disposal facilities	Once in six months
3.	Improvement of existing landfill sites as per provisions of these rules	By 31.12.2001 or earlier
4.	Identification of landfill sites for future use and making site(s) ready for operation	By 31.12.2002 or earlier

INDEX