NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

COURSE CODE: EHS 317

COURSE TITLE: SOLID WASTE MANAGEMENT

COURSE GUIDE

EHS 317
SOLID WASTE MANAGEMENT

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CONTENTS PAGE

INTRODUCTION

EHS 317: Solid Waste Management is a 2-credit unit course. It is broken down into 4 modules and 13 units. It presents an overview of solid waste management. Specifically, what you will learn in this course include: concepts, nature and classification of solid waste; waste management methods and technologies; waste analysis and monitoring, and the effects of waste on the environment and health, etc.

At the end of this course, it is expected that you should be able to explain issues relating to solid waste management.

This Course Guide therefore tells you briefly what the course EHS 317 is all about, the type of course materials to be used, what you are expected to know in each unit, and how to work through the course material. It suggests the general guidelines and also emphasises the need for self-assessment and tutor-marked assignment. There are also tutorial classes that are linked to this course and you are encouraged to attend.

COURSE AIM

This course aims to give you an in-depth understanding of solid waste management. It is hoped that the knowledge will equip you with the necessary skill to excel in your examination and beyond.

COURSE OBJECTIVES

Note that each unit has specific objectives. You should read them carefully before going through the unit. You may want to refer to them during your study to check on your progress. You should always look at the unit objectives after completing a unit. In this way, you can be sure that you have done what is required of you by the unit. However, below are overall objectives of this course.

On successful completion of this course, you should be able to:

- explain concepts of solid waste management
- identify sources of solid waste
- identify different types of solid waste
- make a classification of solid waste
- identify various traditional methods of solid waste disposal
- describe solid waste management principles
- describe the incineration process
- outline various types of incinerators
- list various techniques of composting

- describe the composting process
- outline the processes of waste minimisation
- classify waste minimisation techniques
- state the importance of waste minimisation
- describe some waste recycling processes
- state the advantages and constraints to waste recycling
- define integrated waste management
- outline the guiding principles of integrated waste management
- monitor and analyse solid waste samples
- recommend appropriate waste management methods for a given community
- state the effects of wastes on health and the environment.

WORKING THROUGH THIS COURSE

To complete this course, you are required to read the units, the recommended text books, and other relevant materials. Each unit contains some self-assessment exercises and tutor-marked assignments. There is also a final examination at the end of this course. Stated below are the components of this course and what you have to do.

COURSE MATERIALS

The major components of the course are:

1. Course Guide
2. Study Units
3. Text Books
4. Assignment File
5. Presentation Schedule

STUDY UNITS

There are 13 study units and 4 modules in this course. They are:

Module 1

Unit 1 The Nature and Classification of Solid Waste
Unit 2 Principles of Solid Waste Management
Unit 3 Solid Waste Management Processes
Unit 4 Traditional (Crude) Solid Waste Disposal Methods

Module 2

Unit 1 Sanitary Landfill
Unit 2 Incineration
Unit 3 Composting
Unit 4 Other Methods/Technologies

Module 3

Unit 1 Waste Minimisation/Reduction
Unit 2 Waste Recycling and Reuse (Waste to Wealth)
Unit 3 Integrated Solid Waste Management

Module 4

Unit 1 Field Sampling and Monitoring of Waste Sites
Unit 2 Effects of Solid Waste on the Environment and Health

TEXTBOOKS AND REFERENCES

These texts listed will be of immense benefit to you in this course:

Amadi, A.N. (2009). *Modern Environmental Sanitation*. Owerri: Nationwyde Printers and Publications Co. Ltd.

Amadi, A. N. (2011). *ABC of Environmental Health*. Owerri: Ugomma Publishers Ltd.

Da Zhu Asnani, P. U., Chris, Z., Sebastian, A. & Shyamala, M. (2008). *Improving Municipal Solid Waste Management in India: A Sourcebook for Policy Makers and Practitioners*. http://www.tn.gov.in/cma/swm_in_india.pdf.

ASSIGNMENT FILE

The assignment file will be given to you in due course. In this file, you will find all the details of the work you must submit to your tutor for marking. The marks you obtain for these assignments will count towards the final mark for the course. Altogether, there are 13 tutor-marked assignments (TMA) for this course.

PRESENTATION SCHEDULE

The presentation schedule included in this Course Guide provides important dates for completion of each unit and tutor marked assignment. You should therefore try to meet the deadlines.

ASSESSMENT

There are two aspects to the assessment of this course. First, there are tutor- marked assignments and the written examination.

You are expected to apply the knowledge, comprehension, information and problem solving gathered during the course. Your final TMA will be presented in e-format and this account for 30% of your exam score.

At the end of the course, you will need to sit for a final written examination. This examination will account for 70% of your total score.

TUTOR- MARKED ASSIGNMENTS (TMAs)

You are expected to attempt all the TMAs in your study material. However, four TMAs will be uploaded in your portal. The best three will count towards your final exam grade.

FINAL EXAMINATION AND GRADING

The final examination for EHS 317 will be of 2 hours and have a value of 70%. The examination will consist of questions which reflect the self-assessment exercise and tutor-marked assignments that you have previously encountered. Furthermore, all areas of the course will be examined. It is also better to use the time between finishing the last unit and sitting for the examination, to revise the entire course. You might find it useful to review your TMAs and comment on them before the examination. The final examination covers information from all parts of the course.

COURSE MARKING SCHEME

The following table shows the course marking scheme.

TABLE 1 COURSE MARKING SCHEME

Assessment	Marks
TMAs	30 %
Final Examination	70%
Total	100%

COURSE OVERVIEW

This table indicates the units, the number of weeks required to complete them and the assignments.

TABLE 2 COURSE ORGANISER

Unit	Title of Work	Weeks Activity	Assessment (End of Unit)
	Course Guide	Week 1	
MODULE 1			
Unit 1	The Nature and Classification of Solid Waste	Week 1	Assignment 1
Unit 2	Principles of Solid Waste Management	Week 2	Assignment 2
Unit 3	Solid Waste Management Processes	Week 2	Assignment 3
Unit 4	Traditional (Crude) Solid Waste Disposal Methods	Week 3	Assignment 4
MODULE 2			
Unit 1	Sanitary Landfill	Week 4	Assignment 1
Unit 2	Incineration	Week 4	Assignment 2
Unit 3	Composting	Week 5	Assignment 3
Unit 4	Other Waste Management Technologies	Week 6	Assignment 4
MODULE 3			
Unit 1	Waste Minimisation/Reduction	Week 7	Assignment 1
Unit 2	Waste Recycling and Reuse	Week 8	Assignment 2
Unit 3	Integrated Solid Waste Management	Week 9	Assignment 3
MODULE 4			
Unit 1	Field Sampling and Monitoring of Waste Sites	Week 10	Assignment 1
Unit 2	Effects of Solid Waste on the Environment and Health	Week 11	Assignment 2

HOW TO GET THE MOST OUT OF THIS COURSE

In distance learning, the study units replace the university lecturer. This is one of the huge advantages of distance learning mode; you can read and work through specially designed study materials at your own pace and at a time and place that suit you best. Think of it as reading from the teacher, the study guide tells you what to read, when to read and the relevant texts to consult. You are provided exercises at appropriate points, just as a lecturer might give you an in-class exercise.

Each of the study units follows a common format. The first item is an introduction to the subject matter of the unit and how a particular unit is integrated with the other units and the course as a whole. Next to this is a set of learning objectives. These learning objectives are meant to guide your studies. The moment a unit is finished, you must go back and check whether you have achieved the objectives. If this is made a habit, then you will significantly improve your chances of passing the course.

The main body of the units also guides you through the required readings from other sources. This will usually be either from a recommended text book or from other sources.

Self-assessment exercises are provided throughout the unit, to aid personal studies. Working through these self-tests will help you to achieve the objectives of the unit and also prepare you for tutor marked assignments and examinations. You should attempt each self-test as you encounter them in the units.

The following are practical strategies for working through this course

1. Read the Course Guide thoroughly.
2. Organise a study schedule. Refer to the course overview for more details. Note the time you are expected to spend on each unit and how the assignment relates to the units. Important details, e.g. details of your tutorials and the date of the first day of the semester are available at your study centre. You need to gather together all these information in one place such as a diary, a wall chart calendar or an organiser. Whatever method you choose, do endeavour to adhere to it.
3. Once you have created your own study schedule, do everything you can to stick to it. The major reason that students fail is that they get behind with their course works. If you get into difficulties with your schedule, please let your tutor know before it is too late for help.

4. Turn to unit 1 and read the introduction and the objectives for the unit.
5. Assemble the study materials. Information about what you need for a unit is given in the table of content at the beginning of each unit. You will almost always need both the study unit you are working on and one of the materials recommended for further readings, on your desk at the same time.
6. Work through the unit, the content of the unit itself has been arranged to provide a sequence for you to follow. As you work through the unit, you will be encouraged to read from your set books.
7. Keep in mind that you will learn a lot by doing all your assignments carefully. They have been designed to help you meet the objectives of the course and will help you pass the examination.
8. Review the objectives of each study unit to confirm that you have achieved them. If you are not certain about any of the objectives, review the study material and consult your tutor.
9. When you are confident that you have achieved a unit’s objectives, you can start on the next unit. Proceed unit by unit through the course and try to pace your study so that you can keep yourself on schedule.
10. When you have submitted an assignment to your tutor for marking, do not wait for its return before starting on the next unit. Keep to your schedule. When the assignment is returned, pay particular attention to your tutor’s comments, both on the tutor marked assignment form and also written on the assignment. Consult you tutor as soon as possible if you have any questions or problems.
11. After completing the last unit, review the course and prepare yourself for the final examination. Check that you have achieved the unit objectives (listed at the beginning of each unit) and the course objectives (listed in this Course Guide).

FACILITATORS/TUTORS AND TUTORIALS

There are 16 hours of tutorial provided in support of this course. You will be notified of the dates, time and location together with the name and phone number of your tutor as soon as you are allocated a tutorial group.

Do not hesitate to contact your tutor by telephone, e-mail or discussion board if you need help. The following might be circumstances in which you would find help necessary. Contact your tutor if:

- You do not understand any part of the study units or the assigned readings.
- You have difficulty with the self-test or exercise.
- You have questions or problems with an assignment, with your tutor's comments on an assignment or with the grading of an assignment.

You should try your best to attend the tutorials. This is the only chance to have face to face contact with your tutor and ask questions which are answered instantly.

You can raise any problem encountered in the course of your study. To gain the maximum benefit from the course tutorials, prepare a question list before attending them. You will learn a lot from participating in discussion actively. Good luck!

MAIN COURSE

CONTENTS **PAGE**

MODULE 1

UNIT 1 NATURE AND CLASSIFICATION OF WASTE

CONTENTS

1.0 INTRODUCTION

In this unit, we shall be describing the concept of waste and providing you with the definitions of some terms applied in waste management. The lesson is going to be a living type as the subject of waste management is our everyday experience.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define the following terms – waste, solid waste, garbage, and rubbish, ash
- identify different types of solid waste
- give examples of various types of waste
- outline different sources of waste
- make a classification of solid waste.

3.0 MAIN CONTENT

3.1 Concept/ Definition of Solid Waste

3.1.1 Concept of Waste

Ever since the creation of man, or more markedly since he fell out of the favour of his creator, man had undertaken daily economic activities for his basic needs. These needs continue to vary both in number and complexity according to man's level of development which also leaves him with a multiplicity of options of items to use at a given time to satisfy the said needs.

In the process of satisfying our daily requirements of food, shelter, dressing, transport, entertainment, healthcare etc., we often tend to discard or throw away some of our previously valued belongings – household properties, implements, food, dress etc. which are of less use and are no longer needed. Such materials which are no longer meeting the needs of the owner and are discarded are called wastes. Merriam-Webster defines waste as "refuse from places of human or animal habitation." the world book dictionary defines waste as "useless or worthless material; stuff to be thrown away." unfortunately, both definitions reflect a widespread attitude that does not recognise waste as a resource.

Zero-waste America defines waste as "a resource that is not safely recycled back into the environment or the marketplace." Have you discarded any of your previously valued belongings today? Read along as we further explore the definitions and concept of solid waste.

3.1.2 Definition of Solid Waste

Waste refers to anything that is worthless, useless and discarded. It is defined in Vermont Solid Waste Management Rules (2002), as a material that is discarded or is being accumulated, stored, or physically, chemically or biologically treated prior to being discarded or that has served its originally intended use and is normally discarded or that is a manufacturing or mining by-product and is normally discarded. It further went down to define solid waste as any discarded garbage, refuse, sludge from a waste treatment plant, water supply plant, or pollution control facility and other discarded material including solid, liquid, semi-solid, or contained gaseous materials resulting from industrial, commercial, mining, or agricultural operations and from community activities but does not include animal manure and absorbent bedding used for soil enrichment or solid or dissolved materials in industrial discharges. Solid waste in this context simply refers to tangible and non-free flowing discarded materials arising from human activities. Business dictionary refers to it as "solid or semisolid non-soluble material (including gases and liquids in containers) such as agricultural refuse, demolition waste, industrial waste, mining residues, municipal garbage and sewage sludge. Other examples of solid wastes include waste tires, scrap metal, latex paints, furniture and toys, domestic refuse (garbage), discarded appliances and vehicles, uncontaminated used oil and anti-freeze, empty aerosol cans, paint cans and compressed gas cylinders, construction and demolition debris, asbestos etc.

3.2 Types of Solid Waste

Solid waste can be categorised as refuse, garbage, rubbish, ash, clinkers etc. We will describe them further below. However, in most situations the words can be used interchangeably.

3.2.1 Refuse

Refuse derived from its original connotation means rejects, and in this context, refers to the solid waste component that can easily be burnt or decomposed. It is the combustible and putrescible component of solid waste emanating from human domestic activities especially from the kitchen, homes etc. In other words, all non-hazardous solid waste from a community that requires collection and transport to a processing or disposal site is called refuse (or municipal solid waste). Examples include paper scraps, crusts, husks, dry pods, dry leaves, paper raps and small cartons etc. Refuse is made up of the garbage and rubbish.

3.2.2 Garbage

Garbage is mostly decomposable food wastes which are highly putrescible. The putrescible solid wastes generate humus and thus enrich the soil and some can be sorted and used as hog feed. However, on serious accumulation, they attract and breed flies and other insects. They also provide food for rats and other vermin and their fermentation results in the production of unpleasant odour.

3.2.3 Rubbish

This also means worthless, useless and unwanted matter that is to be disposed of. This is the dry component of refuse which are not easily decomposable or putrescible. Examples are trash, scrap metals, junk, rubble, debris, detritus, glass, cloth etc.

3.2.4 Ash/ Others

Ashes are products of combustion of materials. In may include wastes from utilisation of wood energy in households and small industrial concerns and also by-products of controlled burning or incineration of wastes. A related waste form is cinder or charcoal which in itself is a useful fuel. Dust is another waste type that may accumulate in the environment. These are mainly mineral in nature and may contain a number of trace elements important in agriculture.

3.3 Sources of Solid Waste

We have earlier noted that wastes emanate out of human activities in the environment. It therefore follows to reason that the source of solid waste will depend on the location and type of human activity being carried out. Thus we have domestic or household sources, agricultural activities, industrial processes, clinical activities/research and commercial/trading activities.

3.3.1 Domestic Sources

Human activities in the homes generates wastes of varied characteristics ranging from rejects arising from food preparations to left over foods, rapping materials of purchased items and disused household furniture and materials. The bulk of wastes of domestic origin are either putrescible or combustible. They are mainly biodegradable in nature.

3.3.2 Agricultural Sources

Agricultural activities contribute to the major waste stream of a community. Agricultural wastes are mainly biodegradable refuse (garbage) emanating from the growth and processing of farm products.

It may also include to a minor extent disused materials, implements and machinery.

3.3.3 Industrial Sources

Industrial processes also generate a great proportion of solid wastes of a municipality. Industrial solid wastes may vary dependent on the type of industry but commonly it may consist of rejected packaging materials, disused materials, equipment and machinery and also substandard products of such industries. Some fraction of industrial solid wastes may be hazardous in nature which again depends on the type of industry. For instance electronic manufacturing or assembling industry will generate hazardous wastes as opposed to food processing industry and schools as educational industry.

3.3.4 Clinical Activities/Research

Clinical activities in hospitals and research institutions generate solid wastes which we shall in due course discuss its careful handling due to potential danger inherent in them. Apart from the packaging materials of products and other garbage, hospital solid wastes may contain anatomical wastes, disused drug and vaccine vials, contaminated needles and syringes etc.

3.3.5 Commercial Activities

Commercial or trading activities generate plenty of wastes which are mainly similar to domestic waste in characteristics and composition.

They are mainly composed of disused rapping materials, waste food products and other rejected articles of trade. The nature and composition of market wastes vary according to location and level of development. Rural markets generates up to 80% organic waste (crude estimate) compared to cities and urban areas where sophisticated materials including chemicals and electronic wastes may form part of the bulk waste.

3.4 Classification of Solid Waste

Different writers vary their opinion on the classification of solid waste. It may be categorised according to its origin (domestic, industrial, commercial, construction or institutional); according to its contents (organic material, glass, metal, plastic paper etc.); or according to hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc.). That is, based on the effect on man and environment, solid waste can be classed as hazardous, non-hazardous and infectious wastes. Indeed, there seem to be no end to the manner solid waste can be classified. For the purpose of this course, we shall adopt the classification of waste based on source, mode of handling and health effects.

Solid waste in this respect can be classified into different types depending on their source:

- household waste is generally classified as municipal waste
- industrial waste as hazardous waste
- biomedical waste or hospital waste as infectious waste.

3.4.1 Municipal Solid Waste

Municipal Solid Waste (MSW) is the garbage that we produce in our homes and where we work. The word municipal means anything that is operated and controlled by elected local officials such as city or local governments. Usually, MSW refers to what we throw away each day in our cities and towns. It consists of household waste, construction and demolition debris, sanitation residue, and waste from streets. MSW contains all kinds of garbage including newspapers, yard waste, old appliances, household garbage, used furniture and just about anything you can think of that people throw away at home, schools, and businesses. This garbage is generated mainly from residential and commercial complexes. With rising urbanisation and change in lifestyle and food habits, the amount of municipal solid waste has been increasing rapidly and its composition changing.

3.4.2 Hazardous Waste

Industrial and hospital waste is considered hazardous as they may contain toxic substances. Certain types of household waste are also hazardous. Hazardous wastes could be highly toxic to humans, animals, and plants; are corrosive, highly inflammable, or explosive; and react when exposed to certain things e.g. gases**.** Household wastes that can be categorised as hazardous waste include old batteries, shoe polish, paint tins, old medicines, and medicine bottles.

In the industrial sector, the major generators of hazardous waste are the metal, chemical, paper, pesticide, dye, refining, and rubber goods industries. Direct exposure to chemicals in hazardous waste such as mercury and cyanide can be fatal.

3.4.3 Hospital Waste (Medical Waste)

Hospital waste is generated during the diagnosis, treatment, or immunisation of human beings or animals or in research activities in these fields or in the production or testing of biological. It may include wastes like sharps, soiled waste, disposables, anatomical waste, cultures, discarded medicines, chemical wastes, etc. These are in the form of disposable syringes, swabs, bandages, body fluids, human excreta, etc. This waste is highly infectious and can be a serious threat to human health if not managed in a scientific and discriminate manner. It has been roughly estimated that of the 4 kg of waste generated in a hospital at least 1kg would be infected.

Hospital waste contaminated by chemicals used in hospitals is considered hazardous. These chemicals include formaldehyde and phenols, which are used as disinfectants, and mercury, which is used in thermometers or equipment that measure blood pressure. Most hospitals in India do not have proper disposal facilities for these hazardous wastes.

3.4.4 Street Waste

Street wastes are wastes not easily accounted for in terms of the originator and with less defined and non-palpable responsibility for its removal other than through organised community or local authority/municipal action. There are three types of street waste namely wastes generated by natural causes, 2) wastes generated by road traffic, and 3) wastes generated by the public (behavioral wastes) Street wastes generated by natural phenomena and are difficult to avoid. They include dusts blown from unpaved areas, and leaves and flowers that fall from trees and plants in the community. Others include sand deposits, mud, rocks, and other debris.

Waste generated by road traffic includes dirt and mud, as well as oil and rubber deposited by motor vehicles on the roads. Particulate matter from diesel emissions also accumulates on streets, trees, and building surfaces, creating a public nuisance. In addition, in developing countries, it is common to transport materials in vehicles that are uncovered, and there can be accidental spillage of a vehicle’s load.

Street wastes generated by the public though faulty behavior includes litter thrown onto the streets by pedestrians, and residential and commercial wastes swept or discarded from private premises. As previously indicated, a large fraction of these wastes can be controlled, provided that an efficient and reliable refuse collection service is in operation and that litter bins are provided for use by pedestrians.

4.0 CONCLUSION

In conclusion, waste is a relative term describing the current use or disuse of our materials and property. Solid waste, which is tangible and non-free flowing waste can constitute environmental, economic and health problems when not handled properly.

On the other hand solid waste when handled properly constitutes some useful alternative resource to the individual, household and the general community. Since waste is unavoidable in the life of man, it must be accommodated in our daily activities through careful planning of our course of action, choice of what to acquire and provision for handling of spoilt or disused materials and possessions.

5.0 SUMMARY

In this unit, our focus has been on the understanding of the basic definitions and terminologies used in the study of waste and waste management. You have seen that although waste is inevitable, it is a relative condition that can arise through different human activities in the house, work and commercial activities. You have also seen that solid waste can be categorised into different classes depending on the physical properties, mode of generation and potential to cause harm both to the environment and man. We based our own on the mode of handling and health effects. Explore further as we proceed to discuss the principles of solid waste management.

6.0 TUTOR-MARKED ASSIGNMENT

1. Write a definition for the term "waste"
2. List three types of solid wastes you have studied.
3. Outline five components of municipal solid waste.

7.0 REFERENCES/FURTHER READING

Vermont Solid Waste Management Rules (2002).

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http://www.zerowasteamerica.org/whatiswaste.htm (21/08/2012).

http://www.businessdictionary.com/definition/solid-waste.html (21/08/2012).

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UNIT 2 PRINCIPLES OF SOLID WASTE MANAGEMENT

CONTENTS

1.0 INTRODUCTION

In unit one, emphasis was placed on the basic definitions of the concepts of solid waste and the sources and classification of solid waste. In this unit, we will to discuss concept and principles of managing solid waste in our communities and cities.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define solid waste management
- state the objectives of solid waste management
- outline the principles of solid waste management.

3.0 MAIN CONTENT

3.1 The Concept of Solid Waste Management

The sight of a dustbin overflowing and the stench rising from it are all too familiar sights and smells of a crowded city. You look away from it and hold your nose as you cross it. Have you ever thought that you also have a role to play in the creation of this stench? That you can also play a role in the lessening of this smell and making this waste bin look a little more attractive if you follow proper methods of handling and disposal of the waste generated in the house?

3.1.1 What is Solid Waste Management?

Solid waste management remains one of the most daunting environmental sanitation challenges facing the country today and it has continually remained at its lowest ebb despite huge investments in the sector. Currently, as a result of industrialisation and rapid population growth in many cities and towns, wastes are generated faster than they are collected, transported and disposed.

Solid waste management is the collection, transport, processing or disposal, managing and monitoring of solid waste materials. The term usually relates to materials produced by human activity, and the process is generally undertaken to reduce their effect on health, the environment or aesthetics. Management of solid waste reduces or eliminates adverse impacts on the environment and human health and supports economic development and improved quality of life. Solid waste management is a distinct practice from resource recovery which focuses on delaying the rate of consumption of natural resources. The various processes involved in effectively managing waste for a municipality which include monitoring, collection, transport, processing, recycling and disposal shall be treated in detail in our subsequent discussions.

3.1.2 Objectives of Solid Waste Management

The underlying objectives of any waste management programmes will include:

- to protect human health and improve quality of life among people living in the area
- to reduce environment pollution and make the area clean
- to promote recycling and reuse of both solid waste
- to convert bio waste into energy for ensuring greater energy security at the community level
- to generate employment for the poor by offering new opportunities in waste management by adopting cost effective and environmentally sound solid waste treatment technologies.

3.2 Principles of Solid Waste Management

These are operational rules that will no doubt be followed in carrying out effective solid waste management programmes or services. These principles include the:

- principle of waste hierarchy
- principle of best available technology
- principle of proximity
- principle of self-sufficiency
- polluter pay principle and
- the extended producer responsibility principle.

3.2.1 The Waste Management Hierarchy

Effective and efficient solid waste management is based on a hierarchy of management options: the reduction of waste, its reuse wherever possible, recycling, composting, energy recovery, and final disposal. However, there will always be certain wastes for which incineration is the most reasonable environmental and economic option. The government policy shall seek to choose the best options for waste management that will minimise the risk of environmental pollution and harm to human health.

3.2.2 Principle of Best Available Technology (BAT)

This principle stipulates that disposal facilities must be equipped with the best available technology. The best available technology is selected on technological, environmental and economical criteria. That is, a disposal technology that is most cost effective and eco friendly should gain priority over others.

3.2.3 Principle of Proximity

The principle of proximity recommends that solid waste must be treated as close as possible to the place of production or collection. This will not only minimise cost of haulage but will reduce the risk of littering the transport routes through improved supervisory efficiency.

3.2.4 Principle of Self-Sufficiency

This principle is based on the theory that every member state, every community is responsible of its own waste. Therefore development efforts should encourage the containment of the waste generated by the community or member state no matter the degree of complexity of such wastes. The case of waste export or shift of responsibility to other community or nation should not arise.

3.2.5 Polluter Pays Principle (PPP)

This principle holds that waste disposal facilities must not be paid by tax payers’ money, but by the polluter. That is, every generator of waste – individuals, communities or industries must be taxed according to the quantity and complexity of wastes contributed by them to the municipal waste stream entering a waste management facility. Hence, the cost of waste management is not left in the hand of government as is the case currently in Nigeria but distribute rationally upon the producers. This will not only ease the municipality the burden of cost but give them the chance to provide other services to the populace. Also the polluter pay principle encourages private investment in waste management infrastructure.

3.2.6 Extended Producer Responsibility Principle.

This principle requires that producers of products or services accept a degree of responsibility for the wastes that result from the products/services they market, by reducing materials used in production, making repairable/recyclable goods, and/or reducing packaging.

3.3. Integrated Solid Waste Management

Integrated Waste Management (IWM) is waste management strategy or tool that takes cognisance of the most energy-efficient, least-polluting ways to deal with the various components and items of a community's solid waste stream. IWM is official state policy a nation can adapt to effectively tackle solid waste management challenges. The IWM hierarchy is based upon the material and energy that is embodied in solid waste and that is associated with its recycling and disposal. The twin goals of IWM are to:

- Retain as much as possible of that energy and those materials in a useful state , and
- Avoid releasing that energy or matter into the environment as a pollutant.

Integrated waste management sets up a hierarchy of approaches and technologies for managing solid waste in order to meet these goals. Generally, the farther "up" the hierarchy from which the technology is chosen, the more benefits in efficiency and retained economic value. We are going to study IWM and waste management hierarchy in details in our subsequent lectures.

4.0 CONCLUSION

Solid waste management as a practice is interesting if adequate consideration is given to the principles underlining it. It should be a preplanned activity which should accompany the production and utilisation of any product needed for comfort and services of mankind.

Thus every useable item that is made must have been thought of in terms of its utility, alternative use and waste value. When this is done and consideration given to appropriate management principle of disposal, much will be gained in terms of cost and the environmental effects of the less useful or useless end product. This is a very good plus to sustainable waste management.

5.0 SUMMARY

In this unit, you learnt the definition of solid waste management and identified its objectives. We also noted the processes involved in effective solid waste management to include collection, transport, processing or disposal, and monitoring of solid waste. You also learnt the basic principles guiding the effective management of solid waste in a community or municipality.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define the term “solid waste management”.
2. State the objectives of solid waste management.
3. Describe the principles of effective solid waste management.

7.0 REFERENCES/FURTHER READING

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UNIT 3 SOLID WASTE MANAGEMENT PROCESSES

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt the objectives and principles of solid waste management and gave an introduction to the concept of integrated solid waste management. In this unit, you are going to learn how to describe the various processes and stages involved in solid waste management. As usual, it is going to be a captivating presentation.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- outline the various processes in solid waste management
- discuss the stages of solid waste management process
- describe the features of a standard waste bin
- recommend appropriate waste transport system.

3.0 MAIN CONTENT

3.1 Elements of Solid Waste Management Processes

A typical waste management system in a low- or middle-income country includes the following elements:

- Waste generation and storage
- Segregation, reuse, and recycling at the household level
- Primary waste collection and transport to a transfer station or community bin
- Street sweeping and cleansing of public places
- Management of the transfer station or community bin
- Secondary collection and transport to the waste disposal site
- Waste disposal in landfills
- Collection, transport, and treatment of recyclables at all points on the solid waste pathway (collection, storage, transport, and disposal).

3.2 Waste Storage

Except in systems using the water carriage of refuse, the refuse from households cannot be collected as it is produced. Thus some means of intermediate storage is essential. For domestic refuse, such storage is provided by the dustbin. Establishments producing larger quantities of refuse, e.g. blocks of flats with refuse chutes, will use large containers which can be removed complete or which can be emptied into special collecting vehicles.

The size of the domestic dustbins is most important. It should be large enough to hold all the refuse produced between collections and at the same time, it should be small enough to be hoisted (carried) by one person, possibly with but preferably without the assistance of another in lifting the bin to the shoulder.

3.2.1 Qualities of a Standard Dust Bin

Figures 3.1 and 3.2 show various types of waste bins used in modern-day waste storage. In addition to the size considerations noted above, a standard waste bin should have the following qualities or characteristics:

a. Have a tight fitting cover and should be made of materials resistant to waster
b. Made of galvanised metal or plastic to resist rusting
c. Be fitted with two side handles for easy hoisting or lifting
d. Be easily filled, emptied and cleansed
e. Be placed always on a concrete slab.

3.2.2 Criteria for Hygienic Storage of Solid Waste

The hygienic storage of refuse is achieved through the following:

- The provision of adequate and sufficient number of containers (waste bins) to hold to hold the refuse generated between collections
- Use of approved waste bins properly positioned for users and easy access to the collection crew
- The maintenance of the containers and the surroundings in a sanitary condition.

In summary, the variables that impact the volume required for the storage of domestic wastes are: individual rate of waste generation, number of individuals living in the premises, and frequency of collection.

Fig. 3.1: Galvanised Waste Containers

Source:http://www.unep.org/ietc/portals/136/swm-vol1-part1-chapters4.pdf

Fig. 3.2: Plastic Bags Used for Storage of Wastes
Source:http://www.unep.org/ietc/Portals/136/SWM-Vol1-Part1-Chapters4.pdf

Fig. 3.3: Color Coded Recycling Bins for Waste Separation at the Source of Production
Source: www.unpluggedliving.com

3.3 Segregation, Reuse, and Recycling at the Household Level

The segregation, reuse and recycling of solid waste will be discussed in detail in unit 2 of module 3. Suffice to mention here that the dustbins in Figure 2 are colour coded and provided to ease this process. It is a modern day approach to solid waste management to be discussed under integrated solid waste management.

3.4 Waste Collection

Refuse collection involves the use of different transport equipment and machinery to remove refuse by the aid of the collecting crew either from the individual premises or from approved refuse depots. Waste from our homes is generally collected by our local authorities through regular waste collection, or by special collections for recycling. Within hot climates such as our country Nigeria waste should be collected at least twice a week to control fly breeding, and the harboring of other pests in the community. Other factors to consider when deciding on frequency of collection are the odors caused by decomposition and the accumulated quantities.

Table 3.1: Key Points Concerning Main Collection Systems

System	Description	Advantages	Disadvantages
SHARED: Residents can bring out waste at any time			
Dumping at designated location	Residents and other generators are required to dump their waste at a specified location or in a masonry enclosure.	Low capital costs	Loading the waste into trucks is slow and unhygienic. Waste is scattered around the collection point. Adjacent residents and shopkeepers protest about the smell and appearance.
Shared container	Residents and other generators put their waste inside a container which is emptied or removed.	Low operating costs	If containers are not maintained they quickly corrode or are damaged. Adjacent residents complain about the smell and appearance.
INDIVIDUAL: The generators need a suitable container and must store the waste on their property until it is collected.			
Block	Collector sounds	Economical.	If all family members

collection	horn or rings bell and waits at specified locations for residents to bring waste to the collection vehicle.	Less waste on streets. No permanent container or storage to cause complaints.	are out when collector comes, waste must be left outside for collection. It may be scattered by wind, animals and waste pickers.
Kerbside collection	Waste is left outside property in a container and picked up by passing vehicle, or swept up and collected by sweeper.	Convenient. No permanent public storage.	Waste that is left out may be scattered by wind, animals, children or waste pickers. If collection service is delayed, waste may not be collected or some time, causing considerable nuisance.
Door to door collection	Waste collector knocks on each door or rings doorbell and waits for waste to be brought out by resident.	Convenient for resident. Little waste on street.	Residents must be available to hand waste over. Not suitable for apartment buildings because of the amount of walking required.
Yard collection	Collection labourer enters property to remove waste.	Very convenient for residents. No waste in street.	The most expensive system, because of the walking involved. Cultural beliefs, security considerations or architectural styles may prevent labourers from entering properties.

(Source: http://web.mit.edu/urbanupgrading/upgrading/issues-tools/issues/waste-collection.html#Anchor- Collection-45656).

3.4.1 Organisation of Waste Collection

Table 1 gives a concise description of solid waste collection systems strategy. Organised waste collection systems will normally be found best to have a team composed of an even number of loaders, the usual size being four to eight men. It is only the largest vehicles that can hold all the refuse loaded in one day and, therefore, it will be necessary for the vehicle to travel to the disposal point during the period of collection.

If the haul is a short one, it may be an advantage to allow a break to the loaders; usually however, it will be necessary to arrange for collecting vehicles to work in relay. Where the haul is long and the rate of loading is high, it may be necessary to have two vehicles per team. It should be noted that in modern day applications especially where refuse is stored in central depots, the loading is done mechanically using heavy machinery.

3.4.2 Frequency of Waste Collection

Some communities are accustomed to a collection seven days a week, whilst other collection agencies are striving for just once each week. If fly breeding is to be controlled, the waste should be collected twice a week in hot climates. Other factors to consider are the odours caused by decomposition and the accumulated quantities. If residents are accustomed to daily collection it may not be politically feasible to reduce the frequency to twice a week.

In some cities waste is collected on the day of rest (Sunday or Friday). Some collect waste at night, perhaps for cultural reasons or because of the weather or traffic congestion.

3.4.3 Solid Waste Transport

The collection and transport of solid waste from households or municipal deports are closely tied together. Efficient collection is a function of easy transport systems as indicated above. Different transport systems can be applied for effective solid waste transfer from generation/storage point to the treatment and disposal facilities. At the micro and semi micro level three common types of primary collection vehicles are as follows:

a) The handcart which is pushed by the operator as he walks along

- Very limited capacity in terms of volume and capacity
- Carries 0.25 to 1 cubic metre with a maximum range of 1 km
- Very cheap
- Operated by one person.

b) The pedal tricycle with a tray or box in front of or behind the operator.

- Loads up to 1.5 cu.m
- Range greater because of higher speed when empty
- Lifetime about 2 years
- No negative impact on environment.

c) Animal-drawn cats, often pulled by donkeys

- Common around the world; until recently Cairo Municipality used donkey carts
- Carry up to 1.5 cubic metre and range of up to 7 km
- Cost of feeding and caring for animals added factor
- Negative impact on environment is excreta.

Simple motor-powered vehicles should be considered where longer distances require larger payloads and higher speeds, or where slopes are based on small motorbikes.

A wide variety of trucks are used for collection earlier discussed. Factors to consider in selecting include:

- The weight of waste that the truck can actually carry
- Cost of purchase and operation, including fuel and maintenance
- Delays in obtaining spare parts
- Suitability of the vehicle for the local roads considering width, congestion, and surface conditions
- Ease of loading and unloading.

Efficient waste transport system divides the waste in three lists and sets priorities for each list:

- Green List: free transport (just notification to government) e.g. sorted municipal solid waste
- Orange List: limited transport e.g. unsorted municipal solid waste
- Red List: transport restricted strongly: e.g. hazardous waste.

Products on the green list can be traded freely. Products on the orange and red list are restricted and fall under the principles of proximity and self-sufficiency.

3.5 Disposal of Solid Waste

The final destination of any solid waste is in the disposal facility where it is finally handled and disposed. Most management technologies offer a change in the volume and characteristics of the waste whereas some others serve to hold the waste e.g. burying and landfills. We shall devote unit four and the entire module two to the description of these waste disposal methods and technologies.

4.0 CONCLUSION

The success of any waste management venture depends on the extent to which the planner applies the intricate processes of capturing the waste. The primary handling of the waste from the point source by careful segregation and storage is a first step towards a successful management. Early segregation of waste improves the recovery of resources, minimises cost of handling and environmental insult and increases the overall efficiency of the management process. Sustainable waste management strategy encompasses sound waste storage, collection and transport systems complemented with good treatment and disposal technologies.

5.0 SUMMARY

In this unit, we presented a description of the solid waste management processes starting from the point of solid waste generation, storage, segregation and reuse to waste collection and transport and finally its final disposal in a disposal facility. You have seen that great attention was paid to the capturing and primary storage of waste as well as planned regular collection and transport to the disposal facility. Careful handling of waste in these stages not only saves costs but minimises the environmental abuse and the attendant negative health consequences.

6.0 TUTOR-MARKED ASSIGNMENT

1. Outline the various processes in solid waste management.
2. Discuss the stages of solid waste management process.
3. With a well-labelled diagram describe the features of a standard waste bin.

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UNIT 4 TRADITIONAL (CRUDE) SOLID WASTE DISPOSAL METHODS

CONTENTS

1.0 INTRODUCTION

In the previous units, you were exposed to the processes and stages involved in effective solid waste management in the community and municipal councils. This unit will focus on the description of the traditional and crude methods of solid waste disposal. It will make an interesting reading as we explore our waste management terrain.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- identify various traditional methods of solid waste disposal
- describe the identified traditional waste disposal methods
- outline some advantages and disadvantages of the traditional methods

- recommend appropriate solid waste management method for small communities.

3.0 MAIN CONTENT

3.1 Traditional Solid Waste Disposal Methods

In our earlier discussions of solid waste concept, we noted that the history of waste is closely tied to the varied activities undertaken by man on earth. Hence solid waste disposal has been part of our development and history. What actually have continued to change are the improvements in the techniques and benefits of solid waste management.

The traditional methods of solid waste disposal in most Nigerian communities and cities include but is not limited to the following: - barging into the waters (streams, rivers and sea), open dumping on land, crude or open air burning, feeding of hogs or other animals, burying etc.

3.2 Burial of Solid Waste

This would have been a good method of solid waste disposal as it tends to obey natural process of returning materials especially organic matter content to the soil. However burial can only be applied to smallest quantities of solid waste and even at that it is still cost and labour intensive.

3.2.1 Advantages Burial Method

- It encourages the recycling mineral elements and natural energy resources
- It may increase soil fertility
- It is eco-friendly
- It can be handled at household level
- It does not require skilled labour for operation.

3.2.2 Disadvantages

- It is laborious
- It is not suitable for scale up operations
- It is costly to apply
- It may lead to contamination of land and water resources
- It is not sustainable.

3.3 Open Dumping (Crude Tipping)

This method involves the indiscriminate dumping of solid waste without adequate consideration to their environmental and health effects. Most of the municipal solid waste in developing countries is dumped on land in a more or less uncontrolled manner. Those dumps make very uneconomical use of the available space and often produce unpleasant and hazardous smoke from slow-burning fires.

The present disposal situation is expected to deteriorate even more as, with rapid urbanisation, settlements and housing estates encircle existing dumps and the environmental degradation associated with the dumps directly affects the population. Waste disposal sites are, therefore, also subject to growing opposition, and it is becoming increasingly difficult to find new sites that meet public approval and are located a reasonable distance from the collection area.

3.3.1 Advantages Open Dumping

- It is cheap to operate
- It requires little or no planning
- It does not utilise skilled labour in operation.

3.2.2 Disadvantages

- It produces objectionable odours and it is also unsightly
- It can lead to fire accidents
- It provides ideal breeding places for rats and vermin
- It can lead to fire and physical accident
- It is not sustainable and eco-friendly
- Ground water and run off pollution.

3.4 Dumping into Water Bodies (Barging into the Sea)

This is a method popular in riverine communities but is now in abuse getting popular in unplanned areas of our major cities in the country. Riverine communities with inadequate arable lands use canoes and barges to carry solid waste far into the sea for disposal. However, it is not uncommon to find in Nigerian semi-urban and crowded urban settlements people who dump solid waste directly into small streams as disposal system.

Dumping of solid waste into water bodies is not a good practice as the wastes not only provide nutrients in the water bodies leading to the condition called eutrophication. This causes high oxygen crises for aquatic species and makes the water unsuitable for drinking and other domestic uses.

3.4.1 Advantages Dumping into Water Bodies

- It is almost cost free
- It is a final disposal method as the waste is not amenable to further handling
- It is free of odour nuisance
- It takes care of large volume of solid waste
- It encourages aqua culture when applied to appropriate
- It is convenient to operate.

3.4.2 Disadvantages

- It is a source of water pollution
- It can lead to destruction of aquatic life instead of promoting aqua culture
- It often constitutes grave nuisances as refuse are swept back to the shore either due to wind or water wave action.

3.5 Open Air Burning

This involves the ignition of waste matter in the open from which the products of the combustion are emitted directly into the air without passing through a stack of chimney filter. Open burning can be done in open drums or metal baskets, in fields or yards and in large open sites. Materials commonly disposed of in this manner in some Nigeria cities today includes municipal waste, automobile scrap components, landscape wood, refuse, agricultural field waste, bulky industrial waste, scrap furniture and leaves with other materials raked during street cleaning.

Open burning has been practiced by a number of urban centres because it reduces the volume of refuse received at the dump and therefore extends the life of their dumpsite.

Garbage may be burnt because of the ease and convenience of the method or because of the cheapness of the method. In countries where house holders are required to pay for garbage disposal, burning of waste in the backyard allows the householder to avoid paying the costs associated with collecting, hauling and dumping the waste.

Open burning has many negative effects on both human health and the environment. This uncontrolled burning of garbage releases many pollutants into the atmosphere.

These include dioxins, particulate matter, polycyclic aromatic compounds, volatile organic compounds, carbon monoxide, hexachlorobenzene and ash. All of these chemicals pose serious risks to human health. The dioxins are capable of producing a multitude of health problems; they can have adverse effects on reproduction, development, disrupt the hormonal systems or even cause cancer. The polycyclic aromatic compounds and the hexachlorobenzene are considered to be carcinogenic. The particulate matter can be harmful to persons with respiratory problems such as asthma or bronchitis and carbon monoxide can cause neurological symptoms.

The harmful effects of open burning are also felt by the environment. This process releases acidic gases such as the halo-hydrides; it also may release the oxides of nitrogen and carbon. Nitrogen oxides contribute to acid rain, ozone depletion, smog and global warming. In addition to being a greenhouse gas carbon monoxide reacts with sunlight to produce ozone which can be harmful. The particulate matter creates smoke and haze which contribute to air pollution.

3.5.1 Advantages of Open Air Burning

- Disease pathogens are eliminated in the fire
- It is cheap as it requires less manpower.

3.5.2 Disadvantages

- It may lead to fire accident
- It generates air pollution and may lead to acid rain
- It produces odour nuisance
- Resources are lost in the fire
- Half burnt refuse could afford breeding place for flies and food for rats and other vermin.

3.6 Hog Feeding

This is a method of feeding domestic animals especially pigs with wastes of garbage class. This practice is encouraged as it is in compliance with the principle of integrated waste management. It encourages waste sorting and reuse, energy recycling and serious cost reduction. However it is only most practicable in waste streams composed mainly of garbage and adequately separated at source.

3.6.1 Advantages of Hog Feeding

- It is a source of food to domestic animals
- It saves costs
- It is sustainable and eco-friendly
- It can lend itself to large scale application.

3.6.2 Disadvantages

- It is an intermediate and not final method of solid waste disposal
- It may give rise to nuisances like odour, fly breeding and rodent infestation.
- Scavengers are pre-disposed to diseases like tuberculosis, anthrax and other zoonosis.

4.0 CONCLUSION

Traditional waste management practices are efficient when applied to local situations in small communities with sparse population densities. The methods are however overwhelmed when applied to bulk waste emanating from densely populated urban communities with sophisticated life styles and generating complicated waste profiles. Knowledge and experiences gained in operating the traditional disposal systems may however be a good resource in developing technologies that will help address the challenges of semi urban and urban waste management.

5.0 SUMMARY

In this unit, you were able to identify various methods of traditional waste management. These traditional waste management systems which include earth burial, open dumping, deposition in large water bodies, use as feed for animals, open air burning and earth burial. You also learnt traditional waste disposal systems including their advantages and disadvantages. In any case, no matter how numerous their advantages and how convincing they sound, their disadvantages outweigh them especially when measured against the backdrop of environmental effects and public health concerns.

6.0 TUTOR-MARKED ASSIGNMENT

1 Enumerate five traditional methods of solid waste disposal.
2 Describe any two traditional waste disposal methods.
3 Outline the advantages and disadvantages of barging into the sea.

4 Which traditional method of solid waste management is suitable for a small upland community of about 1000 inhabitants?

5 State any five reasons for your choice of method.

7.0 REFERENCES/FURTHER READING

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MODULE 2

UNIT 1 SANITARY LANDFILL

CONTENTS

1.0 INTRODUCTION

In unit four, you were given a refresher course on the traditional (crude) methods of solid waste management in our rural, semi-urban and some of our urban communities and local councils, thus capping up our study plan for module one which we devoted to preliminary description of the concept of solid waste and solid waste management.

Why were the methods described in unit four above referred to as crude? What will be the improvements in the conventional methods we are going to discuss in subsequent units of this module? Find out as we start with discussion of sanitary landfill.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define sanitary landfill
- outline the basic requirements of sanitary landfill

- describe the processes involved in landfill site operations
- state the advantages and disadvantages of sanitary landfill.

3.0 MAIN CONTENT

3.1 What is Sanitary Landfill?

Sanitary landfill also known as controlled tipping is the practice of waste disposal in which waste is stacked to decay under controlled conditions. *Wikipedia Encyclopedia* defines it as a site for the disposal of waste materials by burial. Historically, landfills have been the most common methods of organised waste disposal and remain so in many places around the world. Some landfills are also used for waste management purposes, such as the temporary storage, consolidation and transfer, or processing of waste material (sorting, treatment, or recycling).

(a) Landfill Site in Poland

Landfills are sites where waste is isolated from the environment until it is safe. It is considered safe, when it has completely degraded biologically, chemically and physically. Four basic conditions should be met before a site can be regarded as a sanitary landfill. The ways of doing this should be adapted to local conditions. The immediate goal is to meet, to the best extent possible, the four stated basic sanitary landfill conditions, with a longer term goal to meet them eventually in full. Figures 1.1 (A, B, C): Landfill Sites in Poland, Ontario and Perth.

(b) A Section of a Landfill Located in Barclay, Ontario

(c) Landfill Site in Perth Western Australia
Source: http://en.wikipedia.org/wiki/Landfill

3.2 Basic Requirements of Sanitary Landfill

As a minimum, four basic conditions should be met by any site design and operation before it can be regarded as a sanitary landfill:

i. Full or partial hydro geological isolation: if a site cannot be located on land which naturally contains leachate security, additional lining materials should be brought to the site to reduce leakage from the base of the site (leachate and help reduce contamination of groundwater and surrounding soil. If a liner - soil or synthetic - is provided without a system of leachate collection all leachate will eventually reach the surrounding environment. Leachate collection and treatment must be stressed as a basic requirement.

ii. Formal engineering preparations: designs should be developed from local geological and hydro geological investigations. A waste disposal plan and a final restoration plan should also be developed.

iii. Permanent Control: trained staff should be based at the landfill to supervise site preparation and construction, the depositing of waste and the regular operation and maintenance.

iv. Planned waste emplacement and covering: waste should be spread in layers and compacted. A small working area which is covered daily helps make the waste less accessible to pests and vermin.

3.3 Components of a Landfill

The main components of any secured, permitted landfill are:

a. Bottom Liner:- The bottom liner separates and prevents the buried waste from coming in contact with underlying natural soils and groundwater. In municipal solid waste landfills, the bottom liners are generally constructed using some type of durable, puncture-resistant synthetic plastic HDPE (high density polyethylene) ranging from 30 to 100 mils thick. The plastic liners may also be designed with a combination of compacted clay soils, along with synthetic plastic.

b. Cells (old and new):- This is the area in a landfill that has been constructed and approve for disposal of waste. These cells range in size (depending upon total tons of waste received each day at the landfill) from a few acres to as large as 20+ acres. Inside these larger cells are smaller cells known as the daily workface, or sometimes referred to as cells. This is where the waste coming into the landfill for disposal that day is prepared by placing the material in layers or lifts where the waste is then compacted and shredded by heavy landfill compaction machinery.

c. Leach ate collection system:- The bottom of each landfill is typically designed so that the bottom surface of the landfill is sloped to a low point, called a sump. This is where any liquids that are trapped inside the landfill — known in the waste industry as leach ate — are collected and removed from the landfill. The leach ate collection system typically consists of a series of perforated pipes, gravel packs and a layer of sand or gravel placed in the bottom of the landfill. once the leach ate is removed from the sump, it is typically pumped or gravity-flowed to a holding tank or pond, where it is either treated on site or hauled off site to a public or private wastewater treatment facility.

d. Storm Water Drainage: - This is an engineered system designed to control water runoff during rain or storm events. This is done by directing the runoff through a series of berms or ditches to holding areas known as seed ponds. In these ponds the runoff water flow is slowed down or held long enough to allow the suspended soil particles to settle out before the water is discharged off site.

e. Methane Collection System:- Bacteria in the landfill break down the trash in the absence of oxygen. This process produces landfill gas, which is approximately 50 percent methane. Since methane gas has the potential to burn or explode, it has to be removed from the landfill. To do this, a series of pipes are embedded within the landfill to collect the methane gas. This gas, once collected, can be either naturally vented or control-burned.

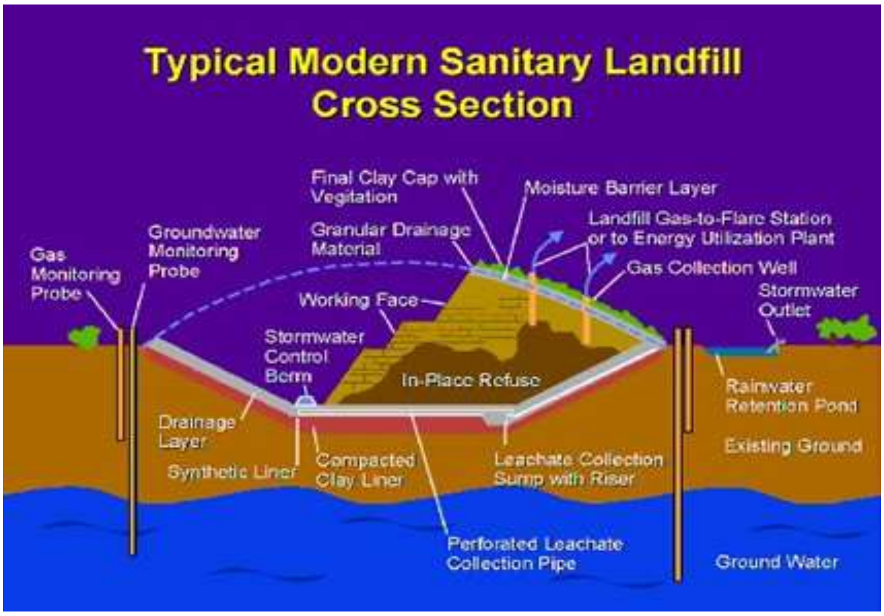

Fig. 1.2a: Cross Section of a Typical Landfill Operation

Source:http://armypubs.army.mil/eng/DR_pubs/DR_a/pdf/tm5_814_5.pdf

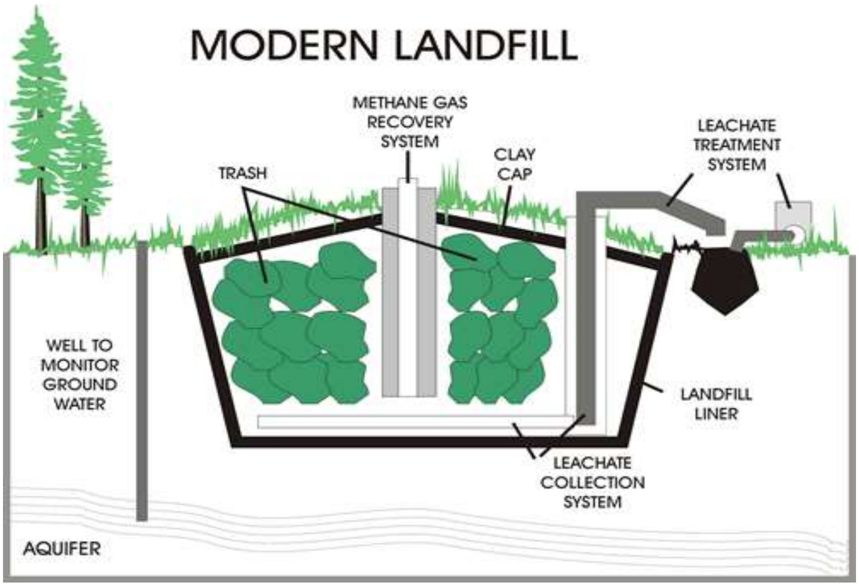

Fig. 1.2b: Main Features of a Modern Landfill

Source:http://www.eia.doe.gov/kids/energyfacts/saving/recycling/solidwaste/landfiller.html

f. Cover (or Cap):- Waste that is placed in a cell is required to be covered daily with either six inches of compacted soil or an alternative daily cover. Some examples of alternative daily covers are the application of spray-on cover material, such as foam or a flame-retardant fiber material. Another type of alternative daily cover is large panels of tarpaulin-type material that is laid over the waste at the end of each day and removed the next day before waste is placed. Other areas within the cells that are not to final grade and will not receive placement of additional waste for a period of time may require additional cover. This is known as intermediate cover — generally 12 to 18 inches of soil. Covering (or capping) is performed in order to isolate the waste from exposure to the air, pests (such as birds, rats and mice) and to control odours. When a section of the landfill is finished or filled to capacity, it is permanently covered with a combination of a layer of polyethylene plastic, compacted soil and a layer of topsoil that will support growth of vegetation to prevent erosion.

g. Groundwater Monitoring Stations: - Stations are set up to directly access and test the groundwater around the landfill for presence of leachate chemicals. Typically a groundwater monitoring system will have a series of wells that are located up-gradient of the landfill disposal area and a series of wells down-gradient. The up-gradient wells test the water quality before it moves under the disposal area in order to get a background analysis of the water. The down-gradient wells then allow testing of the water after it has passed under the disposal area so it can be compared to the quality of the up-gradient wells to make sure there has been no impact or contamination of the groundwater

3.4 Landfill Operation

Typically, in non-hazardous landfills, in order to meet predefined specifications, techniques are applied by which the wastes are:

- Confined to as small an area as possible
- Compacted to reduce their volume
- Covered (usually daily) with layers of soil.

During landfill operations the waste collection vehicles are weighed at a weighbridge on arrival and their load is inspected for wastes that do not accord with the landfill's waste acceptance criteria. Afterward, the waste collection vehicles use the existing road network on their way to the tipping face or working front where they unload their contents. After loads are deposited, compactors or bulldozers are used to spread and compact the waste on the working face. Before leaving the landfill boundaries, the waste collection vehicles pass through a wheel cleaning facility. If necessary, they return to the weighbridge in order to be weighed without their load. Through the weighing process, the daily incoming waste tonnage can be calculated and listed in databases. In addition to trucks, some landfills may be equipped to handle railroad containers. The use of 'rail-haul' permits landfills to be located at more remote sites, without the problems associated with many truck trips.

Typically, in the working face, the compacted waste is covered with soil or alternative materials daily. Alternative waste-cover materials are chipped wood or other "green waste"[, several sprayed-on foam products, chemically 'fixed' bio-solids and temporary blankets. Blankets can be lifted into place at night then removed the following day prior to waste placement. The space that is occupied daily by the compacted waste and the cover material is called a daily cell. Waste compaction is critical to extending the life of the landfill. Factors such as waste compressibility, waste layer thickness and the number of passes of the compactor over the waste affect the waste densities. Note that the area being filled is a single, well-defined "cell" and that a rubberized landfill liner is in place (exposed on the left) to prevent contamination by leachates migrating downward through the underlying geological formation.

The decomposition which takes place within the tip is similar to the septic breakdown of sewage and to the action of composting. Anaerobic biolysis occurs accompanied by a rise in temperature; the maximum temperature may be expected within 14 days and may reach 160 ^{0}F (71

^{0}C). After three or four months, the temperature will have dropped to atmospheric and the content of the tip will be inert. The high temperature ensures the destruction of pathogens.

It is most desirable to prevent the access of flies to landfill operations. Usually, the temporal cover will be sufficient to prevent ovipositor by the female fly; there is danger, however, that housefly eggs or larvae may have been brought to the site in the refuse and it had been shown that a newly hatched fly can wriggle through four feet of earth. A temperature of 140 ^{0}F (60 ^{0}C) and above during their larval stage of 3 – 5 days will be sufficient to destroy them. The temporary seal should be sufficient to render the tip unattractive to vermin, which may however, gain access with the refuse.

3.5 Advantages and Disadvantages of Sanitary Landfill

3.5.1 Advantages

Sanitary landfills when properly sited and operated:

- Do not pollute the ground water
- Checks fly breading and infestation by rodents and vermin
- Prevents unsightliness and odour nuisances
- Is a source of useful energy like methane gas
- Yields manure for agricultural purposes
- Provides employment for numerous operators
- Is a big business for investors
- Useful in waste land reclamation.

3.5.2 Disadvantages

Apart from the prohibitive initial capital outlay and the large expanse of land taken up by landfill sites, a large number of adverse impacts may occur from landfill operations. Damage occurrence can include:

- Infrastructure (e.g., damage to access roads by heavy vehicles)
- Pollution of the local environment (such as contamination of groundwater and/or aquifers by leakage or sinkholes and residual soil contamination during landfill usage, as well as after landfill closure)
- Off gassing of methane generated by decaying organic wastes (methane is a greenhouse gas many times more potent than carbon dioxide, and can itself be a danger to inhabitants of an area)

- Harboring of disease vectors such as rats and flies, particularly from improperly operated landfills, which are common in developing countries
- Injuries to wildlife
- And simple nuisance problems (e.g., dust, odour, vermin, or noise pollution).

This list is growing steadily as time passes.

4.0 CONCLUSION

Sanitary landfill was originally meant to be the last destination of waste materials. As such, by the year 2000, more than 50 per cent of all waste generated nationally in developed countries ended up in landfills. The continuing development of more stringent requirements for landfills is making this ultimate disposal option less environmentally offensive, but more costly. The increasing ability to recover methane from landfills is providing a positive use for what has historically been a non-valued disposal method. Bioreactor landfill technology has the potential to further reduce the environmental impact of landfills and maximise methane recovery from these systems

5.0 SUMMARY

In this unit, you have learnt about one of the modern waste management technologies – the sanitary landfill. This technology use to be an advancement or improvement of the traditional burial of solid waste which allow bulk and varied waste sorts to be handled.

You have seen that when properly sited, engineered and operated, sanitary landfill not only serve for the disposal of community or municipal solid waste but is a source of income for investors, provides job for numerous workers and above all provides a good resource for the generation of energy and recovery of other reclaimable materials.

However, under sub optimal operational conditions, its operation may lend itself to environmental problems like air and ground water pollution, damage of infrastructure like access road and common nuisances like odour, fly and rodent infestation etc. Also, the initial capital outlay for construction is a disadvantage.

6.0 TUTOR-MARKED ASSIGNMENT

1 Define the term ‘sanitary landfill’.
2 Outline the basic requirements of sanitary landfill.

3 Describe the processes involved in landfill site operations.
4 State the advantages and disadvantages of sanitary landfill.

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UNIT 2 INCINERATION

CONTENTS

1.0 INTRODUCTION

In unit 1, you were taken through the discussion of sanitary landfill as a method of final waste disposal. The method involved compacting waste for long time storage underground leading to waste transformation into harmless organic and mineral resources which on the long run may become source of wealth as is already being explored in technology advanced countries.

In this unit, we will describe and discuss incineration as another good technology that can be favorably applied in the management of solid waste. This time the waste is not stored but burnt under controlled conditions to recover energy, remove contamination and reduce bulk.

What is the difference between open burning of waste and incineration? What type of solid waste can be incinerated? Find out these and more as you go through this unit. Happy reading!

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define incineration

- describe the incineration process
- outline various types of incinerators
- describe general features of incinerators
- argue in favour or against incineration.

3.0 MAIN CONTENT

3.1 Incineration

Incineration is the process of destroying waste materials by burning it within the temperature range of 900^0C – 1200^0C. This is a controlled combustion process for burning solid combustible wastes to gases and residue containing little or no combustible material when properly carried out. It is a volume reduction process.

When incineration is operated correctly, it reduces the waste bulk by 90%. This reduction depends upon the recovery degree and composition of materials. This means that incineration however, does not replace the need for land filling but it reduced the amount to be thrown in it. The ash will be safe to use for filling low areas of land (such as erosion site).

It is recognised as a practical way of disposing hazardous waste materials such as biological medical waste.

In the past, incineration was conducted without separating materials thus causing harm to environment. This un-separated waste was not free from bulky and recyclable materials, even. This resulted in risk for plant workers health and environment. Most of such plants and incinerations never generate electricity.

Incineration comes with a number of benefits in specific areas like medical wastes and other life risking waste. In this process, toxins are destroyed when waste is treated with high temperature.

Though incineration is still widely used in many areas (developing countries especially) it is a waste management tool that is becoming controversial for several reasons.

It destroys not only the raw materials, but also all the energy, water, and other natural resources used to produce it. Some energy can be reclaimed as electricity by using the combustion to create steam to drive an electric generator.

3.2 Incineration Process

Before waste products are subjected to incineration, it is good to have such wastes sorted in the first place. Thus readily combustible materials especially dry ones will burn faster and generate fine ash whereas wet bulky materials may require being pretreated or they take longer period and energy to burn. Some recommended steps for handling incinerators include the following:

a. The incinerator must be fully heated up before wastes are added, requiring about 30 min or longer, depending on ambient temperature, type of fuel, fuel moisture content, etc. however, most of the 14 small-scale units surveyed in Kenya (Taylor, 2003) were not being operated in this fashion, rather, safety boxes were loaded prior to lighting

b. Firewood must have a low moisture content (<15%)
c. Temperature monitors when not used, there will be no indication that suitable temperature have been reached. (Grey or black smoke indicates poor combustion and low temperatures)
d. Manual operation requires the constant presence of an operator when burning waste Dry fuels must be added every 5 – 10 min
e. Flame must not be extinguished during burnings
f. Grates must be regularly checked and raked to keep clear.

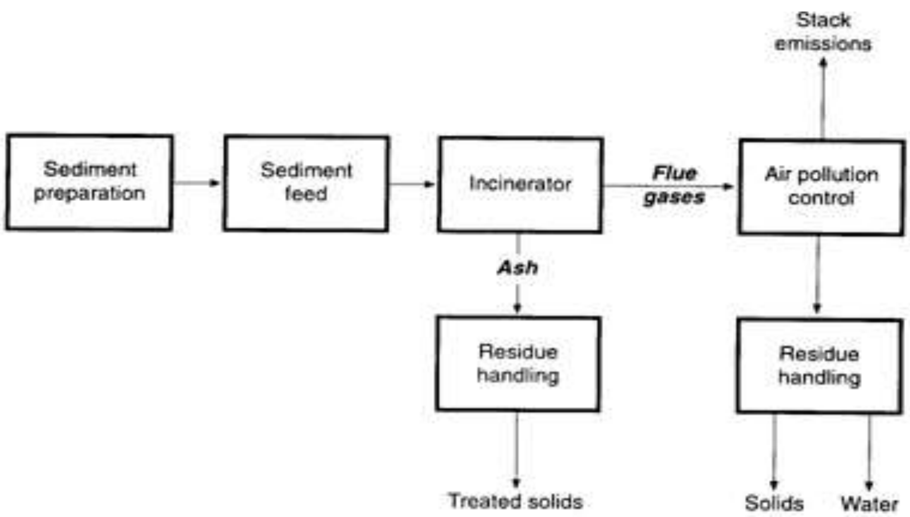

Fig. 2.1: Diagram of an Incineration Process.
Source:http://www.epa.gov/greatlakes/arcs/EPA-905-B94-003/gifs/fig7-1.gif

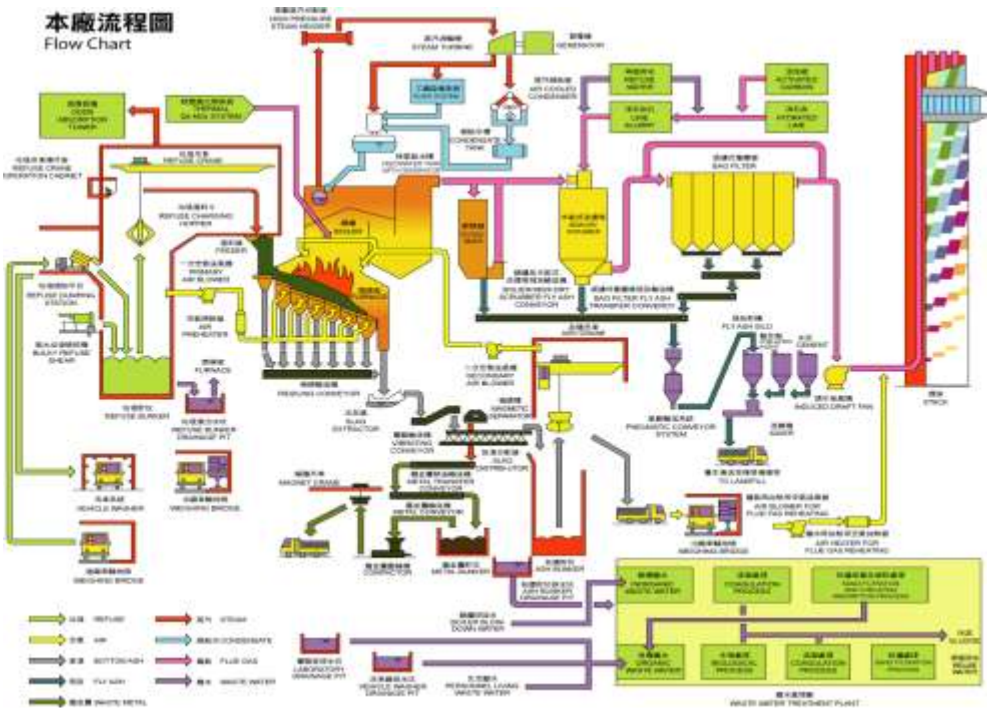

Fig. 2.2: Incineration Process Flowchart (Beitou Refuse Incineration Plant)

Source: http://english.dep.taipei.gov.tw/ct.asp?xItem=204464&ctNode

Table 2.1: Description of Incineration Flow Chart

Our Process Includes	
1.	Garbage receiving and treatment procedures, including: entrance odometer, dumping platform, garbage bunker, garbage crane, ash bunker, ash crane, burning chamber, hearth system, etc.
2.	Combustion air procedures, including: primary and secondary air blower, air preheated, air reheater, etc.
3.	Bottom slag procedures, including: each bottom slag conveyor, ash ejector, vibration conveyor, etc.
4.	Fly ash procedures, including: fly ash conveyor, pneumatic conveying system, fly ash storage tank, fly ash stabiliser, etc.
5.	Waste metal procedures, including: magnetic selector, waste metal conveyor, waste metal bunker, waste metal compressor, waste metal crane, etc.
6.	Steam procedures, including: high pressure steam distributor, steam turbine, power generator, steam condenser, etc.
7.	Condensed water procedures, including: condensed water recycling equipment, such as condensed water tank, degassing & water feeding tank, etc.
8.	Waste gas treatment procedures, including: dioxin prevention equipment, nitrogen oxide removal equipment, semi-dry scrubber,

	bag filter dust collector, attraction exhaust fan, etc.
9.	Wastewater procedures, including: inorganic wastewater treatment system, organic wastewater treatment system, sludge production system, etc.

Source: http://english.dep.taipei.gov.tw/ct.asp?xItem=204464&ctNode

3.3 Incinerators and their Types

Incinerator can be understood more precisely as a furnace where waste is burnt. Modern incinerators are equipped with pollution improvement systems, which play their part in cleaning up the flue gas and such toxicants. The following are the types of plants for burning waste.

3.3.1 Moving Grate

The incineration plant used for treating MSW is moving grate. This grate is capable for hauling waste from combustion chamber to give way for complete and effective combustion. A single such plant is capable for taking in thirty-five metric ton of waste every hour for treatment.

Moving grates are more precisely known as incinerators of municipal solid waste. This waste is poured in the grate with a help of crane from and opening or throat. From here, the waste has to move towards the ash pit. Waste is further treated and water locks wash out ash from it. Air is then flown through the waste and this blown air works for cooling down the grate. Some of grates are cooled with help of water.

Air is blown through the boiler for another time but this time comparatively faster than before. This air helps in complete burning of the flue gases with the introduction of turmoil leading to better mixing and excess of oxygen. In some grates, the combustion air at fast speed is blown in separate chamber.

3.3.2 Fixed Grate

This was the fixed and much older version for grate. This kind generally is lined with the brick while lower or ash pit is made up of metal. This grate generally has an opening at the top and for loading purpose; a side of the grate is left open. A number of fixed grate were first formed in houses, which today are replaced by waste compactors.

3.3.3 Rotary-kiln

Industries and municipalities generally use this sort of incinerator. This incinerator consists of two chambers i.e. primary and secondary chamber.

3.3.4 Fluidised Bed

In this sort of incineration, air is blown at high speed over a sand bed. The air gets going through the bed when a point come where sand granules separates and let air pass through them and here comes the part of mixing and churning. Therefore, a fluidised bed comes in to being and fuel and waste are then can be introduced. The sand along with the pretreated fuel or waste is kept suspended and is pumped through the air currents. The bed is thus mixed violently and is uptight while small inert particles are kept suspended in air in form of fluid like form. This let the volume of the waste, sand and fuel to be circulated throughout the furnace, completely.

3.4 Desirable Features of Incinerators

Incinerators are designed to efficiently and safely burn waste at specified rates and temperatures, with the residual ash containing no combustible material.

i. Air and fuel are mixed in correct proportion
ii. Regulated combustion air
iii. Minimum exhaust gas residence time 1-2 seconds in the secondary chamber
iv. Proper residence time to obtain a complete burn out
v. Provide for creating turbulence in combustion chamber
vi. High temperature and chemical resistant refractory lining
vii. Satisfy and exceed pollution control norms.

Fig. 2.3 (a) and (b): Incinerators (Without and With Roof Covers)
Source:http://www.who.int/water_sanitation_health/medicalwaste/en/sm incinerators3.pdf

3.5 A Debate over Incineration

Usage of incineration is for waste management is divisive. The debate for incinerators generally involves business interests, regulations of government, activists if environment and citizens.

3.5.1 Arguments supporting incinerations

- The first concern for incineration stands against its injurious effects over health due to production of furans and dioxin emission. However, the emission is controlled to greater extent by developing of modern plants and governmental regulations

- Incineration plants are capable for producing energy and can substitute power generation plants of other sort
- The bottom ash after the process is completed is considered non-injurious that still is capable for being land filled and recycled
- Fine particles are removable by processing through filters and scrubbers
- Treating and processing medical and sewage waste produces non-injurious ash as product.

3.5.2 Arguments against Incinerations

- Extremely injurious matter needs adequate disposing off. This requires additional miles and need special locations for land filling this material
- Although after a lot of regulations and restrictions and developments concerns are still alive about emission of furans and dioxins
- Incinerating plants are producers of heavy metals, which are injurious even in minor amounts
- IBA is consistent over a considerably high level of heavy metals and can prove fatal if they are not disposed off or reused properly
- Initial investment costs are only recovered through long periods of contract for incinerating plants
- Local communities always have opposed the presence of incinerating plant in the locality
- The upheld view is to recycle, reuse and waste reduction instead of incineration.

4.0 CONCLUSION

Incineration is the combustion of waste in the presence of oxygen. After incineration, the wastes are converted to carbon dioxide, water vapour and ash. This method may be used as a means of recovering energy to be used in heating or the supply of electricity. In addition to supplying energy, incineration technologies have the advantage of reducing the volume of the waste, rendering it harmless, reducing transportation costs and reducing the production of the greenhouse gas methane.

5.0 SUMMARY

In this unit, you were able to learn how to describe incineration as a method of treatment of solid waste. You have also seen that incineration lays itself applicable in handling different waste types. That is, there are many types of incinerators which can be applied according to the size and complexity of the waste type. Incineration reduces waste volume and eliminates hazardous components of wastes especially microorganisms and if properly sited and operated is suitable for small scale as well as municipal waste processing. However, if not suitably sited and operated, it may contribute greatly to pollution of the environment.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define the term “incineration”.
2. State the advantages of incineration of waste.
3. Enumerate the general features of the incinerator.
4. Describe the incineration process.

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UNIT 3 COMPOSTING

CONTENTS

1.0 INTRODUCTION

In unit 1, you were able to look at incineration as solid waste management technology which involves the use of controlled burning to dispose solid waste. In this unit, we shall discuss composting as a solid waste management technology.

You will find out that whereas incineration destroys both waste and flora, composting benefits from the presence of microorganisms and worms, particularly earthworms to transform organic solid waste materials to manure for further benefit to farmers. We shall adopt a practical oriented approach in describing this most eco-friendly solid waste management technology. Enjoy your reading!

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define composting
- list various techniques of composting
- describe the composting process
- state the advantages of composting.

3.0 MAIN CONTENT

3.1 INTRODUCTION

Composting is one of the options for treatment of solid waste. In composting process the organic matter breaks down under bacterial action resulting in the formation of humus like material called compost.

The value of compost as manure depends on the quantity and quality of feed materials poured into the compost pit. Composting is carried out in two ways:

- Aerobically (in presence of oxygen) and
- Anaerobic ally (in absence of oxygen).

During aerobic composting, aerobic micro – organisms oxidises organic compounds in the solid waste to carbon dioxide, nitrite and nitrate. The carbon from organic compounds is used as a source of energy while nitrogen is recycled. Due to exothermic reactions, temperature of the mass rises.

During anaerobic process, the anaerobic micro-organisms, while metabolising the nutrients, break down the organic compounds through a process of reduction. A very small amount of energy is released during the process and the temperature of the composting mass does not raise much. The gases evolved are mainly methane and carbon dioxide. An anaerobic process is a reduction process and the final product is subjected to some minor oxidations when applied to land.

Manure from composting gives better yield to a farmer and it is also environment friendly. Biodegradable solid waste can be composted either in compost pit or in a Vermi compost pit. Compost pit can be underground unlined compost pit or over-ground compost – heap method or over-ground brick line compost pit. Vermi compost can be done in Vermi tank (four pit model) or Vermi-compost in sheds. Composting of bio degradable solid waste can take place in biogas plants also. Slurry from the biogas plant can also be utilised for production of Vermi compost.

3.2 Composting (Manure Pit)

3.2.1 Description

Composting is carried out in a simple manure pit or garbage pit (lined or unlined). in this process aerobic microorganisms oxidise organic compounds to carbon- dioxide and oxides of nitrogen and carbon from organic compounds is used as a source of energy, while nitrogen is recycled. As discussed above, in the composting process, due to exothermic reactions, temperature of mass rises. In areas/regions with higher rainfall composting in over ground heaps is advisable. The factors affecting the composting process are: (a) micro-organisms; (b) moisture, (c) temperature and (d) carbon/ nitrogen (C/N) ratio.

3.2.2 Household Level Composting

At each household, two manure pits should be dug. The size of the pit will depend upon the quantity of refuse to be disposed of per day. Each day the garbage, cattle dung, straw, plant and agriculture wastes are dumped into the manure pit. When one pit is closed the other one is used. In 5 to 6 months time, the refuse is converted into manure, which can be used in the fields. This is the most effective and simplest method of disposal of waste for the rural households. Cow dung can also be disposed of easily by this method. Mixing of cow dung slurry with the garbage will help greatly in converting the refuse into compost, which provides good manure.

Household level composting pits may be constructed by adopting either lined or unlined pits as described below:

3.2.2.1 Underground Unlined Manure Pit or Garbage Pit

Applicability

- Rural areas with low rainfall
- Houses with an open space of about 7 square m
- Houses with no cattle or with single cattle.

Action

House owner can make this pit with little technical know how
Description

- Dig two pits of 1m x 1m x 1m dimension
- Give a single layer of broken bricks at the bottom
- Make a ridge with the help of mud at the periphery of the pit & compact it by light ramming.

Use and Maintenance of the Pit

- Go on adding garbage from the house over the layer of bricks (only biodegradable type)
- When the garbage attains a height of about 150 mm, add dung slurry, mix it with garbage & level it
- Spread a very thin layer of soil over it (once a week) to avoid odour and fly nuisance
- Continue to add garbage everyday
- Follow the above procedure & repeat the layers till the pit is full. It is recommended to fill the pit up to about 300 mm above ground level
- After 3-4 days the garbage above ground settles down
- Plaster it with soil
- Leave the pit as it is for 3-6 months for maturation
- After 3-6 months take out the compost & use it in the fields
- Till the manure in the pit matures, use another pit of the same dimensions, dug at a minimum distance of 1 m from the first pit.

Limitations

Not suitable for heavy rainfall areas and rocky terrain.

3.2.2.2 Underground Brick Lined Manure Pit or Garbage Pit

Applicability

- Rural areas with low rainfall
- Houses with an open space of about 7 square m
- Houses with no cattle or with a single cattle
- Loose soil structure.

Action

House owner can make this pit with little technical know how

Description

- Dig two pits of 1.1 m diameter and 1m depth

- Construct a circular pit having an inner diameter of 1 m, in honey comb 100 mm thick brick masonry. The height of the circular pit should be 100 mm above ground
- Plaster the top layer of the pit
- The bottom of the pit should not be cemented.

Use and Maintenance of the Pit

- Go on adding garbage from the house over the layer of bricks (only biodegradable type)
- When the garbage attains a height of about 150 mm, add dung slurry, mix it with garbage & level it
- Spread a very thin layer of soil over it (once a week) to avoid odour & fly nuisance
- Continue to add garbage everyday
- Follow the above procedure & repeat the layers till the pit is full. It is recommended to fill the pit up to about 300 mm above ground level
- After 3-4 days, the garbage above ground settles down
- Plaster it with soil
- Leave the pit as it is for 3-6 months for maturation
- After 3-6 months take out the compost & use it in the fields
- Till the manure in the pit matures, use another pit of the same dimensions, dug at a minimum distance of 1 m from the first pit.

Limitations

Not suitable for heavy rainfall areas and rocky terrain.

3.2.2.3 Over Ground Heap

Applicability

- Rural areas with high rainfall and rocky terrain
- Houses with an open space of about 7 square m
- Houses with no cattle or with single cattle.

Action

House owner can make this heap with little technical know-how.

Description

Make a raised platform of 1 x 1m dimension at a suitable site by ramming the soil or by paving with bricks.

Use and Maintenance of the Heap

- Go on adding garbage from the house over the platform (only biodegradable type)
- When the garbage attains a height of about 150 mm, add dung slurry, mix it with garbage
- Spread a very thin layer of soil over it (once a week) to avoid odour and fly nuisance
- Continue to add garbage everyday
- Follow the above procedure & repeat the layers till the heap attains the height of 1m.
- After 3-4 days the garbage above ground settles down
- Plaster it with soil
- Leave the heap as it is for 3-6 months for maturation
- After 3-6 months take out the compost & use it in the fields
- Till the manure in the heap matures, make another heap of the same dimensions at a minimum distance of 1 m from the first heap.

3.2.2.4 Over Ground Brick Lined Compost Tank

Applicability

- Rural areas with high rainfall and rocky terrain
- Houses with an open space of about 7 square m
- Houses with no cattle or with single cattle.

Action

House owner can make this with little technical knowhow.

Description

- Make two compost tanks of 1.1 m diameter and 1m height
- Construct a circular /square tank having an inner dimension of 1 m, in honey comb 225 mm thick brick masonry. The height of the tank should be 0.8 m above ground
- Plaster the top layer of the tank.

Use and Maintenance of the Tank

- Go on adding garbage from the house over the platform in the tank (only biodegradable type)
- When the garbage attains a height of about 150 mm, add dung slurry, mix it with garbage

- Spread a very thin layer of soil over it (once a week) to avoid odour and fly nuisance
- Continue to add garbage everyday
- Follow the above procedure and repeat the layers till the heap attains the height of 1m.
- After 3-4 days the garbage above ground settles down
- Plaster it with soil
- Leave the heap as it is for 3-6 months for maturation
- After 3-6 months take out the compost and use it in the fields
- Till the manure in the tank matures, make another tank of the same dimensions at a minimum distance of 1 m from the first tank.

3.2.3 Community Level Composting

Community level composting may be resorted to when management of solid waste at household level is not possible. For community level composting, the waste managers should select a suitable site as compost yard for the village. Site should be selected taking into consideration wind flow direction, so that the inhabited areas don’t get any foul odour. The site should be easily accessible for transportation of waste and manure. It should not be a low lying area to avoid water logging.

Size of the Pit- Depth of the pit should not be more than 1 meter and width should not exceed 1.5 meter. Length of the pit may go up to 3 meter. In the pit, waste takes about 4-6 months to compost. Hence, adequate number of pits will be required. Distance between two pits should be more than 1.5 meter. While digging pits, adequate care should be taken to ensure that there is adequate facility to transport the garbage and store the manure.

3.2.3.1 Underground Unlined Manure Pit or Garbage Pit

Applicability

- Rural areas with low rainfall
- Villages where there is lack of space at household level for composting.

Description

- Dig adequate number of pits of not more than 1m (depth)x 1.5m (width) x 3m (length) dimension depending upon quantum of garbage generated

- Make a ridge with the help of soil at the periphery of the pit & compact it by light ramming.

Use and Maintenance of the Pits

- Go on adding collected garbage in the pits (only biodegradable type)
- Wherever possible, it is advisable to add cow dung slurry to the garbage to enhance the composting process
- Spread a very thin layer of soil over it (once a week) to avoid odour and fly nuisance
- Continue to add garbage everyday
- Follow the above procedure & repeat the layers till the pit is full. It is recommended to fill the pit up to about 300 mm above ground level
- After 3-4 days the garbage above ground settles down
- Plaster it with soil
- Leave the pit as it is for 3-6 months for maturation and start other pits sequentially
- After 3-6 months take out the compost & use it in the fields.

Limitations

Not suitable for heavy rainfall areas and rocky terrain.

3.2.3.2 Underground Brick Lined Manure Pit or Garbage Pit

Applicability

- Rural areas with low rainfall
- Villages where there is lack of space at household level for composting.

Description

- Dig adequate number of pits of not more than 1m (depth)x 1.5m (width) x 3m (length) dimension depending upon quantum of garbage generated
- Construct rectangular pits having inner dimensions of 1m x 1.5 m x 3m in honey comb 225 mm thick brick masonry. The height of the pit should be 100 mm above ground.
- Plaster the top layer of the pit
- The bottom of the pit should not be cemented.

Use and Maintenance of the Pit

- Go on adding collected garbage from the houses in the pits (only biodegradable type)
- Wherever possible, it is advisable to add cow dung slurry to the garbage to enhance the composting process
- Spread a very thin layer of soil over it (once a week) to avoid odour and fly nuisance
- Continue to add garbage everyday
- Follow the above procedure & repeat the layers till the pit is full. It is recommended to fill the pit up to about 300 mm above ground level
- After 3-4 days the garbage above ground settles down
- Plaster it with soil
- Leave the pit as it is for 3-6 months for maturation and start other pits sequentially
- After 3-6 months take out the compost & use it in the fields.

Limitations

- Not suitable for heavy rainfall areas and rocky terrain.
- Capital intensive option.

3.2.3.3 Over- Ground Heap

Applicability

- Rural areas with high rainfall and rocky terrain
- Villages where there is lack of space at household level for composting.

Description

Make a raised platform of 1.5m x 3m dimension at a suitable site by ramming the soil or by paving with bricks.

Use and Maintenance of the Heap

- Go on adding garbage collected from the houses over the platform (only biodegradable type)
- Wherever possible, it is advisable to add cow dung slurry to the garbage to enhance the composting process
- Spread a very thin layer of soil over it (once a week) to avoid odour & fly nuisance
- Continue to add garbage everyday

- The heaps should be sprinkled with water periodically to maintain the moisture level
- Follow the above procedure & repeat the layers till the heap attains the height of 0.8m.
- After 3-4 days the garbage above ground settles down
- Plaster it with soil
- Leave the heap as it is for 3-6 months for maturation and start another heap
- After 3-6 months take out the compost & use it in the fields
- Till the manure in the heap matures, make another heap of the same dimensions at a minimum distance of 1 m from the first heap.

3.2.3.4 Over-ground Brick Lined Compost Tank

Applicability

- Rural areas with high rainfall and rocky terrain
- Villages where there is lack of space at household level for composting.

Description

- Make adequate number of compost tanks of dimension 0.8 m height, 1.5 m width and 3 m length in honey comb 225 mm thick brick masonry.
- Plaster the top layer of the tank.

Use and Maintenance of the Tank

- Go on adding collected garbage from the houses in the tank (only biodegradable type)
- Wherever possible, it is advisable to add cow dung slurry to the garbage to enhance the composting process
- Spread a very thin (1-2 inch) layer of soil over it (once a week) to avoid odour and fly nuisance
- Continue to add garbage everyday
- Follow the above procedure & repeat the layers till the heap attains the height of 1m.
- After 3-4 days the garbage above ground settles down
- Plaster it with soil
- Leave the heap as it is for 3-6 months for maturation
- After 3-6 months take out the compost & use it in the fields

- Till the manure in the tank matures, make another tank of the same dimensions at a minimum distance of 1 m from the first tank.

3.3 Vermi Composting

3.3.1 Overview

Vermi composting involves the stabilisation of organic solid waste through earthworm consumption which converts the material into worm castings. Vermi composting is the result of combined activity of microorganisms and earthworms. Microbial decomposition of biodegradable organic matter occurs through extracellular enzymatic activities (primary decomposition) whereas decomposition in earthworm occurs in alimentary tract by microorganisms inhabiting the gut (secondary decomposition).

Microbes such as fungi, actinomycetes, protozoa etc. are reported to inhabit the gut of earthworms. Ingested feed substrates are subjected to grinding in the interior part of the worms gut (gizzard) resulting in particle size reduction.

Vermitechnology, a tripartite system which involves biomass, microbes and earthworms is influenced by the biotic factors such as temperature, moisture, aeration etc. Microbial ecology changes according to change of a biotic factor in the biomass but decomposition never ceases.

Conditions unfavorable to aerobic decomposition result in mortality of earthworms and subsequently no Vermi composting occurs. Hence, preprocessing of the waste as well as providing favorable environmental condition is necessary for Vermi composting.

The Vermi compost is relatively more stabilised and harmonises with soil system without any ill effect. Unfavorable conditions such as particle size of biomass and extent of its decomposition, very large temperature increase, anaerobic condition, toxicity of decomposition products etc. influence activity of worms. The worm species that are commonly used in Vermi composting are: two exotic varieties (Eisenia foetida and Eudrilus euginiae) and one indigenous variety (Lampito mauritii). It is recommended that local variety of worms which consume garbage should be used to the extent possible. 50 kg worms give 50kg manure per day. These worms are known to survive in the moisture range of 20-80% and the temperature range of 20 - 40°C. The worms do not survive in pure organic substrates containing more that 40% fermentable organic substances. Hence fresh waste is commonly mixed with partially or fully stabilised waste before it is subjected to Vermi composting.

Vermi composting may be done using compost beds as well as tanks at both household and community levels.

Advantages

i. Conversion of cattle dung and cattle dung based bio gas slurry, kitchen/food waste, and leaves etc (organic solid waste) into high quality organic manure which are otherwise wasted
ii. It is a fast process which requires only 40-45 days as compared to the conventional process
iii. The process is free from foul odour
iv. Complete destruction of weed seeds
v. Vermi compost contains plant growth and anti fungula elements which lead to high value addition and profitability
vi. Prevents vector breeding
vii. Prevents insanitary conditions
viii. The technology is simple and it is easy to adopt and replicate
ix. Requires very little land area.

Applicability

Applicability is in household community and mini commercial scale.

3.4 Advantages of Composting

1. By proper decomposition, biodegradable waste gets converted into good quality organic manure whereby waste is turned into wealth
2. Prevents vector breeding and breeding of rodents
3. In aerobic composting process considerable heat is generated, resulting in destruction of pathogens and weed seeds
4. Insanitary conditions arising out of solid waste are removed and aesthetically, environment looks neat and clean.

4.0 CONCLUSION

Composting is the controlled aerobic decomposition of organic matter by the action of microorganisms and small invertebrates. The process is controlled by making the environmental conditions optimum for the waste decomposers to thrive. The rate of compost formation is controlled by the composition and constituents of the materials i.e. their carbon/nitrogen (C/N) ratio, the temperature, the moisture content and the amount of air.

The C/N ratio is very important for the process to be efficient. The microorganisms require carbon as an energy source and nitrogen for the synthesis of some proteins. Moisture content greatly influences the composting process. The microbes need the moisture to perform their metabolic functions. If the waste becomes too dry the composting is not favoured. If however there is too much moisture then it is possible that it may displace the air in the compost heap depriving the organisms of oxygen and drowning them.

A high temperature is desirable for the elimination of pathogenic organisms. However, if temperatures are too high, above 75^{o}C then the organisms necessary to complete the composting process are destroyed.

Optimum temperatures for the process are in the range of 50-60^{o}C with the ideal being 60^{o}C. Aeration also is a very important and the quantity of air needs to be properly controlled when composting. If there is insufficient oxygen the aerobes will begin to die and will be replaced by anaerobes. This will slow the process, produce odours and also highly flammable methane gas. Air can be incorporated by churning the compost.

5.0 SUMMARY

In this unit, you were exposed to the description of composting as a solid waste management technology. We adopted a practical oriented approach to emphasise the various composting techniques available for efficient management of solid waste both at household and community levels including in vessel composting, windrow composting, vermi composting and static pile composting. You have seen that composting is achieved by making the environmental conditions optimum for the waste decomposers to thrive. The rate of compost formation is controlled by the composition and constituents of the materials i.e. their carbon/nitrogen (C/N) ratio, the temperature, the moisture content and the amount of air. Composting have numerous advantages including the yield of good quality organic manure, prevents breeding of vectors, rodents and vermin; destroys pathogens and weed seeds; promotes aesthetics and is environmental friendly.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define composting.
2. State the advantages of composting.
3. List various techniques of composting.
4. Describe the operation of Vermi compost plant.

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UNIT 4 OTHER METHODS/TECHNOLOGIES

CONTENTS

1.0 INTRODUCTION

In our last unit, you learnt about the concept and various techniques of composting as a veritable technology for the management of solid waste both at individual household, small communities and large municipality levels. In this unit, we will describe other methods or technologies which are equally sound in the management of solid waste, even those that can be composted and those that cannot be composted. Other technologies to be described in this unit include pyrolysis, pulverisation and the biogas technology. Read on as we explore the advances in waste management technology.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- outline other solid waste management technologies
- describe the technologies outlined
- state five advantages and two disadvantages of each technology
- recommend appropriate technology for a prevailing local situation.

3.0 MAIN CONTENT

3.1 Other Methods/Technologies

We have previously described most conventional methods/technologies for solid waste treatment available to all especially in the third world or developing economies. We shall use this section to describe the emerging waste treatment technologies which are equally sound and with varying benefits. These technologies includes but not limited to: pyrolysis/gasification, pulverisation, biogas digester etc. We shall describe each technology in turn.

3.2 Pyrolysis and Gasification

Pyrolysis and gasification are quite new methods for treatments of municipal solid waste and remain relatively unproven in African usage compared with classical methods. Despite the fact that these technologies are widely used and well established as industrial processes for energy recovery from hydrocarbons feedstock, their use as process for dealing with mixed municipal waste streams is at an early stage of development.

Both pyrolysis and gasification turn wastes into energy rich fuels by heating the waste under controlled conditions. In contrast to incineration, which fully converts the input waste into energy and ash, these processes deliberately limit the conversion so that combustion does not take place directly. Instead, they convert the waste into valuable intermediates that can be further processed for materials recycling or energy recovery e.g. a mixture of carbon monoxide and hydrogen, oils and char.

Pyrolysis is a thermal decomposition of fuel in the absence of air. Solid waste is converted to a gas and/or liquid, which is then converted to electricity by combustion in a gas turbine or diesel engine. Some solid residue generally remains. Heat has to be provided to the fuel for decomposition to occur and this is normally integrated into the overall process scheme.

One advantage of the pyrolysis technique is that some liquid fuel can be produced, which is versatile, easily transportable and could be used, for example, as a transport fuel in an international combustion engine. Because much of the fuel produced in the pyrolysis process is consumed within the operation, pyrolysis tends not to be an efficient conversion technology.

Gasification is a reaction between the fuel and oxidant (steam and oxygen) carried out in a restricted supply of oxygen so that complete combustion of the fuel does not take place. Instead the volatile gas comprising combustible components, such as hydrogen, carbon monoxide, methane and higher hydrocarbons is produced, which is subsequently burned to generate electricity, normally in a gas turbine.

Gasification reactions include partial oxidation of the fuel and the water gas reaction and so are generally autothermic, not requiring heat to be supplied from elsewhere in the process. Therefore, thermochemical conversion of the fuel to electricity effectively takes place in two stages.

The advantage of this is that pollutants can be removed from the small fuel gas stream. Also, the second stage is often in a gas turbine or diesel engine. Consequently a higher overall plant efficiency can be achieved through the use of combined cycles with the potential for further increase as gas turbine firing temperatures are increased.

Gasification is an energy efficient technique for minimising the solid waste volume and for recovering energy. It generates 500-600 kWh useable energy per ton of waste. This technology has been used more widely than pyrolysis because it doesn't have problems with heat transfer and is a more efficient process that produces a single gaseous product.

3.3 Pulverisation/Shredding

Although dictionaries differentiate between shredding and pulverising, the expressions are often used interchangeably when applied to the processing of solid waste. This discussion of the processing of solid waste for size reduction and uniformity will adopt the accepted interchangeable use of shredding and pulverizing. However, it is noted that the end product of the process does differentiate between the shredded or cut and torn shape, and the pulverized or crushed and ground fine particle.

There are four types of shredders used for the shredding or pulverising of solid waste: hammer mills, drum pulverisiers, crushers, and wet pulverisiers. Each type of equipment has a variety of designs, advantages, and disadvantages. Major considerations in selecting a shredder are its capacity, speed, power requirements, maintenance needs, ability to produce the end product desired and, most important, and reliability. These characteristics will differ significantly for various types of solid waste and differing end products. In choosing a type and particular design of a shredder, it is desirable to obtain information on the performance of the shredder in circumstances similar to those for which the machine is to be used.

Solid waste is shredded for several reasons, including volume reduction. Under certain circumstances, shredded refuse can be disposed of in a landfill without requiring as stringent compaction and cover procedures as would be applied to unprocessed refuse.

If solid waste is to be converted to refuse derived fuel (RDF), shredding and/or pulverising is an element of the RDF production process.

Resource recovery plants that separate waste into recyclables often include one or more shredding operations to improve the mechanical separation characteristics of the waste. If solid waste is to be transported mechanically, pneumatically, or hydraulically, shredding is a desirable if not essential first step before transport. It is obvious that shredding and pulverising of solid waste is a process with many uses.

3.4 Biogas Technology

3.4.1 Background

When biodegradable organic solid waste is subjected to anaerobic decomposition, a gaseous mixture of Methane (CH4) and Carbon di-oxide (C02) known as Biogas could be produced under favorable conditions.

The decomposition of the waste materials is mainly done by the fermentation process which is carried out by different group of microorganisms like bacteria, fungus, actinomycetes etc. The group of micro-organisms involved for biogas generation is mainly the bacteria.

The process involves a series of reactions by several kinds of anaerobic bacteria feeding on the raw organic matter. “In anaerobic conditions, anaerobic bacteria disintegrate the biodegradable solids by a biochemical process shown below.

3.4.2 Digestion Process

The anaerobic digestion of the organic waste matter occurs in three different stages:

i. Hydrolysis
ii. Acidogenesis
iii. Methanogenesis.

3.4.2.1 Hydrolysis

Most of the organic waste materials subjected to bio-methanation contain the macromolecules like cellulose, hemicellulose, lignin etc. which are insoluble in water. In the first step of digestion, these macromolecules are subjected to breakdown into micro-molecules with the help of some enzymes which are secreted by the bacteria. In the initial step, oxygen in the feed materials is used up by oxygen loving bacteria and large amounts of carbon dioxide (CO2) are released and the major end product of this step is glucose.

3.4.2.2 Acid Formation

The components released during the hydrolytic breakdown become the substrate for the acid forming bacteria. The acid forming bacteria convert the water soluble substances into volatile acids. The major component of the volatile acid is acetic acid. Besides this, some other acids like butric acid, propionic acid and gases like CO_2 and H_2 are also produced. The acid forming bacteria during the conversion process utilise the amount of oxygen remaining in the medium and make the environment anaerobic.

3.4.2.3 Methane Formation

This is the last stage of the biogas generation. In this stage, the methanogenic bacteria convert the volatile acids formed in the second step by the acidogenic bacteria to methane and carbon di-oxide. Some excess CO_2 in the medium is also converted to methane gas by reacting with the hydrogen present in the environment.

The End Products of Bio-Gas Technology are:

- **Biogas:** It is a marsh gas, a mixture of Methane (55- 65%), Carbon di—oxide (35- 45%), trace amount of Hydrogen, Hydrogen Sulphide and Amonia. It is a combustible gas and can be used for heating, lighting, powering irrigation pump, generating electric power and for local use for cooking purpose. The gas is smokeless, environment friendly and efficient fuel.
- **Left over slurry**: Environmental friendly manure would be produced which can be used as organic fertiliser for gardening and agricultural purpose. It can be used to enrich the soil. It can also be dovetailed to vermin composting to enrich manure value of compost.

3.4.3 Fuel Efficiency of Biogas

The fuel efficiency of cattle dung is 11% and that of Biogas from same dung is 60%, Biogas technology holds promise of revolutionising energy scene-conserving forests, preventing soil erosion and providing energy security in rural areas. Normally a 3 cubic meter capacity Biogas plant is considered sufficient to meet the heating and lighting needs of a rural family of 6 to 9 persons

3.4.4 Biogas Plant Construction

Currently in Nigeria, the Environmental Health Officers Registration Council of Nigeria is championing the course of widening the horizon of knowledge of the public that the biogas plant can be constructed a hundred percent using local materials. Two types of the plant are being advocated by EHORECON for domestic biogas plant – the flexible type and the dome type.

The flexible type is made of rectangular sewn air tight tarpaulins material with provisions for charging the plant and removal of the gas and spent slurry respectively. A flexible tank of 2.5 cubic meters submerged about one (1) meter on the surface of the ground will be sufficient for a family of 4 – 10 persons.


A


B

Fig. 4.1 (a) & (b): Construction of Flexible Tank Biogas Plant and the Plant with Full Gas Yield. Photo taken at Federal University of Technology Owerri).

Also, the dome type has been successfully constructed in Nigeria using local available materials as shown below. The tank is a modification of PVC water tanks making provision for stirring, charging, and gas harvest and slurry removal.

C

D

E

F

3.4.4 Use of Biogas Technology for Solid Waste Management

The biogas technology can be used for management of bio degradable solid waste (portion) generated from:

i. Household
ii. Community
iii. Commercial Establishment.

3.4.5.1 Household Level

Kitchen waste, cattle dung, garden waste, leaves of trees can be digested and digested product reused at household level.

3.4.5.2 Community Level

Community bio degradable waste such as cattle dung of stray cattle and from abattoirs, garden waste, leaves of roadside trees, human excreta from individual/community toilet etc., can be digested in community biogas plant and end products can be reused.

3.4.5.3 Commercial Establishment

Commercial bio degradable waste generated from hotels, parks and gardens, and leaves of roadside trees etc. can be digested in commercial biogas plant and the end products can be fruitfully utilised commercially such as gas engine, liquefied natural gas productions, lifting water for irrigation purposes etc.

The gas production varies from 0.29 cubic metres per kg of volatile solids added per day to 0.19 cubic metre 0.16 cubic metres per kg added per day in different seasons. The volatile solids destruction ranges from 40 to 55%. The sludge has good manurial value of Nitrogen, phosphorous, and potassium (NPK ratio is 1.6: 0.85: 0.93). The process gives a good performance at a retention time of 30 to 55 days varies as per season.

4.0 CONCLUSION

Amongst the sundry technologies for the management of solid waste described in this chapter, it is obvious that pyrolysis/gasification and pulverisation/shredding require advanced technological development though pyrolysis may be applied to a wide range of solid waste materials. It is only the biogas technology that is within the technological reach of the third world and less developed countries like ours. Besides this, the biogas technology holds a great promise as a source of manure for farmers aside from its energy recovery characteristics. The technology can serve individual households, communities and small to medium scale industries as energy source.

5.0 SUMMARY

In this unit, our major focus has been the description of sundry methods and technologies available for waste treatment aside from the conventional ones earlier described. Apart from the fact that some of these methods especially pyrolysis/gasification and pulverisation and shredding require a bit of technological advances and cost, pyrolysis/gasification can handle a broad spectrum of waste types and is very efficient energy recovery technology. Pulverisation/shredding minimises waste volume and is very useful in waste handling and recycling processes. Biogas technology on its own is not so very capital intensive and can be operated at household and community level as well as large scale municipal waste treatment situation. It is very eco-friendly, efficient energy recovery and generates byproduct of great use in agriculture.

6.0 TUTOR-MARKED ASSIGNMENT

1 Outline four solid waste management technologies you have studied.
2 Describe any two of the technologies outlined.
3 State five advantages and two disadvantages of each technology.
4 Recommend appropriate waste management technology for a rural farming community of 200 households. Give five reasons for your recommended choice.

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MODULE 3

UNIT 1 WASTE MINIMISATION/REDUCTION

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt about the various technologies involved in the management of solid waste. In this unit, we will describe the concept of waste minimisation, a procedure for limiting the occurrence of waste or in the alternative reducing the volume of waste to be handled and treated. As usual, the lesson is going to be a living type as the subject of waste minimisation and reduction is our everyday experience.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define waste minimisation
- outline the processes of waste minimisation
- classify waste minimisation techniques
- state the importance of waste minimisation.

3.0 MAIN CONTENT

3.1 INTRODUCTION

Traditionally, waste is viewed as an unnecessary element arising from the activities of any industry. In reality, waste is a misplaced resource, existing at a wrong place at a wrong time. Waste is also the inefficient use of utilities such as electricity, water, and fuel, which are often considered unavoidable overheads. The costs of these wastes are generally underestimated by managers. It is important to realise that the cost of waste is not only the cost of waste disposal, but also other costs such as: - disposal cost, purchase cost of wasted raw material, production cost for the waste material, management time spent on waste material, lost revenue for what could have been a product instead of waste and potential liabilities due to waste.

3.2 What is Waste Minimisation?

Waste minimisation can be defined as "systematically reducing waste at source". It means:

- Prevention and/or reduction of waste generated
- Efficient use of raw materials and packaging
- Efficient use of fuel, electricity and water
- Improving the quality of waste generated to facilitate recycling and/or reduce hazard
- Encouraging re-use, recycling and recovery.

Waste minimisation is the process and the policy of reducing the amount of waste produced by a person or a society. It involves efforts to minimise resource and energy use during manufacture. For the same commercial output, usually the fewer materials are used, the less waste is produced. Waste minimisation usually requires knowledge of the production process, cradle-to-grave analysis (the tracking of materials from their extraction to their return to earth) and detailed knowledge of the composition of the waste.

Waste minimisation is also known by other terms such as waste reduction, pollution prevention, source reduction and cleaner technology. It makes use of managerial and/or technical interventions to make industrial operations inherently pollution free.

It should be also clearly understood that waste minimisation, however attractive, is not a panacea for all environmental problems and may have to be supported by conventional treatment/disposal solutions.

3.2.1 Processes of Waste Minimisation

a. Resource Optimisation
Minimising the amount of waste produced by organisations or individuals goes hand-in-hand with optimising their use of raw materials. For example, a dressmaker may arrange pattern pieces on a length of fabric in a particular way to enable the garment to be cut out from the smallest area of fabric.

b. Reuse of Scrap Material
Scraps can be immediately re-incorporated at the beginning of the manufacturing line so that they do not become a waste product. Many industries routinely do this; for example, paper mills return any damaged rolls to the beginning of the production line, and in the manufacture of plastic items, Off-cuts and scrap are re-incorporated into new products.

c. Improved Quality Control and Process Monitoring
Steps can be taken to ensure that the number of reject batches is kept to a minimum. This is achieved by increasing the frequency of inspection and the number of points of inspection. For example, installing automated continuous monitoring equipment can help to identify production problems at an early stage.

d. Waste Exchanges
This is where the waste product of one process becomes the raw material for a second process. Waste exchanges represent another

way of reducing waste disposal volumes for waste that cannot be eliminated.

e. Ship to Point of Use
This involves making deliveries of incoming raw materials or components direct to the point where they are assembled or used in the manufacturing process to minimise handling and the use of protective wrappings or enclosures.

3.2.2 Classification of Waste Minimisation (WM) Techniques

The waste minimisation is based on different techniques. These techniques are classified as shown in figure 1.1

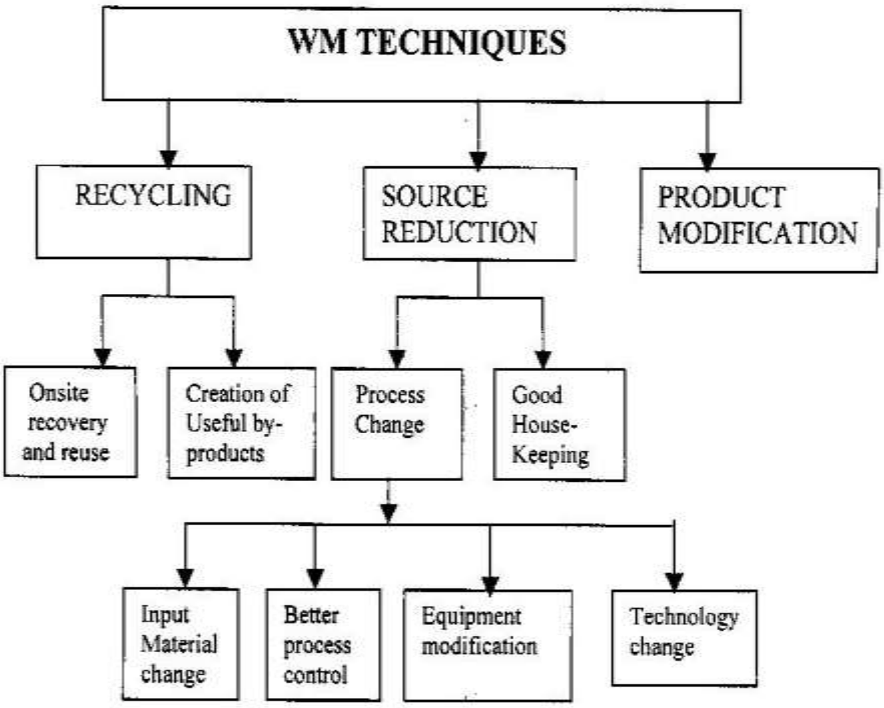

Fig. 1.1: Schematic Diagram of Waste Minimisation Techniques
Source:http://www.em-ea.org/Guide%20Books/book4/4.13%20Waste%20minimisation%20&%20resouce%20conservation.pdf

Source Reduction

Under this category, four techniques of WM are briefly discussed below:

a) Good Housekeeping- Systems to prevent leakages & spillages through preventive maintenance schedules and routine equipment inspections. Also, well-written working instructions, supervision, awareness and regular training of workforce would facilitate good housekeeping.

b) Process Change: Under this head, four CP techniques are covered:

(i) Input Material Change - Substitution of input materials by eco-friendly (non-toxic or less toxic than existing and renewable) material preferably having longer service time.

(ii) Better Process Control - Modifications of the working procedures, machine-operating instructions and process record keeping in order to run the processes at higher efficiency and with lower waste generation and emissions.

(iii) Equipment Modification - Modification of existing production equipment and utilities, for instance, by the addition of measuring and controlling devices, in order to run the processes at higher efficiency and lower waste and emission generation rates.

(iv) Technology Change - Replacement of the technology, processing sequence and/or synthesis route, in order to minimise waste and emission generation during production.

c) Recycling

i) On-Site Recovery and Reuse - Reuse of wasted materials in the same process or for another useful application within the industry.

ii) Production of useful By-product - Modification of the waste generation process in order to transform the wasted material into a material that can be reused or recycled for another application within or outside the company.

d) Product Modification

Characteristics of the product can be modified to minimise the environmental impacts of its production or those of the product itself during or after its use (disposal).

3.2.3 Importance of Waste Reduction

In affluent countries, the main motivations for waste reduction are frequently related to the high cost and scarcity of suitable sites associated with the establishment of new landfills, and the environmental degradation caused by toxic materials in the deposited wastes. The same considerations apply to:

1) Large metropolitan areas in developing countries that generally are surrounded by other populous jurisdictions, and
2) Isolated small communities (such as island communities).

However, any areas that currently do not have significant difficulties associated with the final dispositions of their wastes disposal pressures can still derive significant benefits from encouraging waste reduction. Their solid waste management departments, already overburdened, are ill-equipped to spend more funds and efforts on the greater quantities of wastes that will inevitably be produced, if not otherwise controlled, as consumption levels rise and urban wastes change.

3.3 Key Concepts in Municipal Waste Reduction

Action for waste reduction can take place at both the national and local levels.

3.3.1 At the National Level

Some strategies for waste reduction include:

- Redesign of products or packaging
- Promotion of consumer awareness and
- Promotion of producer responsibility for post-consumer wastes.

3.3.2 At the local level

The main means of reducing waste are:

- Diversion of materials from the waste stream through source separation and trading
- Recovery of materials from mixed waste
- Pressure on national or regional governments for legislation on redesigning packaging or products and
- Support of home composting, either centralized or small-scale.

3.3.3 Household Waste Minimisation

- Waste minimisation at household level can be achieved by the adoption of a variety of strategies. But in a domestic situation, the potential for minimisation is often dictated by lifestyle. Some people may view it as wasteful to purchase new products solely to follow fashion trends when the older products are still usable. Adults working full-time have little free time, and so may have to purchase more convenient foods that require little preparation, or prefer disposable nappies if there is a baby in the family

- Appropriate amounts and sizes can be chosen when purchasing goods; buying large containers of paint for a small decorating job or buying larger amounts of food than can be consumed create unnecessary waste. Also, if a pack or can is to be thrown away, any remaining contents must be removed before the container can be recycled

- Home composting, the practice of turning kitchen and garden waste into compost can be considered waste minimisation. Individuals can reduce the amount of waste they create by buying fewer products and by buying products which last longer.

Mending broken or worn items of clothing or equipment also contributes to minimising household waste

- The amount of waste an individual produces is a small portion of all waste produced by society, and personal waste reduction can only make a small impact on overall waste volumes. Yet, influence on policy can be exerted in other areas. Increased consumer awareness of the impact and power of certain purchasing decisions allows industry and individuals to change the total resource consumption. Consumers can influence manufacturers and distributors by avoiding buying products that do not have eco-labeling, which is currently not mandatory, or choosing products that minimise the use of packaging
- Where reuse schemes are available, consumers can be proactive and use them.

3.4 Systems of Waste Reduction

3.4.1 Industrialised Countries

Perhaps in no field of municipal solid waste management are the differences between the industrialised countries and the developing countries so apparent as in waste reduction and materials recovery.

Rising overall living standards and the advent of mass production have reduced markets for many used materials and goods in the affluent countries whereas, in most of the economically developing countries, traditional labour-intensive practices of repair, reuse, waste trading, and recycling have endured. Thus, there is a large potential for waste reduction in economically developing countries, and the recovery of synthetic or processed materials is now being emphasised. Public or consumer financing of the full range of initiatives for waste reduction (from changes in manufacturing and packaging, to waste reduction audits to identify waste reduction opportunities) are practiced by several affluent industrialised countries.

One of the main motivations, from the point of view of municipal authorities, is to reduce materials that must be collected and deposited in landfills. At the national level, under the concept of producer responsibility, governments have created agreements and legal frameworks designed to reduce the generation of waste. For instance, industry is given responsibility for achieving certain levels of packaging reduction goals of a certain percentage within a given time period.

3.4.2 Developing Countries

In many developing countries, waste reduction occurs naturally as matter of normal practice because of the high value placed on material resources by the people, as well as other factors.

Consequently, reuse of a variety of materials is prevalent. The motivations for materials reuse in developing countries include: scarcity or expense of virgin materials; the level of absolute poverty; the availability of workers who will accept minimal wages; the frugal values of even relatively well-to-do households; and the large markets for used goods and products made from recycled plastics and metals. Wastes that are of no use in affluent societies and cannot be recycled have value in developing countries e.g. coconut shells and dung used as fuel. If one takes into account the use of compost from dumps sites as well as materials recovery, in countries like India, Vietnam, and China, the majority of municipal wastes of all kinds are ultimately utilised.

Waste reduction that could be achieved by legislation and protocols (such as agreements to change packaging) is not, at present, a high priority in these countries, although some are now moving in this direction. Because unskilled labour costs are low and there is a high demand for manufactured materials, manufacturers can readily use leftovers as feedstock or engage in waste exchange. Residuals and old machines are sold to less advanced, smaller industries. Public health is benefiting from plastic and boxboard packaging that reduces contamination of foods, and much of the superior packaging is recovered and recycled.

In offices and institutions, cleaners and caretakers organise the sale of paper, plastics, etc. At the household level, gifts of clothes and goods to relatives, charities, and servants are still significant in waste reduction.

All cities and towns have markets for used goods. However, the greatest amount of materials recovery is achieved through networks of itinerant buyers, small- and medium-sized dealers, and wholesaling brokers. The extent to which the waste trading enterprises are registered ("formalised") varies in developing regions: in Latin America and Asia, there is more formal registration than in Africa. The system is adaptive to market fluctuations, as the lowest level workers form a dispensable labour cushion: they must find other work, if they can, when there is reduced demand for the materials that they sell.

From the point of view of waste reduction, the traditional practices of repair and reuse, and the sale, barter, or gift-giving of used goods and surplus materials are an advantage to the poorer countries. Quantities of inorganic post-consumer wastes entering the MSW stream would be higher if these forms of waste reduction did not exist.

4.0 CONCLUSION

In conclusion, waste minimisation involves all processes and techniques applied to preclude as much as possible or reduce to the barest minimum the occurrence of waste and wasteful situations in the production, distribution and use of any product and services. Waste minimisation strategies are applied at different levels especially in the industries during product design and production and continue up to the consumer level.

At the consumer/household level, discrimination as to what to buy and in what quantity, product quality, re-use or recycling etc. are some of the major considerations to be taken to minimise waste. Household waste minimisation or reduction is influenced by level of knowledge, socio-economic status and lifestyle.

5.0 SUMMARY

In this unit, our focus has been on the understanding of the concept of waste minimisation/reduction. You have seen that although waste is inevitable, it can be minimised or drastically reduced through quality production and considerate use.

When manufacturers build quality into their products through good housekeeping and process change and recycle defective ones; and consumers make considerate purchases and good use of products including re-use, exchange (barter) and recycle of materials, the bulk of waste in the municipal waste stream would have been reduced. In the next unit, we shall be discussing waste recycling and reuse.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define waste minimisation.
2. Outline the processes of waste minimisation.
3. Classify waste minimisation techniques.

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http://www.dep.state.pa.us/dep/deputate/airwaste/wm/recycle/facts/reduce.htm.

UNIT 2 WASTE RECYCLING AND REUSE

CONTENTS

1.0 INTRODUCTION

In unit 1, you learnt the concept of waste minimisation, the processes and methods of minimising waste and the associated economic, social, health and environmental benefits inherent in waste minimisation. In this unit, you will learn the concept of waste recycling and reuse.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define waste recycling
- describe some waste recycling processes
- state the advantages and constraints to waste recycling
- differentiate between waste recycling and reuse.

3.0 MAIN CONTENT

3.1 What is Waste Recycling?

Recycling involves the collection of used and discarded materials which are processed and turn into making new products. It reduces the amount of waste that is thrown into the community dustbins thereby making the environment cleaner and the air more fresh to breath. From this definition recycling occurs in three phases: first the waste is sorted and recyclables collected, the recyclables are used to create raw materials. These raw materials are then used in the production of new products.

Serious attention has been shown by government and non-government agencies in the country on the need to recycle wastes having all recognised the importance of recycling wastes. However, the methodology for safe recycling of waste has not been standardised.

Currently, less than 7 %-15% of the waste is recycled in the country. If recycling is done in a proper manner, it will solve the problems of waste or garbage.

3.2 Steps Involved in Waste Recycling

The steps involved in the process prior to recycling include:

a) Collection of waste from doorsteps, commercial places etc.
b) Collection of waste from community dumps
c) Collection/picking up of waste from final disposal sites.

The sorting of recyclables may be done at the source (i.e. within the household or office) for selective collection by the municipality or to be dropped off by the waste producer at a recycling centres. The pre-sorting at the source requires public participation which may not be forthcoming if there are no benefits to be derived. Also a system of selective collection by the government can be costly. It would require more frequent circulation of trucks within a neighborhood or the importation of more vehicles to facilitate the collection.

Another option is to mix the recyclables with the general waste stream for collection and then sorting and recovery of the recyclable materials can be performed by the municipality at a suitable site. The sorting by the municipality has the advantage of eliminating the dependence on the public and ensuring that the recycling does occur.

The disadvantage however, is that the value of the recyclable materials is reduced since being mixed in and compacted with other garbage can have adverse effects on the quality of the recyclable material.

3.3 Strategies for Carrying out Waste Recycling

Before developing a strategy for implementing 3R practices, municipal authorities must answer the following questions:

- Who are the recyclers?
- What are the advantages of recycling solid waste?
- What is being recycled?
- What is not being recycled and why?
- What are the main challenges?
- What steps are necessary to improve the recycling and resource recovery of materials?

Ideally, the 3R (reduce, reuse and recycle) concept will be applied as early as possible in the waste generation and management chain so that managers of waste can:

- maintain the high material quality and value of recyclable waste materials
- reduce the loss of valuable natural resources and virgin raw materials
- limit pollution of land
- reduce long-distance transport of waste
- reduce landfill space requirements and environmental pollution
- minimise the costs of both production of goods and management of waste.

3.4 Recycling Materials

Almost every material can be recycled; however, the value of the recycled material can vary significantly depending on the demand and uses for it. Indeed the value of a material is the driving factor for private recycling initiatives or—in the case of many developing countries—the informal sector. If and how a material is recycled depends not only on local policies but also on the availability of a buyer, processing facilities, and a transport chain.

Most of the garbage generated in the household can be recycled and reused. Organic kitchen waste such as leftover foodstuff, vegetable peels, and spoilt or dried fruits and vegetables can be recycled by putting them in the compost pits that have been dug in the garden. Old newspapers, magazines and bottles can be sold to the waste vendor the man who buys these items from homes. In your own homes you can contribute to waste reduction and the recycling and reuse of certain items. Table below shows some household wastes that can be recycled or reused.

Table 2.1: Recyclable Household Wastes

S/No	Waste Item	Examples
1	Paper	Old copies, Old books Paper bags, Newspapers Old greeting cards Cardboard box
2	Plastic	Containers, Bottles Bags, Sheets
3	Glass and Ceramics	Bottles, Plates Cups,Bowls
4	Miscellaneous	Old cans,Utensils Clothes,Furniture

Source: http://edugreen.teri.res.in/explore/solwaste/recycle.htm

Waste Recycling can be further Illustrated using a Schematic Diagram as Shown in Figure 2.1 below.

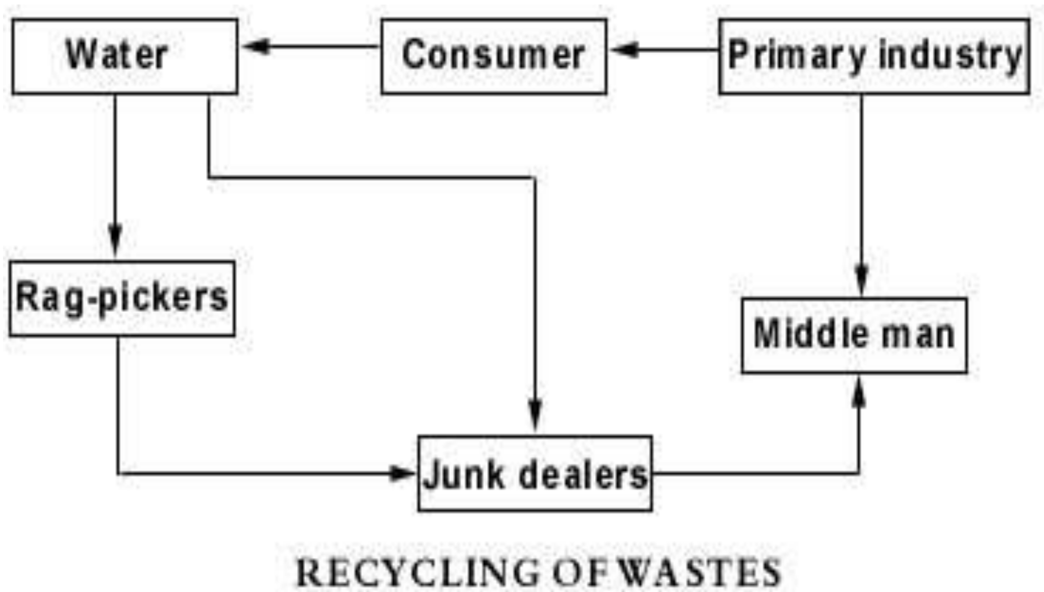

Fig. 2.1: Waste Recycling
Source: CPCB Report on Management of Municipal Solid Waste:
(http://edugreen.teri.res.in/explore/solwaste/recycle.htm)

The table below gives an overview of typical recycling materials and their potential treatment options

Table 2.2: Important Recycling Materials: Advantages and Drawbacks

Material	Advantages	Drawbacks
Aluminum	• Aluminum has high market value • It can be easily recycled by shredding and melting • It can be recycled indefinitely because it does not deteriorate from reprocessing • Aluminum recycling requires significantly less energy than producing aluminum from ore.	○ Separate collection is important ○ Recycling is suitable only if a processing plant is available.
Batteries	• Recycling recovers valuable metals • Recycling protects the environment from heavy metals such as lead, cadmium, and mercury.	• Large variation in type and size of batteries requires specific recycling processes. • Older batteries have high heavy metal content.
Concrete and demolition waste	• Demolition waste can be crushed to gravel and be reused in road construction and landscaping	• Machinery required for crushing is maintenance intensive. • Recycled waste is valuable only if there is a lack of other construction material.
Glass	• Glass has a moderate market value • It can be sorted into colours and melted • Use of recycled glass saves	• Broken glass can contaminate and eliminate opportunities for recycling.

	energy compared with processing raw material. • Glass can be recycled indefinitely because it does not deteriorate from reprocessing.	
Organic waste	• Most commonly recycled by composting or anaerobic digestion	• Though compost is very beneficial to depleted soils, it still has a low market value
Other metal	• Scrap metal has a high market value (especially steel, copper, silver, and platinum) • It can be recycled indefinitely because it does not deteriorate from reprocessing.	• High-value metals (such as copper and silver) are incorporated in electronic devices, but extraction can cause severe environmental impacts.
Paper	• Paper can be easily recycled; however, quality deteriorates with each cycle. • Paper or cardboard from recycled paper requires less energy to produce and protects forests	• Appropriate technologies with circular processes are required to protect the environment.
Polyethylene terephthalate (PET)	• PET can be recycled if segregated from other waste. • Reprocessing into granulate is very easy. • PET has a high market value if processing plants are available.	• More “downcycling” than recycling occurs because quality decreases with every processing cycle.
Other plastic	• Other plastic, such as polyethylene or polyvinyl chloride, can be recycled but has less value on the market than PET; the value depends on recycling and manufacturing options in the vicinity.	• Recycling requires specific machinery
Electronic	• Electronic waste (such as	• Metals are often

waste	computers or mobile phones) contains high value metals. • Electronic items can be dismantled,reused, or recycled	covered with polyvinyl chloride or resins, which are often smelted or burned, causing toxic emissions

Source: http://www.tn.gov.in/cma/swm_in_india.pdf

3.5 Materials Recycling Process

3.5.1 Paper Recycling

This is the process of turning waste paper into new paper products.

There are three categories of paper that can be used as feed stocks for making recycled paper: mill broke pre-consumer waste, and post-consumer waste. The process of paper recycling involves mixing used paper with water and chemicals to break the paper down. The paper is then chopped up and heated, which breaks the paper down further into strands of cellulose, which is a type of organic plant material from the pulp. The resulting mixture called slurry is strained through screens, which remove any glue or plastic that may still be in the mixture then cleaned, de-inked, bleached, and mixed with water. Then this can be made into new paper. The same fibers can be recycled about seven times, but they get shorter every time and eventually are strained out.

Mill broke is paper trimmings and other paper scrap from the manufacture of paper, and the paper recycled internally in a paper mill. Pre consumer waste is material which left the paper mill but was discarded before it was ready for consumer use. Post-consumer waste is material discarded after consumer use, such as old corrugated containers, old magazines, old newspapers, office paper, old telephone directories, and residential mixed paper. Paper suitable for recycling is called "scrap paper", often used to produce molded pulp packaging. The industrial process of removing printing ink from paper fibers of recycled paper to make deinked pulp is called deinking, an invention of the German Jurist Justus Claproth.

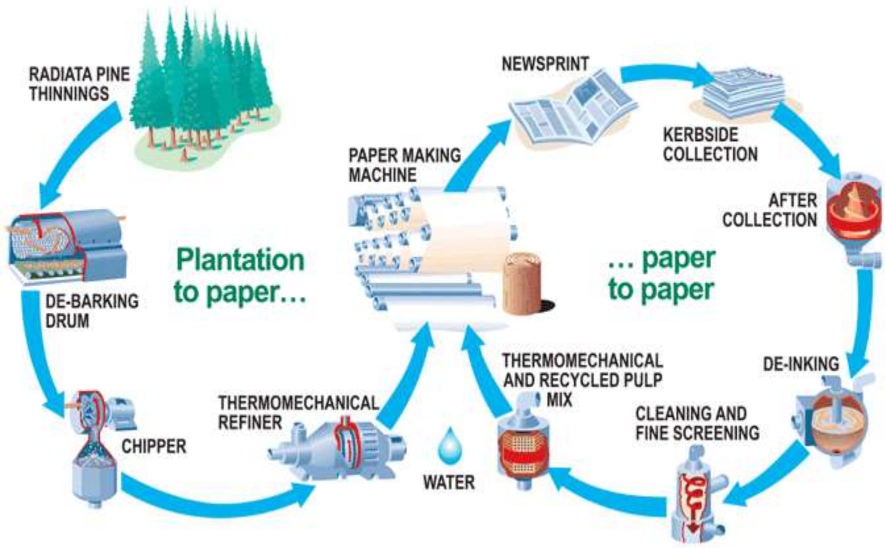

Fig. 2.2: Paper Recycling
Source: http://www.infotech2.com/?p=117

Steps in Paper Recycling

Here is how paper waste is recycled:

1. Collection, Transportation and Storage

The biggest task for paper recycling companies is probably the collection, transporting and sorting of waste paper. This is because we always add paper to other waste items and get them contaminated with food, plastics and metals. Sometimes collected paper is sent back to the landfills because they are too contaminated for use. Try to keep waste paper in separate grades at home or in the office —example, do not mix newspapers and corrugated boxes up.

Fig. 2.3: Types of Recycled Papers
Source:http://www.eschooltoday.com/waste-recycling/paper-waste-recycling-process.html

All paper recovered is sent to the recycling center, where it is packed, graded, put into bales and sent to the paper mill. At the mill, all the paper is stored in a warehouse until it is needed.

2. Repulping and Screening

From the storage shelves, they are moved into a big paper-grinding machine called a vat (pulper). Here the paper is chopped into tiny pieces, mixed with water and chemicals and heated up to break it down into organic plant material called fibre. After, it is screened to remove contaminants such as bits of plastic and globs of glue.

3. Deinking

This involves 'washing' the pulp with chemicals to remove printing ink and glue residue. Sometimes, a process called floatation is applied to further remove stubborn stains and stickies. Floatation involves the use of chemicals and air to create bubbles which absorb the stickies in the pulp.

4. Refining, Bleaching and Colour Stripping

Refining involves beating the recycled pulp to make them ideal for paper-making. After refining, additional chemicals are added to remove any dyes from the paper. It is then bleached to whiten and brighten it up.

5. Paper Making

At this stage, the pulp is ready to be used for paper. Sometimes new pulp (virgin pulp) is added to give it extra strength and smoothness. Water is added to the pulp and sprayed onto a large metal screen in continuous mode. The water is drained on the screen and the fibres begin to bond with each other. As it moves through the paper-making machines, press rollers squeeze out more water, heat them dry and coat them up. They are then finished into rolls.

3.5.2 Aluminum Recycling

In recent time, there has been a massive improvement in recycling aluminum cans. In 2003, it was reported that Americans recycled 62.6 billion aluminum cans. Those cans, placed end-to-end, could make 171 circles around the earth. Every minute an average of 105,800 aluminum cans are recycled. That is how important can recycling has become. But what is involved here?

1. Collection

Local councils provide special can recycling containers (bins) that are clearly marked. This helps people to know what to place in them. The various cans include soda cans, fruit cans and vegetable cans. Trucks come for these at pick up spots to the recycling centres. Cans may also be metallic or steel, but people do not know the difference.

2. Preparation

At the collection center, a huge magnet is rolled over them as they move on the conveyor belt to pull out all the metal and steel cans. Only the aluminum cans are washed, crushed, condensed in to 30-pounds briquettes for other companies for further processing. The rest is also sorted and sent to their appropriate recycling centres.

3. Melting

The crushed cans are loaded into a burning furnace, where all printing and designs on the cans are removed, melted and blended with new (virgin) aluminum. The molten (liquid) aluminum is poured into moulds and made into bars called ingots.

4. Sheets

The ingots are then fed into powerful rollers, which flatten them into thin sheets of aluminum of about 25.4 in thickness. These thin sheets are rolled into coils and sold or sent to can-making factories. They use the aluminum coils to prepare cans and containers for other food and drink manufacturers. It is estimated that cans collected at collection points take up to 60 days to be appear in the shops again as new cans containing your favorite soda, juice or food.

3.5.3 Glass Recycling

How is glass recycled?

Recycling glass starts in your home. There is a reason why many local types of council provide different containers for green, brown, plain glass and even glass from broken windows. The reason is that they are all made very differently and mixing them can create huge problems at the recycling center.

1. Collection

Many cities have collection spots. Trucks may also pick them up from your home, or you may be required to drop them off at a point in your town. In all cases, try to do what the authorities have suggested. So, be sure you know the various glass types that are collected from your home. Always wash and separate them into the required grades for collection.

2. Cleaning and Crushing

The glass is transported to the processing plant where contaminants such as metal caps and plastic sleeves are removed. Different grades are treated separately. Clean glass is then crushed into small pieces called cullet. Cullet is in high demand from glass manufacturers. It melts at a lower temperature and it is cheaper than raw glass materials.

3. Ready for Use

The cullet is then transported to glass-making factories. Here, it is mixed with sand, soda ash and limestone. It is heated at very high temperature and melted into liquid glass. This liquid is then poured into moulds that give glass its shape. Glass is used for many things—depending on what grade they were recycled from. A few items made of recycled glass include fibre-glass, countertops, bottles and jars.

3.6 Advantages of Waste Recycling

Waste recycling has some significant advantages. Recycling turns materials that would otherwise become waste into valuable resources and generates a host of environmental, financial, and social benefits. It prevents the emission of many greenhouse gases and water pollutants. Recycling decreases the need to extract and process virgin material, which pollute air, soil and water with toxic material. It saves energy necessary to produce new materials. It can save from 1.5 to 5 times more energy than is generated by incineration. In summary, waste recycling offers the following advantages:

i. For the Managers of Waste

- Reduction of waste volume
- Cost savings in collection, transport, and disposal
- Longer life span for landfills
- Reduction of adverse environmental impacts.

ii. For the Economy

- Reduction of imports (for fertilisers or soil amendments) and thus less foreign currency required
- Job opportunities and income for the people

- Cheap products (made from recycled materials) for the poor
- Reduces the amount of energy required to manufacture new products.

iii. For the Environment

- Sustainable use of resources: for example, less energy consumption and thus less pollution
- Reduced amount of waste going to storage sites, resulting in a more manageable system
- Reduces environmental impacts arising from waste treatment and disposal
- Makes the surroundings cleaner and healthier.

3.7 Waste Reuse

Waste recycling and reuse are very closely associated terms which are often used interchangeably but are not essentially the same when viewed closely at its micro levels. Whereas waste recycling describes the reprocessing of waste materials into new useful products of the same or varied type from the original waste, waste reuse is the application of waste materials to same or different use by a different user. This is essentially very advantageous given that the term waste is a relative description of use of materials to satisfy human needs. Commonly reused materials include clothing materials, jewelry and trinkets, kitchen utensils, household furniture, books and electronic equipment and to a larger extent motor vehicles and other heavy machinery.

Waste reuse is very economical and a ready aid to the less ostentatious and the poor. However, it may pose serious environmental and health challenges as the disposal challenges are shifted to the less endowed who may not have the education and capacity to dispose the waste finally.

4.0 CONCLUSION

In conclusion, waste recycling involves all processes applied to preserve waste materials and put it into further use. Successful recycling of waste starts with separation of the waste at point of generation which ensures the quality of the waste product as a potential raw material for future processing into new desirous products. Waste reuse goes further to describe the continued use of a product by another user when the initial owner or user had done with the said materials and discarded them. Product quality, re-use and or recycling potential are some of the major considerations to be taken to minimise waste. Waste recycling and reuse has great economic advantages aside from its environmental friendly and sustainability considerations.

5.0 SUMMARY

You have seen that recycling is processing used materials (waste) into new, useful products. This is done to reduce the use of raw materials that would have been used. Recycling also uses less energy and great way of controlling air, water and land pollution. Effective recycling starts with household (or the place where the waste was created). In many serious countries, the authorities help households with bin bags with labels on them. Households then sort out the waste themselves and place them in the right bags for collection. This makes the work less difficult.

Items usually recycled include Plastic waste (plastic bags, water bottles, rubber bags and plastic wrappers), Glass waste (broken bottles, beer and wine bottles), Aluminum waste (Cans from soda drink, tomato, fruit cans and all other cans can be recycled).

Recycling is beneficial in many ways. It helps protect the environment, pollution of the air, land, water and soil is reduced, it conserves natural resources and saves energy.

6.0 TUTOR-MARKED ASSIGNMENT

1 Define the term “waste recycling”.
2 Enumerate 5 waste materials that can be recycled at household level.
3 State the advantages of waste recycling.

7.0 REFERENCES/FURTHER READING

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UNIT 3 INTEGRATED WASTE MANAGEMENT

CONTENTS

1.0 INTRODUCTION

In the last units, you learned how to describe various methods and models of sound waste management including waste minimisation, waste reduction, recycling and reuse, composting, incineration, sanitary land fill etc. you were able to appreciate the individual benefits and challenges of each of these waste management techniques and technologies. In this unit, we present to you a good description and vivid illustration of yet a sound waste management model which is, some kind of interplay of the various waste management techniques and methods.

This is called integrated waste management. You will find in the unit yet another interesting presentation.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define integrated waste management
- outline the guiding principles of integrated waste management
- illustrate integrated waste management using a named waste type
- enumerate the benefits of integrated waste management.

3.0 MAIN CONTENT

3.1 Concept of Integrated Waste Management

3.1.1 What is Integrated Waste Management?

Integrated Waste Management, or IWM, is a tool to determine the most energy-efficient, least-polluting ways to deal with the various components and items of a community's solid waste stream. The IWM hierarchy is based upon the material and energy that is embodied in solid waste and that is associated with its recycling and disposal.

3.1.2 The Goals of Integrated Waste Management

The twin goals of IWM are to:

(1) Retain as much as possible of that energy and those materials in a useful state, and
(2) Avoid releasing that energy or matter into the environment as a pollutant.

3.2 Hierarchy of Integrated Waste Management

Integrated waste management sets up a hierarchy of approaches and technologies for managing solid waste in order to meet these goals. Generally, the farther "up" the hierarchy from which the technology is chosen, the more benefits in efficiency and retained economic value.

The very highest option in the hierarchy is, don't create the solid waste in the first place, and is termed “source reduction.” Source reduction can be done in several ways:

- Manufacturing processes can be devised which create fewer or less toxic waste by-products
- Consumers can choose not to purchase products with excessive packaging or

- Consumers can choose not to purchase products which are unnecessary "luxuries," which require unjustifiably large amounts of energy or natural resources to manufacture, or which cause toxic waste problems in manufacture, use, or disposal.

The other higher level IWM options are (in order):

Reuse - The use of a product more than once in its same form for the same or similar purpose.

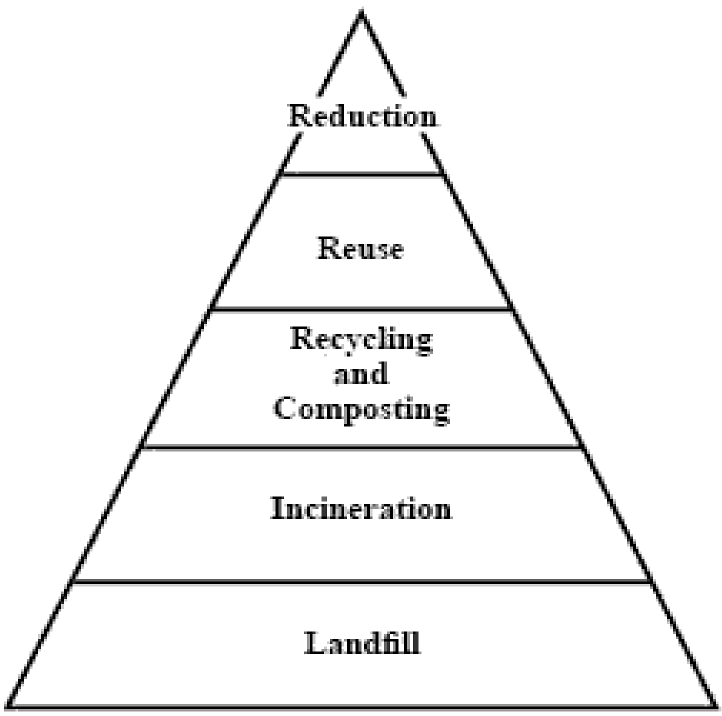

Fig: 3.1(a): Hierarchy of Integrated Solid Waste Management
Source: http://ohioline.osu.edu/cd-fact/images/0106_1.gif

Recycling -- The process, by which materials otherwise destined for disposal are collected, processed, remanufactured into the same or different product, and purchased as new products.

Composting -- The controlled process whereby organic materials are biologically broken down and converted into a stabilised humus material.

Materials retain their value for longer periods of time if they are handled within these “top four” levels of the IWM hierarchy.

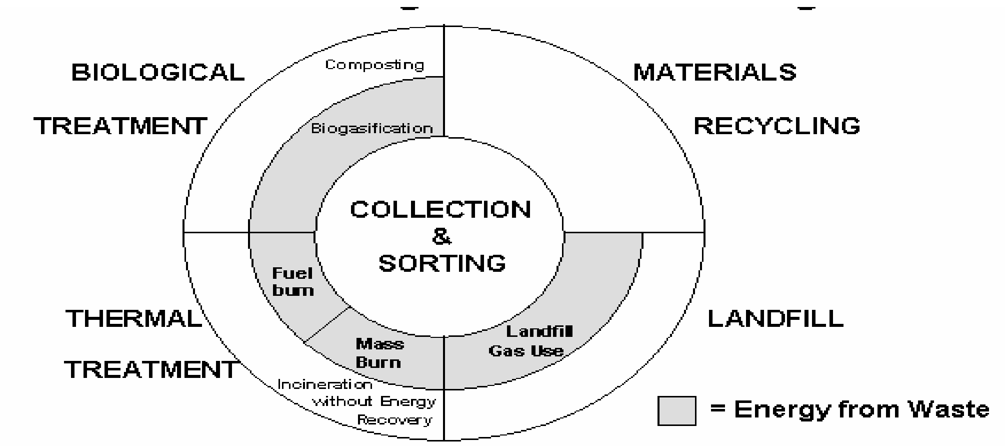

Fig.3.1 (b): Elements of Integrated Solid Waste Management
Source: http://viso.ei.jrc.it/iwmlca/ in http://www.cyen.org/innovaeditor/assets/Solid%20waste%20 management.pdf***).***

3.2.1 Integrated Waste Management (IWM): The Case of the Corrugated Box

- Energy is used to transform raw materials into a corrugated cardboard box. The first consideration for the box in a waste management planning process is to look at strategies for source reduction, or not using the box at all, if it represents excessive packaging (or using alternative packaging which requires fewer raw materials and less energy to manufacture; or packaging which is more readily re-usable or recyclable, etc.)
- After unpacking the TV set that was delivered in the box, the Smiths discard it into the waste stream. The box's utility/value derives from the properties of its current ordered state (rectangular, dry, strong, closeable, etc.)
- The highest and best use for the box is to re-use it again as a box. The management strategy would then be to keep the box from becoming crushed, wet or otherwise damaged, in order to reuse it as packaging several more times
- If it is already crushed, the next best thing is to recycle it -- to expend new energy to transport it to a paper mill and process it into a new product, then re-sell it, etc
- If it can't be recycled for some reason, several options are available which limit the use of the box’s energy to a one-time recapture. The box might be composted for use as a soil amendment; made into refuse-derived fuel to be burned in a boiler for its energy value; or it might be mass-burned (incineration with energy recovery) together with mixed solid waste to produce steam or electricity

- The next choices are simply to reduce the volume of the waste before disposal. Baling the box is one option, as is burning it without energy recovery, just to reduce the volume to ash
- Finally, after all else has been considered or done, land filling (burial) is the last resort. Not only will the box exit the loop of economic usefulness, but it may become part of a pollution problem and, at least, occupy costly landfill space
- When we choose a waste management option for the box after it has been used once.

Goal No.1 of IWM is to retain as much of its current usefulness as possible in order to avoid having to use the same amount of wood pulp and energy to make another box to do the same job again.

Goal No. 2 is to keep the energy-matter represented by that box tied up in a useful product and not released as a pollutant (which the box might become if it ends up along a roadside as litter, or buried in a landfill where its usefulness will be forgone indefinitely).

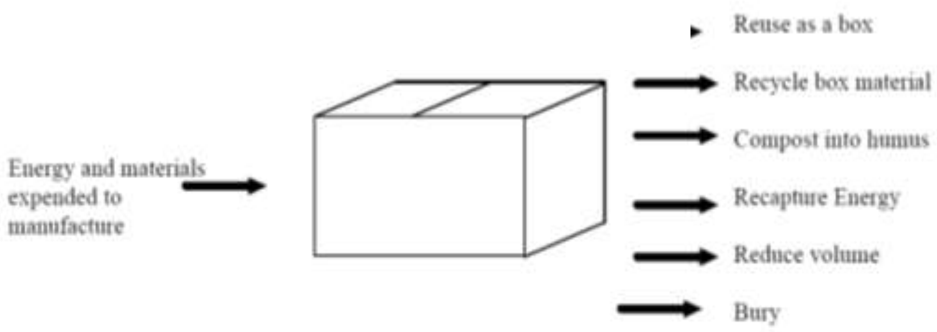

Fig. 3.1©: Box Potential According to the IWM Hierarchy
Source: http://www.usda.gov/rus/water/docs/swmgmt.pdf

3.3 Practical Applications of IWM for Rural Communities

3.3.1 IWM and Local Economies

There are several ways to describe integrated waste management and its benefits. Perhaps the best way for our purposes is to look at the effect of solid waste on the economy and environment of a community. The job creation and economic potential of IWM stem from the following:

i. The economic value of recovered materials as re-usable products (either "as is," or through refurbishment) or as raw materials.

ii. The opportunity for simpler, more decentralised sometimes more labor-intensive solid waste management solutions which can create jobs in rural communities. Such decentralized solutions often work better in more sparsely-populated, rural communities because they do not depend upon high population densities to achieve economies of scale (e.g., centralised solutions may be expensive in rural areas because of the long transport distances required to serve relatively few people. Community or backyard composting of yard, food, and other organic waste is often better suited to rural areas because it saves transportation of these heavy waste stream components over relatively longer distances than in urban areas).

iii. Opportunities to intentionally create and recruit businesses and industries which use the waste streams of existing business as feed stocks. Such arrangements can help to plug economic "leaks" from our rural communities. Such methods can be integrated into the strategies of local business development specialists, industrial recruiters, and existing industry managers.

iv. The short-term and long-term economic value to rural communities of avoided land filling.

Benefits of this include:

- Deferring expensive landfill sitting processes
- Reducing annual operation and maintenance costs for existing landfills
- Reducing transportation costs to the community and
- Reducing the rate at which successive cells of expensive new subtitle **D** landfills must be developed and lined.

Community resources saved at the landfill can be diverted into economic development efforts.

The traditional economic model views economic activity – and its benefits – as the extraction of raw materials, their manufacture or processing, the sale of the product or commodity, and then its use by consumers. The rest of the life cycle of the raw materials and energy consists of disposal at some cost, and control of the associated pollutants. In other words, once a product, by-product or material becomes classified as a "waste," it has not only zero value but a negative value, i.e., the cost to local government of "disposal," pollution control, and the health cost to society of any pollutants not successfully controlled.

3.3.2 Benefits of Integrated Waste Management

Integrated waste management provides a new approach to solid waste. It seeks to keep products, the materials and energy embodied in their manufacture, and the by-products of their manufacture, in the productive part of the economy -- and out of the "waste" stream -- as long as possible, and to wring as much economic value out of them as possible before giving up on them as "waste." When this is done, the following happens:

a. Local and regional economies benefit by the continued exchange value of the reclaimed materials and products and the jobs created in reprocessing and reselling them.

b. Private businesses often find these materials a cheaper source of raw materials than virgin sources, especially when virgin materials are becoming scarce, more difficult to access, under more stringent regulatory controls, or must be shipped from far away.

c. It often takes less energy to reprocess or re-manufacture these reclaimed materials than raw materials, because of the energy already embodied in their original manufacture. This increases the value of these materials to industry, since energy savings in manufacturing can be added to the acquisition savings for a more competitive "bottom line."

d. National and global resource natural depletion is reduced, contributing to a more sustainable long-term economy.

e. Local governments benefit through reduced cost of ultimate "disposal" of the materials because many would-be "waste" materials and products are diverted from their landfills for an extended period of time.

f. Pollution from landfills is reduced because many toxic or otherwise polluting materials are diverted from the landfills, and because the overall volume of land filled material is reduced.

Another valuable feature of IWM is that it applies to all solid waste situations, from the largest city or industry to commercial and office waste streams, right down to the individual household. This means that its positive impact can be understood and enjoyed by the whole community, not just by solid waste managers and planners. It also means that the economic impact of IWM can be felt by all economic sectors in the community.

3.4 Guiding Principles of IWM

Experience has shown that designing one neatly-packaged, systematic approach for communities to achieve the greatest possible measure of IWM benefits may be difficult. However, the following set of integrated waste management application principles has opened up some new opportunities in guiding the community planning process in our region.

We’ve found that these "application principles" are consistent with the values, culture, resources and preferences commonly held in rural areas.

3.4.1 Principle 1: Search for Value

Solid waste only becomes "waste" when people lose sight of its value. Virtually everything in the "waste stream" has residual value for someone or some business in the community. The key message to the IWM planning team and the community is, find the value and redirect it back into the community. Part of this process is to find or create local markets for reused, recycled, reprocessed or composted materials.

Another important element in redirecting value is to create new local enterprises based on waste stream redirection.

3.4.2 Principle 2: Start Upstream

If we think of solid waste as a flow of materials entering the community at different places, traveling through the community as they are used one or more times, and ending up in other places, we can use the analogy of a river or stream. Intercepting a would-be waste item as far "upstream" as possible after its initial use has several advantages:

- It often has more value left in it
- It is usually cleaner & easier to re-use or recycle
- Less energy has been wasted transporting it and
- The original purchaser of the item has the first opportunity to re-use it.

In this way of looking at solid waste management, we try to intercept each item as far upstream as possible, redirecting it before it becomes defined as "waste." First owners of the item get the first chance to re-use it. Waste management becomes the responsibility of each member of the community, and doesn't just "get passed on to the ward, city or town."

3.4.3 Principle 3: Use the IWM Hierarchy to Retain Value

The integrated waste management hierarchy gives us a systematic way to search for the value in would-be waste items. For example, it suggests that re-using an item usually captures more value and saves more money than, say, burning it. In combination with Principle 2, we can systematically look at each component of the waste stream.

3.4.4 Principle 4: Start Where the Community Is

Each rural community - and each person, business, institution and local government in the community - has its own unique culture and way of looking at solid waste and its economy. The solid waste management process works best if it reflects both the values of the community and the local approach to waste management practices. Some communities may have specific waste issues on the table, such as toxic wastes, cost of disposal, tipping fees, flow control, meeting regulatory mandates, or controversial waste management technologies. Not only will one waste management strategy not work for all rural communities, but even different industries, businesses, or neighborhoods may prefer different approaches.

Planners should be sensitive to what motivates each waste generator, and encourage innovative, localised solutions.

3.4.5 Principle 5: Keep Materials Separated

Mixing unlike solid wastes together often contaminates otherwise useful materials and reduces their value.

It also causes additional processing to be done to re-separate the materials or items farther "downstream."

Materials and items are often transported great distances and handled several times, wasting public funds which could better be used elsewhere.

3.4.6 Principle 6: Minimise Handling, Transportation and Processing

This is related to principles 2, 3 and 5. The earlier in the "waste stream" an article or material can be intercepted and returned or diverted to its next use, the more money the community saves in hauling and handling costs -- including vehicle fuel and its polluting effects, labor, and equipment costs.

3.4.7 Principle 7: Start with the Low-Tech, Low-Cost, Flexible Solutions

People find it easier to participate in low-technology solid waste solutions. It is easier to visualize doing your part in a backyard or small-town composting operation than to send your garbage to a high-tech, regional incinerator in the next county. Low-tech solutions usually cost less to put in place and less to abandon, dismantle, or alter if they are no longer viable. Citizens who have participated first hand in such solutions will learn their pros and cons, and may be better able to understand the need for higher tech and/or regional solutions at a later date.

Solid waste management is a rapidly-changing endeavor. A community's strategy for dealing with old newspapers should include a contingency plan for rising and falling paper recycling markets. Without an alternative solution such as storage or composting, a mountain of old newsprint can get out of control.

When the market prices are low, inflexible contingency plans may trap a program in a system which is not economically viable. When prices are high, an inflexible system may not allow a community to take full advantage of the market.

3.4.8 Principle 8: Measure Results in a Meaningful Way

Three guidelines of the “total quality” philosophy in business are "measure, measure, and measure." In order to monitor the success of a rural community's solid waste management strategies, solid waste managers must first measure results against the objectives the community intended to achieve. Secondly, it must measure the total costs and benefits in some agreed-upon way. In a community whose primary motivation is to defer the sitting of a new landfill, measuring reductions in compacted-in-place, buried waste may be the most appropriate and important measure of success. In a community which chooses to use solid waste management to create new jobs, the number of jobs created and the dollar value of materials and items recovered may be the most important measure.

At the same time, the costs to the community of achieving their solid waste goals should not be ignored.

For example, if the community seeking to extend the life of its landfill decides to ship waste out of the county, it should have some way of measuring the costs associated with hauling, liability risks, reduced motivation for waste reduction within the community, etc. Some form of full cost accounting should be agreed upon and adopted by the community, so that offsetting costs and benefits of each solution can be recognised and evaluated.

4.0 CONCLUSION

Integrated Solid Waste Management (ISWM) takes an overall approach to creating sustainable systems that are economically affordable, socially acceptable and environmentally effective. An integrated solid waste management system involves the use of a range of different treatment methods, and key to the functioning of such a system is the collection and sorting of the waste. It is important to note that no one single treatment method can manage all the waste materials in an environmentally effective way. Thus all of the available treatment and disposal options must be evaluated equally and the best combination of the available options suited to the particular community chosen. Effective management schemes therefore need to operate in ways which best meet current social, economic, and environmental conditions of the municipality.

5.0 SUMMARY

In this unit, you have been given a good description of the principles and practice of integrated waste management a hypothetical master solution to all waste management challenges. Actually, it combines all the gains and advantages of the different waste management techniques that form part of the integral constituents of this strategy. In this, the principal focus is to reduce the waste as much as possible, and encourage the reuse of materials for the original intended purposes or other useful alternatives and recycle the recyclable ones. This is known as the 3Rs principle whose successes largely depend on waste separation or segregation at source. Other elements of integrated waste management include composting, incineration and landfill. Despite the fact that integrated waste management does not discriminate on the waste type, it lays itself open to and encourages minimisation, reuse and other energy recovery techniques and wealth generation from waste. It also creates employment, is eco-friendly and sustainable.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define the term “integrated waste management”.
2. State the goals of integrated waste management.
3. Outline the guiding principles of integrated waste management.
4. Enumerate 5 benefits of integrated waste management.

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MODULE 3

UNIT 1 WASTE MINIMISATION/REDUCTION

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt about the various technologies involved in the management of solid waste. In this unit, we will describe the concept of waste minimisation, a procedure for limiting the occurrence of waste or in the alternative reducing the volume of waste to be handled and treated. As usual, the lesson is going to be a living type as the subject of waste minimisation and reduction is our everyday experience.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define waste minimisation
- outline the processes of waste minimisation

- classify waste minimisation techniques
- state the importance of waste minimisation.

3.0 MAIN CONTENT

3.1 INTRODUCTION

Traditionally, waste is viewed as an unnecessary element arising from the activities of any industry. In reality, waste is a misplaced resource, existing at a wrong place at a wrong time. Waste is also the inefficient use of utilities such as electricity, water, and fuel, which are often considered unavoidable overheads. The costs of these wastes are generally underestimated by managers. It is important to realise that the cost of waste is not only the cost of waste disposal, but also other costs such as: - disposal cost, purchase cost of wasted raw material, production cost for the waste material, management time spent on waste material, lost revenue for what could have been a product instead of waste and potential liabilities due to waste.

3.2 What is Waste Minimisation?

Waste minimisation can be defined as "systematically reducing waste at source". It means:

- Prevention and/or reduction of waste generated
- Efficient use of raw materials and packaging
- Efficient use of fuel, electricity and water
- Improving the quality of waste generated to facilitate recycling and/or reduce hazard
- Encouraging re-use, recycling and recovery.

Waste minimisation is the process and the policy of reducing the amount of waste produced by a person or a society. It involves efforts to minimise resource and energy use during manufacture. For the same commercial output, usually the fewer materials are used, the less waste is produced. Waste minimisation usually requires knowledge of the production process, cradle-to-grave analysis (the tracking of materials from their extraction to their return to earth) and detailed knowledge of the composition of the waste.

Waste minimisation is also known by other terms such as waste reduction, pollution prevention, source reduction and cleaner technology. It makes use of managerial and/or technical interventions to make industrial operations inherently pollution free.

It should be also clearly understood that waste minimisation, however attractive, is not a panacea for all environmental problems and may have to be supported by conventional treatment/disposal solutions.

3.2.1 Processes of Waste Minimisation

a. Resource Optimisation

Minimising the amount of waste produced by organisations or individuals goes hand-in-hand with optimising their use of raw materials. For example, a dressmaker may arrange pattern pieces on a length of fabric in a particular way to enable the garment to be cut out from the smallest area of fabric.

b. Reuse of Scrap Material

Scraps can be immediately re-incorporated at the beginning of the manufacturing line so that they do not become a waste product. Many industries routinely do this; for example, paper mills return any damaged rolls to the beginning of the production line, and in the manufacture of plastic items, Off-cuts and scrap are re-incorporated into new products.

c. Improved Quality Control and Process Monitoring

Steps can be taken to ensure that the number of reject batches is kept to a minimum. This is achieved by increasing the frequency of inspection and the number of points of inspection. For example, installing automated continuous monitoring equipment can help to identify production problems at an early stage.

d. Waste Exchanges

This is where the waste product of one process becomes the raw material for a second process. Waste exchanges represent another way of reducing waste disposal volumes for waste that cannot be eliminated.

e. Ship to Point of Use

This involves making deliveries of incoming raw materials or components direct to the point where they are assembled or used in the manufacturing process to minimise handling and the use of protective wrappings or enclosures.

3.2.2 Classification of Waste Minimisation (WM) Techniques

The waste minimisation is based on different techniques. These techniques are classified as shown in figure 1.1

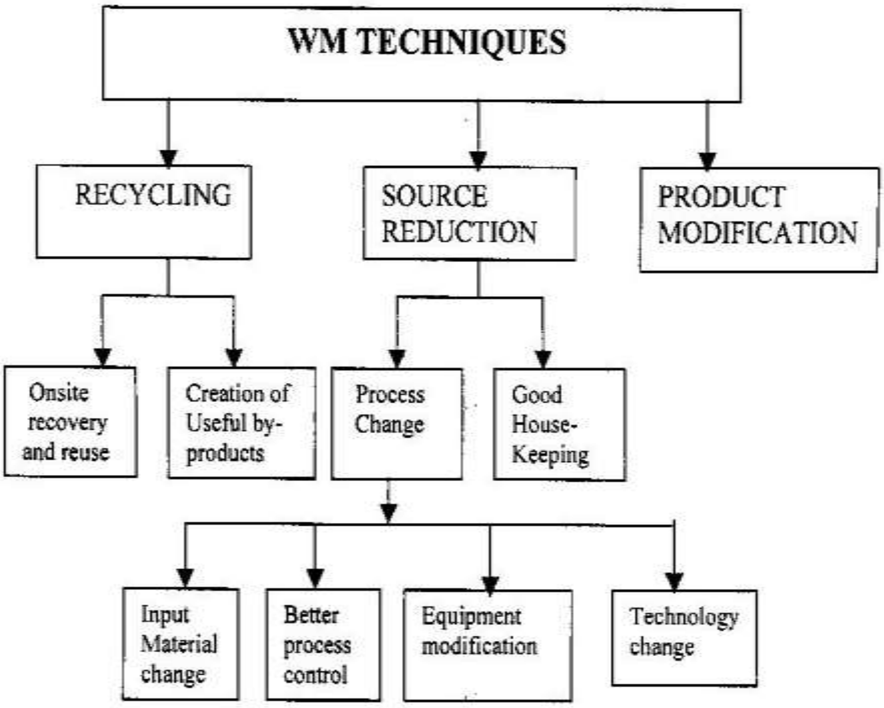

Fig. 1.1: Schematic Diagram of Waste Minimisation Techniques
Source:http://www.em-ea.org/Guide%20Books/book4/4.13%20Waste%20minimisation%20&%20resouce%20conservation.pdf

Source Reduction

Under this category, four techniques of WM are briefly discussed below:

a) Good Housekeeping- Systems to prevent leakages & spillages through preventive maintenance schedules and routine equipment inspections. Also, well-written working instructions, supervision, awareness and regular training of workforce would facilitate good housekeeping.

b) Process Change: Under this head, four CP techniques are covered:

   (i) Input Material Change - Substitution of input materials by eco-friendly (non-toxic or less toxic than existing and renewable) material preferably having longer service time.

   (ii) Better Process Control - Modifications of the working procedures, machine-operating instructions and process record keeping in order to run the processes at higher efficiency and with lower waste generation and emissions.

(iii) Equipment Modification - Modification of existing production equipment and utilities, for instance, by the addition of measuring and controlling devices, in order to run the processes at higher efficiency and lower waste and emission generation rates.

(iv) Technology Change - Replacement of the technology, processing sequence and/or synthesis route, in order to minimise waste and emission generation during production.

c) Recycling

i) On-Site Recovery and Reuse - Reuse of wasted materials in the same process or for another useful application within the industry.

ii) Production of useful By-product - Modification of the waste generation process in order to transform the wasted material into a material that can be reused or recycled for another application within or outside the company.

d) Product Modification

Characteristics of the product can be modified to minimise the environmental impacts of its production or those of the product itself during or after its use (disposal).

3.2.3 Importance of Waste Reduction

In affluent countries, the main motivations for waste reduction are frequently related to the high cost and scarcity of suitable sites associated with the establishment of new landfills, and the environmental degradation caused by toxic materials in the deposited wastes. The same considerations apply to:

3) Large metropolitan areas in developing countries that generally are surrounded by other populous jurisdictions, and
4) Isolated small communities (such as island communities).

However, any areas that currently do not have significant difficulties associated with the final dispositions of their wastes disposal pressures can still derive significant benefits from encouraging waste reduction. Their solid waste management departments, already overburdened, are ill-equipped to spend more funds and efforts on the greater quantities of wastes that will inevitably be produced, if not otherwise controlled, as consumption levels rise and urban wastes change.

3.3 Key Concepts in Municipal Waste Reduction

Action for waste reduction can take place at both the national and local levels.

3.3.1 At the National Level

Some strategies for waste reduction include:

- Redesign of products or packaging
- Promotion of consumer awareness and
- Promotion of producer responsibility for post-consumer wastes.

3.3.2 At the local level

The main means of reducing waste are:

- Diversion of materials from the waste stream through source separation and trading
- Recovery of materials from mixed waste
- Pressure on national or regional governments for legislation on redesigning packaging or products and
- Support of home composting, either centralized or small-scale.

3.3.3 Household Waste Minimisation

- Waste minimisation at household level can be achieved by the adoption of a variety of strategies. But in a domestic situation, the potential for minimisation is often dictated by lifestyle. Some people may view it as wasteful to purchase new products solely to follow fashion trends when the older products are still usable. Adults working full-time have little free time, and so may have to purchase more convenient foods that require little preparation, or prefer disposable nappies if there is a baby in the family

- Appropriate amounts and sizes can be chosen when purchasing goods; buying large containers of paint for a small decorating job or buying larger amounts of food than can be consumed create unnecessary waste. Also, if a pack or can is to be thrown away, any remaining contents must be removed before the container can be recycled

- Home composting, the practice of turning kitchen and garden waste into compost can be considered waste minimisation. Individuals can reduce the amount of waste they create by buying fewer products and by buying products which last longer.

Mending broken or worn items of clothing or equipment also contributes to minimising household waste

- The amount of waste an individual produces is a small portion of all waste produced by society, and personal waste reduction can only make a small impact on overall waste volumes. Yet, influence on policy can be exerted in other areas. Increased consumer awareness of the impact and power of certain purchasing decisions allows industry and individuals to change the total resource consumption. Consumers can influence manufacturers and distributors by avoiding buying products that do not have eco-labeling, which is currently not mandatory, or choosing products that minimise the use of packaging
- Where reuse schemes are available, consumers can be proactive and use them.

3.4 Systems of Waste Reduction

3.4.1 Industrialised Countries

Perhaps in no field of municipal solid waste management are the differences between the industrialised countries and the developing countries so apparent as in waste reduction and materials recovery.

Rising overall living standards and the advent of mass production have reduced markets for many used materials and goods in the affluent countries whereas, in most of the economically developing countries, traditional labour-intensive practices of repair, reuse, waste trading, and recycling have endured. Thus, there is a large potential for waste reduction in economically developing countries, and the recovery of synthetic or processed materials is now being emphasised. Public or consumer financing of the full range of initiatives for waste reduction (from changes in manufacturing and packaging, to waste reduction audits to identify waste reduction opportunities) are practiced by several affluent industrialised countries.

One of the main motivations, from the point of view of municipal authorities, is to reduce materials that must be collected and deposited in landfills. At the national level, under the concept of producer responsibility, governments have created agreements and legal frameworks designed to reduce the generation of waste. For instance, industry is given responsibility for achieving certain levels of packaging reduction goals of a certain percentage within a given time period.

3.4.2 Developing Countries

In many developing countries, waste reduction occurs naturally as matter of normal practice because of the high value placed on material resources by the people, as well as other factors.

Consequently, reuse of a variety of materials is prevalent. The motivations for materials reuse in developing countries include: scarcity or expense of virgin materials; the level of absolute poverty; the availability of workers who will accept minimal wages; the frugal values of even relatively well-to-do households; and the large markets for used goods and products made from recycled plastics and metals. Wastes that are of no use in affluent societies and cannot be recycled have value in developing countries e.g. coconut shells and dung used as fuel. If one takes into account the use of compost from dumps sites as well as materials recovery, in countries like India, Vietnam, and China, the majority of municipal wastes of all kinds are ultimately utilised.

Waste reduction that could be achieved by legislation and protocols (such as agreements to change packaging) is not, at present, a high priority in these countries, although some are now moving in this direction. Because unskilled labour costs are low and there is a high demand for manufactured materials, manufacturers can readily use leftovers as feedstock or engage in waste exchange. Residuals and old machines are sold to less advanced, smaller industries. Public health is benefiting from plastic and boxboard packaging that reduces contamination of foods, and much of the superior packaging is recovered and recycled.

In offices and institutions, cleaners and caretakers organise the sale of paper, plastics, etc. At the household level, gifts of clothes and goods to relatives, charities, and servants are still significant in waste reduction.

All cities and towns have markets for used goods. However, the greatest amount of materials recovery is achieved through networks of itinerant buyers, small- and medium-sized dealers, and wholesaling brokers. The extent to which the waste trading enterprises are registered ("formalised") varies in developing regions: in Latin America and Asia, there is more formal registration than in Africa. The system is adaptive to market fluctuations, as the lowest level workers form a dispensable labour cushion: they must find other work, if they can, when there is reduced demand for the materials that they sell.

From the point of view of waste reduction, the traditional practices of repair and reuse, and the sale, barter, or gift-giving of used goods and surplus materials are an advantage to the poorer countries. Quantities of inorganic post-consumer wastes entering the MSW stream would be higher if these forms of waste reduction did not exist.

4.0 CONCLUSION

In conclusion, waste minimisation involves all processes and techniques applied to preclude as much as possible or reduce to the barest minimum the occurrence of waste and wasteful situations in the production, distribution and use of any product and services. Waste minimisation strategies are applied at different levels especially in the industries during product design and production and continue up to the consumer level.

At the consumer/household level, discrimination as to what to buy and in what quantity, product quality, re-use or recycling etc. are some of the major considerations to be taken to minimise waste. Household waste minimisation or reduction is influenced by level of knowledge, socio-economic status and lifestyle.

5.0 SUMMARY

In this unit, our focus has been on the understanding of the concept of waste minimisation/reduction. You have seen that although waste is inevitable, it can be minimised or drastically reduced through quality production and considerate use.

When manufacturers build quality into their products through good housekeeping and process change and recycle defective ones; and consumers make considerate purchases and good use of products including re-use, exchange (barter) and recycle of materials, the bulk of waste in the municipal waste stream would have been reduced. In the next unit, we shall be discussing waste recycling and reuse.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define waste minimisation.
2. Outline the processes of waste minimisation.
3. Classify waste minimisation techniques.

7.0 REFERENCES/FURTHER READING

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UNIT 2 WASTE RECYCLING AND REUSE

CONTENTS

1.0 INTRODUCTION

In unit 1, you learnt the concept of waste minimisation, the processes and methods of minimising waste and the associated economic, social, health and environmental benefits inherent in waste minimisation. In this unit, you will learn the concept of waste recycling and reuse.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define waste recycling
- describe some waste recycling processes
- state the advantages and constraints to waste recycling
- differentiate between waste recycling and reuse.

3.0 MAIN CONTENT

3.1 What is Waste Recycling?

Recycling involves the collection of used and discarded materials which are processed and turn into making new products. It reduces the amount of waste that is thrown into the community dustbins thereby making the environment cleaner and the air more fresh to breath. From this definition recycling occurs in three phases: first the waste is sorted and recyclables collected, the recyclables are used to create raw materials. These raw materials are then used in the production of new products.

Serious attention has been shown by government and non-government agencies in the country on the need to recycle wastes having all recognised the importance of recycling wastes. However, the methodology for safe recycling of waste has not been standardised.

Currently, less than 7 %-15% of the waste is recycled in the country. If recycling is done in a proper manner, it will solve the problems of waste or garbage.

3.2 Steps Involved in Waste Recycling

The steps involved in the process prior to recycling include:

a) Collection of waste from doorsteps, commercial places etc.
b) Collection of waste from community dumps
c) Collection/picking up of waste from final disposal sites.

The sorting of recyclables may be done at the source (i.e. within the household or office) for selective collection by the municipality or to be dropped off by the waste producer at a recycling centres. The pre-sorting at the source requires public participation which may not be forthcoming if there are no benefits to be derived. Also a system of selective collection by the government can be costly. It would require more frequent circulation of trucks within a neighborhood or the importation of more vehicles to facilitate the collection.

Another option is to mix the recyclables with the general waste stream for collection and then sorting and recovery of the recyclable materials can be performed by the municipality at a suitable site. The sorting by the municipality has the advantage of eliminating the dependence on the public and ensuring that the recycling does occur.

The disadvantage however, is that the value of the recyclable materials is reduced since being mixed in and compacted with other garbage can have adverse effects on the quality of the recyclable material.

3.3 Strategies for Carrying out Waste Recycling

Before developing a strategy for implementing 3R practices, municipal authorities must answer the following questions:

- Who are the recyclers?
- What are the advantages of recycling solid waste?
- What is being recycled?
- What is not being recycled and why?
- What are the main challenges?
- What steps are necessary to improve the recycling and resource recovery of materials?

Ideally, the 3R (reduce, reuse and recycle) concept will be applied as early as possible in the waste generation and management chain so that managers of waste can:

- maintain the high material quality and value of recyclable waste materials
- reduce the loss of valuable natural resources and virgin raw materials
- limit pollution of land
- reduce long-distance transport of waste
- reduce landfill space requirements and environmental pollution
- minimise the costs of both production of goods and management of waste.

3.4 Recycling Materials

Almost every material can be recycled; however, the value of the recycled material can vary significantly depending on the demand and uses for it. Indeed the value of a material is the driving factor for private recycling initiatives or—in the case of many developing countries—the informal sector. If and how a material is recycled depends not only on local policies but also on the availability of a buyer, processing facilities, and a transport chain.

Most of the garbage generated in the household can be recycled and reused. Organic kitchen waste such as leftover foodstuff, vegetable peels, and spoilt or dried fruits and vegetables can be recycled by putting them in the compost pits that have been dug in the garden. Old newspapers, magazines and bottles can be sold to the waste vendor the man who buys these items from homes. In your own homes you can contribute to waste reduction and the recycling and reuse of certain items. Table below shows some household wastes that can be recycled or reused.

Table 2.1: Recyclable Household Wastes

S/No	Waste Item	Examples
1	Paper	Old copies, Old books Paper bags, Newspapers Old greeting cards Cardboard box
2	Plastic	Containers, Bottles Bags, Sheets
3	Glass and Ceramics	Bottles, Plates Cups,Bowls
4	Miscellaneous	Old cans,Utensils Clothes,Furniture

Source: http://edugreen.teri.res.in/explore/solwaste/recycle.htm

Waste Recycling can be further Illustrated using a Schematic Diagram as Shown in Figure 2.1 below.

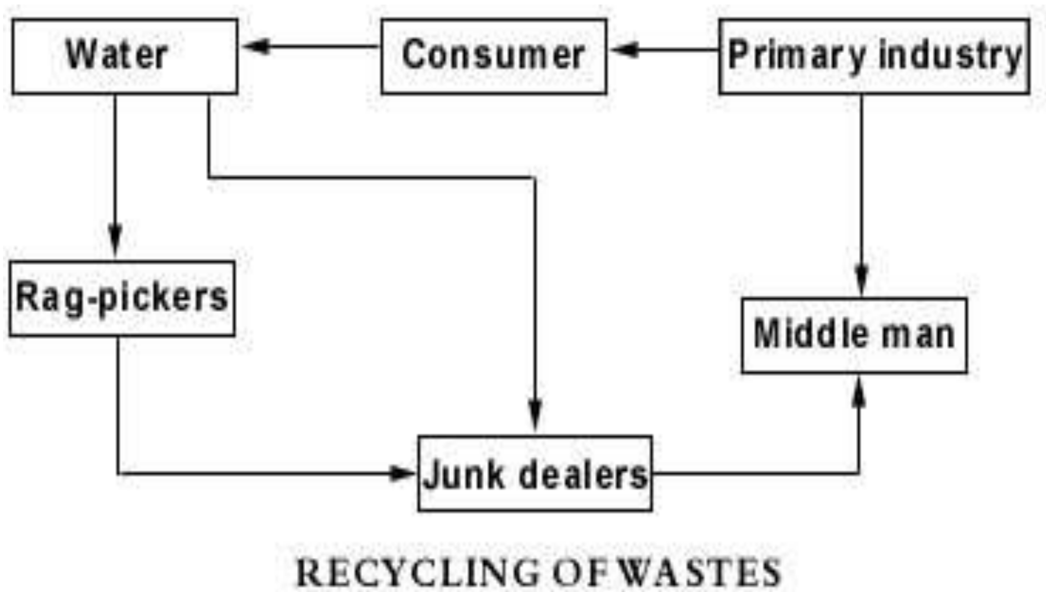

Fig. 2.1: Waste Recycling

Source: CPCB Report on Management of Municipal Solid Waste: (http://edugreen.teri.res.in/explore/solwaste/recycle.htm)

The table below gives an overview of typical recycling materials and their potential treatment options

Table 2.2: Important Recycling Materials: Advantages and Drawbacks

Material	Advantages	Drawbacks
Aluminum	• Aluminum has high market value • It can be easily recycled by shredding and melting • It can be recycled indefinitely because it does not deteriorate from reprocessing • Aluminum recycling requires significantly less energy than producing aluminum from ore.	○ Separate collection is important ○ Recycling is suitable only if a processing plant is available.
Batteries	• Recycling recovers valuable metals • Recycling protects the environment from heavy metals such as lead, cadmium, and mercury.	• Large variation in type and size of batteries requires specific recycling processes. • Older batteries have high heavy metal content.
Concrete and demolition waste	• Demolition waste can be crushed to gravel and be reused in road construction and landscaping	• Machinery required for crushing is maintenance intensive. • Recycled waste is valuable only if there is a lack of other construction material.
Glass	• Glass has a moderate market value • It can be sorted into colours and melted • Use of recycled glass saves	• Broken glass can contaminate and eliminate opportunities for recycling.

	energy compared with processing raw material. • Glass can be recycled indefinitely because it does not deteriorate from reprocessing.	
Organic waste	• Most commonly recycled by composting or anaerobic digestion	• Though compost is very beneficial to depleted soils, it still has a low market value
Other metal	• Scrap metal has a high market value (especially steel, copper, silver, and platinum) • It can be recycled indefinitely because it does not deteriorate from reprocessing.	• High-value metals (such as copper and silver) are incorporated in electronic devices, but extraction can cause severe environmental impacts.
Paper	• Paper can be easily recycled; however, quality deteriorates with each cycle. • Paper or cardboard from recycled paper requires less energy to produce and protects forests	• Appropriate technologies with circular processes are required to protect the environment.
Polyethylene terephthalate (PET)	• PET can be recycled if segregated from other waste. • Reprocessing into granulate is very easy. • PET has a high market value if processing plants are available.	• More “downcycling” than recycling occurs because quality decreases with every processing cycle.
Other plastic	• Other plastic, such as polyethylene or polyvinyl chloride, can be recycled but has less value on the market than PET; the value depends on recycling and manufacturing options in the vicinity.	• Recycling requires specific machinery
Electronic	• Electronic waste (such as	• Metals are often

waste	computers or mobile phones) contains high value metals. • Electronic items can be dismantled,reused, or recycled	covered with polyvinyl chloride or resins, which are often smelted or burned, causing toxic emissions

Source: http://www.tn.gov.in/cma/swm_in_india.pdf

3.5 Materials Recycling Process

3.5.1 Paper Recycling

This is the process of turning waste paper into new paper products.

There are three categories of paper that can be used as feed stocks for making recycled paper: mill broke pre-consumer waste, and post-consumer waste. The process of paper recycling involves mixing used paper with water and chemicals to break the paper down. The paper is then chopped up and heated, which breaks the paper down further into strands of cellulose, which is a type of organic plant material from the pulp. The resulting mixture called slurry is strained through screens, which remove any glue or plastic that may still be in the mixture then cleaned, de-inked, bleached, and mixed with water. Then this can be made into new paper. The same fibers can be recycled about seven times, but they get shorter every time and eventually are strained out.

Mill broke is paper trimmings and other paper scrap from the manufacture of paper, and the paper recycled internally in a paper mill. Pre consumer waste is material which left the paper mill but was discarded before it was ready for consumer use. Post-consumer waste is material discarded after consumer use, such as old corrugated containers, old magazines, old newspapers, office paper, old telephone directories, and residential mixed paper. Paper suitable for recycling is called “scrap paper”, often used to produce molded pulp packaging. The industrial process of removing printing ink from paper fibers of recycled paper to make deinked pulp is called deinking, an invention of the German Jurist Justus Claproth.

Fig. 2.2: Paper Recycling
Source: http://www.infotech2.com/?p=117

Steps in Paper Recycling

Here is how paper waste is recycled:

1. Collection, Transportation and Storage

The biggest task for paper recycling companies is probably the collection, transporting and sorting of waste paper. This is because we always add paper to other waste items and get them contaminated with food, plastics and metals. Sometimes collected paper is sent back to the landfills because they are too contaminated for use. Try to keep waste paper in separate grades at home or in the office —example, do not mix newspapers and corrugated boxes up.

Fig. 2.3: Types of Recycled Papers
Source:http://www.eschooltoday.com/waste-recycling/paper-waste-recycling-process.html

All paper recovered is sent to the recycling center, where it is packed, graded, put into bales and sent to the paper mill. At the mill, all the paper is stored in a warehouse until it is needed.

2. Repulping and Screening

From the storage shelves, they are moved into a big paper-grinding machine called a vat (pulper). Here the paper is chopped into tiny pieces, mixed with water and chemicals and heated up to break it down into organic plant material called fibre. After, it is screened to remove contaminants such as bits of plastic and globs of glue.

3. Deinking

This involves ‘washing’ the pulp with chemicals to remove printing ink and glue residue. Sometimes, a process called floatation is applied to further remove stubborn stains and stickies. Floatation involves the use of chemicals and air to create bubbles which absorb the stickies in the pulp.

4. Refining, Bleaching and Colour Stripping

Refining involves beating the recycled pulp to make them ideal for paper-making. After refining, additional chemicals are added to remove any dyes from the paper. It is then bleached to whiten and brighten it up.

5. Paper Making

At this stage, the pulp is ready to be used for paper. Sometimes new pulp (virgin pulp) is added to give it extra strength and smoothness. Water is added to the pulp and sprayed onto a large metal screen in continuous mode. The water is drained on the screen and the fibres begin to bond with each other. As it moves through the paper-making machines, press rollers squeeze out more water, heat them dry and coat them up. They are then finished into rolls.

3.5.2 Aluminum Recycling

In recent time, there has been a massive improvement in recycling aluminum cans. In 2003, it was reported that Americans recycled 62.6 billion aluminum cans. Those cans, placed end-to-end, could make 171 circles around the earth. Every minute an average of 105,800 aluminum cans are recycled. That is how important can recycling has become. But what is involved here?

1. Collection

Local councils provide special can recycling containers (bins) that are clearly marked. This helps people to know what to place in them. The various cans include soda cans, fruit cans and vegetable cans. Trucks come for these at pick up spots to the recycling centres. Cans may also be metallic or steel, but people do not know the difference.

2. Preparation

At the collection center, a huge magnet is rolled over them as they move on the conveyor belt to pull out all the metal and steel cans. Only the aluminum cans are washed, crushed, condensed in to 30-pounds briquettes for other companies for further processing. The rest is also sorted and sent to their appropriate recycling centres.

3. Melting

The crushed cans are loaded into a burning furnace, where all printing and designs on the cans are removed, melted and blended with new (virgin) aluminum. The molten (liquid) aluminum is poured into moulds and made into bars called ingots.

4. Sheets

The ingots are then fed into powerful rollers, which flatten them into thin sheets of aluminum of about 25.4 in thickness. These thin sheets are rolled into coils and sold or sent to can-making factories. They use the aluminum coils to prepare cans and containers for other food and drink manufacturers. It is estimated that cans collected at collection points take up to 60 days to be appear in the shops again as new cans containing your favorite soda, juice or food.

3.5.3 Glass Recycling

How is glass recycled?

Recycling glass starts in your home. There is a reason why many local types of council provide different containers for green, brown, plain glass and even glass from broken windows. The reason is that they are all made very differently and mixing them can create huge problems at the recycling center.

1. Collection

Many cities have collection spots. Trucks may also pick them up from your home, or you may be required to drop them off at a point in your town. In all cases, try to do what the authorities have suggested. So, be sure you know the various glass types that are collected from your home. Always wash and separate them into the required grades for collection.

2. Cleaning and Crushing

The glass is transported to the processing plant where contaminants such as metal caps and plastic sleeves are removed. Different grades are treated separately. Clean glass is then crushed into small pieces called cullet. Cullet is in high demand from glass manufacturers. It melts at a lower temperature and it is cheaper than raw glass materials.

3. Ready for Use

The cullet is then transported to glass-making factories. Here, it is mixed with sand, soda ash and limestone. It is heated at very high temperature and melted into liquid glass. This liquid is then poured into moulds that give glass its shape. Glass is used for many things—depending on what grade they were recycled from. A few items made of recycled glass include fibre-glass, countertops, bottles and jars.

3.6 Advantages of Waste Recycling

Waste recycling has some significant advantages. Recycling turns materials that would otherwise become waste into valuable resources and generates a host of environmental, financial, and social benefits. It prevents the emission of many greenhouse gases and water pollutants. Recycling decreases the need to extract and process virgin material, which pollute air, soil and water with toxic material. It saves energy necessary to produce new materials. It can save from 1.5 to 5 times more energy than is generated by incineration. In summary, waste recycling offers the following advantages:

iv. For the Managers of Waste

- Reduction of waste volume
- Cost savings in collection, transport, and disposal
- Longer life span for landfills
- Reduction of adverse environmental impacts.

v. For the Economy

- Reduction of imports (for fertilisers or soil amendments) and thus less foreign currency required
- Job opportunities and income for the people

- Cheap products (made from recycled materials) for the poor
- Reduces the amount of energy required to manufacture new products.

vi. For the Environment

- Sustainable use of resources: for example, less energy consumption and thus less pollution
- Reduced amount of waste going to storage sites, resulting in a more manageable system
- Reduces environmental impacts arising from waste treatment and disposal
- Makes the surroundings cleaner and healthier.

3.7 Waste Reuse

Waste recycling and reuse are very closely associated terms which are often used interchangeably but are not essentially the same when viewed closely at its micro levels. Whereas waste recycling describes the reprocessing of waste materials into new useful products of the same or varied type from the original waste, waste reuse is the application of waste materials to same or different use by a different user. This is essentially very advantageous given that the term waste is a relative description of use of materials to satisfy human needs. Commonly reused materials include clothing materials, jewelry and trinkets, kitchen utensils, household furniture, books and electronic equipment and to a larger extent motor vehicles and other heavy machinery.

Waste reuse is very economical and a ready aid to the less ostentatious and the poor. However, it may pose serious environmental and health challenges as the disposal challenges are shifted to the less endowed who may not have the education and capacity to dispose the waste finally.

4.0 CONCLUSION

In conclusion, waste recycling involves all processes applied to preserve waste materials and put it into further use. Successful recycling of waste starts with separation of the waste at point of generation which ensures the quality of the waste product as a potential raw material for future processing into new desirous products. Waste reuse goes further to describe the continued use of a product by another user when the initial owner or user had done with the said materials and discarded them. Product quality, re-use and or recycling potential are some of the major considerations to be taken to minimise waste. Waste recycling and reuse has great economic advantages aside from its environmental friendly and sustainability considerations.

5.0 SUMMARY

You have seen that recycling is processing used materials (waste) into new, useful products. This is done to reduce the use of raw materials that would have been used. Recycling also uses less energy and great way of controlling air, water and land pollution. Effective recycling starts with household (or the place where the waste was created). In many serious countries, the authorities help households with bin bags with labels on them. Households then sort out the waste themselves and place them in the right bags for collection. This makes the work less difficult.

Items usually recycled include Plastic waste (plastic bags, water bottles, rubber bags and plastic wrappers), Glass waste (broken bottles, beer and wine bottles), Aluminum waste (Cans from soda drink, tomato, fruit cans and all other cans can be recycled).

Recycling is beneficial in many ways. It helps protect the environment, pollution of the air, land, water and soil is reduced, it conserves natural resources and saves energy.

6.0 TUTOR-MARKED ASSIGNMENT

4 Define the term "waste recycling".
5 Enumerate 5 waste materials that can be recycled at household level.
6 State the advantages of waste recycling.

7.0 REFERENCES/FURTHER READING

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UNIT 3 INTEGRATED WASTE MANAGEMENT

CONTENTS

1.0 INTRODUCTION

In the last units, you learned how to describe various methods and models of sound waste management including waste minimisation, waste reduction, recycling and reuse, composting, incineration, sanitary land fill etc. you were able to appreciate the individual benefits and challenges of each of these waste management techniques and technologies. In this unit, we present to you a good description and vivid illustration of yet a sound waste management model which is, some kind of interplay of the various waste management techniques and methods.

This is called integrated waste management. You will find in the unit yet another interesting presentation.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define integrated waste management
- outline the guiding principles of integrated waste management
- illustrate integrated waste management using a named waste type
- enumerate the benefits of integrated waste management.

3.0 MAIN CONTENT

3.1 Concept of Integrated Waste Management

3.1.1 What is Integrated Waste Management?

Integrated Waste Management, or IWM, is a tool to determine the most energy-efficient, least-polluting ways to deal with the various components and items of a community's solid waste stream. The IWM hierarchy is based upon the material and energy that is embodied in solid waste and that is associated with its recycling and disposal.

3.1.2 The Goals of Integrated Waste Management

The twin goals of IWM are to:

(1) Retain as much as possible of that energy and those materials in a useful state, and
(2) Avoid releasing that energy or matter into the environment as a pollutant.

3.2 Hierarchy of Integrated Waste Management

Integrated waste management sets up a hierarchy of approaches and technologies for managing solid waste in order to meet these goals. Generally, the farther "up" the hierarchy from which the technology is chosen, the more benefits in efficiency and retained economic value.

The very highest option in the hierarchy is, don't create the solid waste in the first place, and is termed “source reduction.” Source reduction can be done in several ways:

- Manufacturing processes can be devised which create fewer or less toxic waste by-products
- Consumers can choose not to purchase products with excessive packaging or

- Consumers can choose not to purchase products which are unnecessary "luxuries," which require unjustifiably large amounts of energy or natural resources to manufacture, or which cause toxic waste problems in manufacture, use, or disposal.

The other higher level IWM options are (in order):

Reuse - The use of a product more than once in its same form for the same or similar purpose.

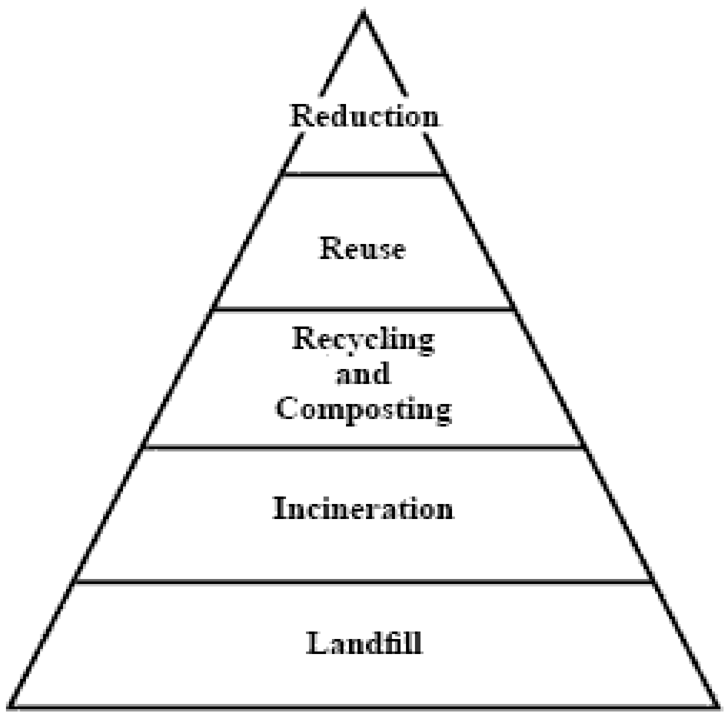

Fig: 3.1(a): Hierarchy of Integrated Solid Waste Management
Source: http://ohioline.osu.edu/cd-fact/images/0106_1.gif

Recycling -- The process, by which materials otherwise destined for disposal are collected, processed, remanufactured into the same or different product, and purchased as new products.

Composting -- The controlled process whereby organic materials are biologically broken down and converted into a stabilised humus material.

Materials retain their value for longer periods of time if they are handled within these “top four” levels of the IWM hierarchy.

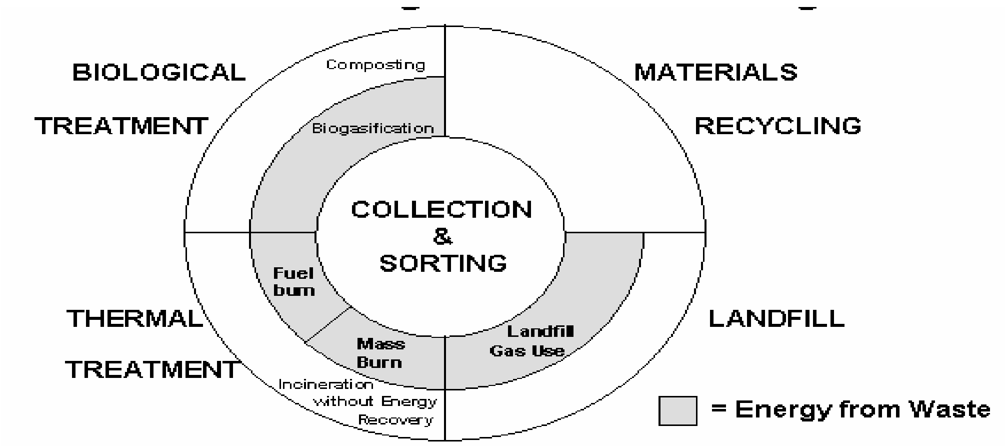

Fig.3.1 (b): Elements of Integrated Solid Waste Management
Source: http://viso.ei.jrc.it/iwmlca/ in
http://www.cyen.org/innovaeditor/assets/Solid%20waste%20 management.pdf***).***

3.2.1 Integrated Waste Management (IWM): The Case of the Corrugated Box

- Energy is used to transform raw materials into a corrugated cardboard box. The first consideration for the box in a waste management planning process is to look at strategies for source reduction, or not using the box at all, if it represents excessive packaging (or using alternative packaging which requires fewer raw materials and less energy to manufacture; or packaging which is more readily re-usable or recyclable, etc.)
- After unpacking the TV set that was delivered in the box, the Smiths discard it into the waste stream. The box's utility/value derives from the properties of its current ordered state (rectangular, dry, strong, closeable, etc.)
- The highest and best use for the box is to re-use it again as a box. The management strategy would then be to keep the box from becoming crushed, wet or otherwise damaged, in order to reuse it as packaging several more times
- If it is already crushed, the next best thing is to recycle it -- to expend new energy to transport it to a paper mill and process it into a new product, then re-sell it, etc
- If it can't be recycled for some reason, several options are available which limit the use of the box's energy to a one-time recapture. The box might be composted for use as a soil amendment; made into refuse-derived fuel to be burned in a boiler for its energy value; or it might be mass-burned (incineration with energy recovery) together with mixed solid waste to produce steam or electricity

- The next choices are simply to reduce the volume of the waste before disposal. Baling the box is one option, as is burning it without energy recovery, just to reduce the volume to ash
- Finally, after all else has been considered or done, land filling (burial) is the last resort. Not only will the box exit the loop of economic usefulness, but it may become part of a pollution problem and, at least, occupy costly landfill space
- When we choose a waste management option for the box after it has been used once.

Goal No.1 of IWM is to retain as much of its current usefulness as possible in order to avoid having to use the same amount of wood pulp and energy to make another box to do the same job again.

Goal No. 2 is to keep the energy-matter represented by that box tied up in a useful product and not released as a pollutant (which the box might become if it ends up along a roadside as litter, or buried in a landfill where its usefulness will be forgone indefinitely).

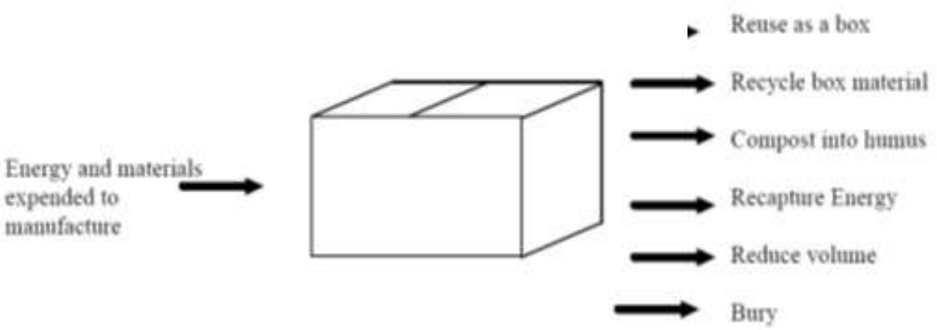

Fig. 3.1©: Box Potential According to the IWM Hierarchy
Source: http://www.usda.gov/rus/water/docs/swmgmt.pdf

3.3 Practical Applications of IWM for Rural Communities

3.3.1 IWM and Local Economies

There are several ways to describe integrated waste management and its benefits. Perhaps the best way for our purposes is to look at the effect of solid waste on the economy and environment of a community. The job creation and economic potential of IWM stem from the following:

i. The economic value of recovered materials as re-usable products (either "as is," or through refurbishment) or as raw materials.

ii. The opportunity for simpler, more decentralised sometimes more labor-intensive solid waste management solutions which can create jobs in rural communities. Such decentralized solutions often work better in more sparsely-populated, rural communities because they do not depend upon high population densities to achieve economies of scale (e.g., centralised solutions may be expensive in rural areas because of the long transport distances required to serve relatively few people. Community or backyard composting of yard, food, and other organic waste is often better suited to rural areas because it saves transportation of these heavy waste stream components over relatively longer distances than in urban areas).

iii. Opportunities to intentionally create and recruit businesses and industries which use the waste streams of existing business as feed stocks. Such arrangements can help to plug economic "leaks" from our rural communities. Such methods can be integrated into the strategies of local business development specialists, industrial recruiters, and existing industry managers.

iv. The short-term and long-term economic value to rural communities of avoided land filling.

Benefits of this include:

- Deferring expensive landfill sitting processes
- Reducing annual operation and maintenance costs for existing landfills
- Reducing transportation costs to the community and
- Reducing the rate at which successive cells of expensive new subtitle **D** landfills must be developed and lined.

Community resources saved at the landfill can be diverted into economic development efforts.

The traditional economic model views economic activity – and its benefits – as the extraction of raw materials, their manufacture or processing, the sale of the product or commodity, and then its use by consumers. The rest of the life cycle of the raw materials and energy consists of disposal at some cost, and control of the associated pollutants. In other words, once a product, by-product or material becomes classified as a "waste," it has not only zero value but a negative value, i.e., the cost to local government of "disposal,” pollution control, and the health cost to society of any pollutants not successfully controlled.

3.3.2 Benefits of Integrated Waste Management

Integrated waste management provides a new approach to solid waste. It seeks to keep products, the materials and energy embodied in their manufacture, and the by-products of their manufacture, in the productive part of the economy -- and out of the "waste" stream -- as long as possible, and to wring as much economic value out of them as possible before giving up on them as "waste." When this is done, the following happens:

a. Local and regional economies benefit by the continued exchange value of the reclaimed materials and products and the jobs created in reprocessing and reselling them.

b. Private businesses often find these materials a cheaper source of raw materials than virgin sources, especially when virgin materials are becoming scarce, more difficult to access, under more stringent regulatory controls, or must be shipped from far away.

c. It often takes less energy to reprocess or re-manufacture these reclaimed materials than raw materials, because of the energy already embodied in their original manufacture. This increases the value of these materials to industry, since energy savings in manufacturing can be added to the acquisition savings for a more competitive "bottom line."

d. National and global resource natural depletion is reduced, contributing to a more sustainable long-term economy.

e. Local governments benefit through reduced cost of ultimate "disposal" of the materials because many would-be "waste" materials and products are diverted from their landfills for an extended period of time.

f. Pollution from landfills is reduced because many toxic or otherwise polluting materials are diverted from the landfills, and because the overall volume of land filled material is reduced.

Another valuable feature of IWM is that it applies to all solid waste situations, from the largest city or industry to commercial and office waste streams, right down to the individual household. This means that its positive impact can be understood and enjoyed by the whole community, not just by solid waste managers and planners. It also means that the economic impact of IWM can be felt by all economic sectors in the community.

3.4 Guiding Principles of IWM

Experience has shown that designing one neatly-packaged, systematic approach for communities to achieve the greatest possible measure of IWM benefits may be difficult. However, the following set of integrated waste management application principles has opened up some new opportunities in guiding the community planning process in our region.

We've found that these "application principles" are consistent with the values, culture, resources and preferences commonly held in rural areas.

3.4.1 Principle 1: Search for Value

Solid waste only becomes "waste" when people lose sight of its value. Virtually everything in the "waste stream" has residual value for someone or some business in the community. The key message to the IWM planning team and the community is, find the value and redirect it back into the community. Part of this process is to find or create local markets for reused, recycled, reprocessed or composted materials.

Another important element in redirecting value is to create new local enterprises based on waste stream redirection.

3.4.2 Principle 2: Start Upstream

If we think of solid waste as a flow of materials entering the community at different places, traveling through the community as they are used one or more times, and ending up in other places, we can use the analogy of a river or stream. Intercepting a would-be waste item as far "upstream" as possible after its initial use has several advantages:

- It often has more value left in it
- It is usually cleaner & easier to re-use or recycle
- Less energy has been wasted transporting it and
- The original purchaser of the item has the first opportunity to re-use it.

In this way of looking at solid waste management, we try to intercept each item as far upstream as possible, redirecting it before it becomes defined as "waste." First owners of the item get the first chance to re-use it. Waste management becomes the responsibility of each member of the community, and doesn't just "get passed on to the ward, city or town."

3.4.3 Principle 3: Use the IWM Hierarchy to Retain Value

The integrated waste management hierarchy gives us a systematic way to search for the value in would-be waste items. For example, it suggests that re-using an item usually captures more value and saves more money than, say, burning it. In combination with Principle 2, we can systematically look at each component of the waste stream.

3.4.4 Principle 4: Start Where the Community Is

Each rural community - and each person, business, institution and local government in the community - has its own unique culture and way of looking at solid waste and its economy. The solid waste management process works best if it reflects both the values of the community and the local approach to waste management practices. Some communities may have specific waste issues on the table, such as toxic wastes, cost of disposal, tipping fees, flow control, meeting regulatory mandates, or controversial waste management technologies. Not only will one waste management strategy not work for all rural communities, but even different industries, businesses, or neighborhoods may prefer different approaches.

Planners should be sensitive to what motivates each waste generator, and encourage innovative, localised solutions.

3.4.5 Principle 5: Keep Materials Separated

Mixing unlike solid wastes together often contaminates otherwise useful materials and reduces their value.

It also causes additional processing to be done to re-separate the materials or items farther "downstream."

Materials and items are often transported great distances and handled several times, wasting public funds which could better be used elsewhere.

3.4.6 Principle 6: Minimise Handling, Transportation and Processing

This is related to principles 2, 3 and 5. The earlier in the "waste stream" an article or material can be intercepted and returned or diverted to its next use, the more money the community saves in hauling and handling costs -- including vehicle fuel and its polluting effects, labor, and equipment costs.

3.4.7 Principle 7: Start with the Low-Tech, Low-Cost, Flexible Solutions

People find it easier to participate in low-technology solid waste solutions. It is easier to visualize doing your part in a backyard or small-town composting operation than to send your garbage to a high-tech, regional incinerator in the next county. Low-tech solutions usually cost less to put in place and less to abandon, dismantle, or alter if they are no longer viable. Citizens who have participated first hand in such solutions will learn their pros and cons, and may be better able to understand the need for higher tech and/or regional solutions at a later date.

Solid waste management is a rapidly-changing endeavor. A community's strategy for dealing with old newspapers should include a contingency plan for rising and falling paper recycling markets. Without an alternative solution such as storage or composting, a mountain of old newsprint can get out of control.

When the market prices are low, inflexible contingency plans may trap a program in a system which is not economically viable. When prices are high, an inflexible system may not allow a community to take full advantage of the market.

3.4.8 Principle 8: Measure Results in a Meaningful Way

Three guidelines of the “total quality” philosophy in business are "measure, measure, and measure." In order to monitor the success of a rural community's solid waste management strategies, solid waste managers must first measure results against the objectives the community intended to achieve. Secondly, it must measure the total costs and benefits in some agreed-upon way. In a community whose primary motivation is to defer the sitting of a new landfill, measuring reductions in compacted-in-place, buried waste may be the most appropriate and important measure of success. In a community which chooses to use solid waste management to create new jobs, the number of jobs created and the dollar value of materials and items recovered may be the most important measure.

At the same time, the costs to the community of achieving their solid waste goals should not be ignored.

For example, if the community seeking to extend the life of its landfill decides to ship waste out of the county, it should have some way of measuring the costs associated with hauling, liability risks, reduced motivation for waste reduction within the community, etc. Some form of full cost accounting should be agreed upon and adopted by the community, so that offsetting costs and benefits of each solution can be recognised and evaluated.

4.0 CONCLUSION

Integrated Solid Waste Management (ISWM) takes an overall approach to creating sustainable systems that are economically affordable, socially acceptable and environmentally effective. An integrated solid waste management system involves the use of a range of different treatment methods, and key to the functioning of such a system is the collection and sorting of the waste. It is important to note that no one single treatment method can manage all the waste materials in an environmentally effective way. Thus all of the available treatment and disposal options must be evaluated equally and the best combination of the available options suited to the particular community chosen. Effective management schemes therefore need to operate in ways which best meet current social, economic, and environmental conditions of the municipality.

5.0 SUMMARY

In this unit, you have been given a good description of the principles and practice of integrated waste management a hypothetical master solution to all waste management challenges. Actually, it combines all the gains and advantages of the different waste management techniques that form part of the integral constituents of this strategy. In this, the principal focus is to reduce the waste as much as possible, and encourage the reuse of materials for the original intended purposes or other useful alternatives and recycle the recyclable ones. This is known as the 3Rs principle whose successes largely depend on waste separation or segregation at source. Other elements of integrated waste management include composting, incineration and landfill. Despite the fact that integrated waste management does not discriminate on the waste type, it lays itself open to and encourages minimisation, reuse and other energy recovery techniques and wealth generation from waste. It also creates employment, is eco-friendly and sustainable.

6.0 TUTOR-MARKED ASSIGNMENT

5 Define the term “integrated waste management”.
6 State the goals of integrated waste management.
7 Outline the guiding principles of integrated waste management.
8 Enumerate 5 benefits of integrated waste management.

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MODULE 4

UNIT 1 EFFECTS OF SOLID WASTE ON THE ENVIRONMENT AND HEALTH

CONTENTS

1.0 INTRODUCTION

In the last unit, you were given a good description of solid waste analysis and characterisation, including the rationale, procedure for analysing waste, waste analysis equipment and laboratory specimen handling. In this unit, we shall take you through a description that will improve your understanding of part of the reasons of waste sampling and analysis, that is, the effects of wastes on the environment, health and economy.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- outline the effects of solid waste on the environment
- describe the impact of solid waste on human health
- enumerate solid waste associated diseases
- identify economic effects of solid waste accumulation.

3.0 MAIN CONTENT

3.1 Background

Imagine what will happen if we all throw garbage, junk and rubbish away anyhow. Imagine there was no authority to supervise waste management activities from all the sources mentioned earlier. Imagine we all just sent our rubbish to the landfill, or just dumped them in a nearby river. What do you think will happen? A disaster!

3.2 Effects of Solid Waste on the Environment

Solid waste can pose serious effect on the environment if not properly managed. The proper management of solid waste from the point of generation to the point where it is finally disposed is very important to prevent environmental degradation. Below are some effects of solid waste on the environment:

- Global warming-change in climate and destruction of ozone layer due to waste biodegradable
- Air pollution
- Water pollution
- Pollution of soil by leaching i.e. a process by which solid waste enter soil and contaminating them
- Blockage of drainage leading to flood.

3.2.1 Air Pollution

Gases are generated through anaerobic decomposition of organic solid waste. If a significant amount of methane is present, it may be explosive and greatly lead to greenhouse effect. People who live near those sites may suffer from respiratory disorders occurring with toxic gases, dust, and fumes. When pollutants get mixed with air, this causes acid rain. Acid rain degrades the top soil.

3.2.2 Water Pollution

Rain can penetrate and pass through solid waste and can reach out and carry hazardous organic chemicals & inorganic chemicals such as heavy metals into the groundwater as well as nearby surface water sources. People who utilise the ground water or the surface water will absolutely expose to those pollutants and severe health problems may occur. Also elements such as N, P, leaching to surface water sources will be create eutrophication conditions. This will increase the biological oxygen demand of water sources and reduce the bio-diversity of water source.

3.2.3 Soil Pollution

Open dumps of solid waste or landfill pose serious threats to environment. One of the greatest environmental concerns associated with land filling is the generation of leachate. During degradation process, one tonne of land filled solid waste generates about 0.2 m3 of leachate, depending on the type of waste and seasonal climate. This wastewater primarily results from the degradation of the organic portion of the waste in combination with percolating rainwater and moisture that leaches out organic and inorganic constituents through the waste layer in the soil. A landfill site may still produce leachate with a high concentration of ammonia for over 50 years after filling operations have ceased. If not properly treated, leachate seeping from a landfill can enter the underlying groundwater, posing potentially serious hazards to the environment and to public health. For this reason, the generation of leachate has become a worldwide environmental concern in recent years.

3.2.4 Land Pollution

Land wasting damages microbial population and other soil fauna by releasing various toxic substances & disturbing their normal habitats. Garbage dumping, especially plastics, reduce the soil fertility as they are non-biodegradable. These waste change the soil texture and prepare artificial environment inside the soil. This will disturbs root movement of trees and habitats of the soil fauna.

3.2.5 Global Warming

Methane and carbon dioxide are two major gases produced from the decomposition of the organic fraction of solid waste in the landfill. Methane gas has a 21-fold global warming potential as compared to carbon dioxide. According to the Intergovernmental Panel on Climate Change, such emissions contribute to 18% of the total methane emissions to the atmosphere, ranging from 9 to 70 Tg (Mega Tonnes) annually.

Therefore, landfills have been implicated as the largest source of atmospheric methane in the world, leading to a natural phenomenon called "global warming" (Hansen, 2005a).Due to global warming, changing temperature and rainfall patterns will bring a variety of pressure upon plant and animal life. If temperature rises as projected, one-third of species will be lost from their habitat, either by moving elsewhere or by becoming extinct (Hansen, 2005b).

3.2.6 Flooding

Indiscriminate dumping of solid waste can lead to blockage of drainage thereby causing floods posing serious public health and environmental problems.

3.3 Health Impacts of Solid Waste

3.3.1 General

Modernisation and progress has had its share of disadvantages and one of the main aspects of concern is the pollution it is causing to the earth – be it land, air, and water.

With increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. This waste is ultimately thrown into municipal waste collection centres from where it is collected by the area municipalities to be further thrown into the landfills and dumps. However, either due to resource crunch or inefficient infrastructure, not all of this waste gets collected and transported to the final dumpsites. If at this stage the management and disposal is improperly done, it can cause serious impacts on health and problems to the surrounding environment.

Waste that is not properly managed, especially excreta and other liquid and solid waste from households and the community, are a serious health hazard and lead to the spread of infectious diseases. Unattended waste lying around attracts flies, rats, and other creatures that in turn spread disease. Normally it is the wet waste that decomposes and releases a bad odour. This leads to unhygienic conditions and thereby to a rise in the health problems. Plastic waste is another cause for ill health. Thus excessive solid waste that is generated should be controlled by taking certain preventive measures.

The group at risk from the unscientific disposal of solid waste include – the population in areas where there is no proper waste disposal method, especially the pre-school children; waste workers; and workers in facilities producing toxic and infectious material. Other high-risk group includes population living close to a waste dump and those, whose water supply has become contaminated either due to waste dumping or leakage from landfill sites. Uncollected solid waste also increases risk of injury, and infection.

In particular, organic domestic waste poses a serious threat, since they ferment, creating conditions favourable to the survival and growth of microbial pathogens. Direct handling of solid waste can result in various types of infectious and chronic diseases with the waste workers and the rag pickers being the most vulnerable.

Exposure to hazardous waste can affect human health, children being more vulnerable to these pollutants. In fact, direct exposure can lead to diseases through chemical exposure as the release of chemical waste into the environment leads to chemical poisoning. Many studies have been carried out in various parts of the world to establish a connection between health and hazardous waste.

Waste from agriculture and industries can also cause serious health risks. Other than this, co-disposal of industrial hazardous waste with municipal waste can expose people to chemical and radioactive hazards. Uncollected solid waste can also obstruct storm water runoff, resulting in the forming of stagnant water bodies that become the breeding ground of disease. Waste dumped near a water source also causes contamination of the water body or the ground water source. Waste dumping in rivers, seas, and lakes results in the accumulation of toxic substances in the food chain of these areas. Through the plants and animals that feed on it directly or indirectly.

Disposal of hospital and other medical waste requires special attention since this can create major health hazards. This waste generated from the hospitals, health care centres, medical laboratories, and research centres such as discarded syringe needles, bandages, swabs, plasters, and other types of infectious waste are often disposed with the regular non-infectious waste.

Waste treatment and disposal sites can also create health hazards for the neighbourhood. Improperly operated incineration plants cause air pollution and improperly managed and designed landfills attract all types of insects and rodents that spread disease. Ideally, these sites should be located at a safe distance from all human settlement. Landfill sites should be well lined and walled to ensure that there is no leakage into the nearby ground water sources.

Recycling too carries health risks if proper precautions are not taken. Workers working with waste containing chemical and metals may experience toxic exposure. Disposal of health-care wastes require special attention since it can create major health hazards, such as hepatitis B and C, through wounds caused by discarded syringes. Rag pickers and others, who are involved in scavenging in the waste dumps for items that can be recycled, may sustain injuries and come into direct contact with these infectious items.

3.3.2 Specific Effects of Solid waste on Human Health

Poor solid waste management can pose a serious risk to human health. The improper management of solid wastes represents a source of environmental pollution, and poses risks to human health. Below are some effects of solid waste on human health.

a. Spread of vector borne-diseases-Poor disposal of solid waste is associated with spread of vector borne-diseases like malaria and dengue fever. Malaria accounts for an estimated 300-500 million cases globally; which is an endemic disease in sub-Saharan Africa. It accounts for about 1.5-2.5 million deaths yearly, most of them among children under five years.
b. Respiratory diseases-Inhalation of poisonous chemicals can cause serious danger to human health. Chemicals inhaled may cause catarrh, cough, and bronchitis and may aggravate some health conditions such as asthma. Incineration of solid waste contributes to air pollution by the release of gases into the air, which may cause ill-health. Malfunctioning incinerator can also cause fire outbreak.
c. Breeding ground for pest of public health importance-decomposing organic materials can become breeding sites for pests, rats, flies and vermin that enhance the likelihood of disease transmission like diarrhea and Lassa fever. Lassa fever for example is a hemorrhagic fever common in four African countries: Guinea, Liberia, Nigeria and Sierra Leone. It is transmitted to humans from contacts with food or household items contaminated with rodent excreta.
d. Flooding to health risks-indiscriminate dumping of wastes in the streets can block water drains and channels which can cause flooding, posing significant environmental and public health risks. Water pollution can occur when rain water combines with decomposing waste and seep through permeable soil, finally contaminating surface and ground water with both lethal

materials and pathogenic organisms; this is extremely dangerous as ground water is the main source of drinking water for most people in Nigeria.

e. Low birth weight- children of women exposed to hazardous solid waste materials may have low weight at birth.

f. Cancer- solid waste containing carcinogenic materials can pose danger to human health. Solid waste materials such as polyethylene may emit carcinogens during combustion and anybody expose to it will be at risk.

g. Congenital malformations-congenital malformations may occur as a result of exposure by pregnant women to some toxic constituents known as teratogens in solid wastes.

h. Increase in neurological disease-solid waste may also impart negatively on human health by increase in neurological diseases due to handling of bulky materials

i. Nausea and vomiting-obnoxious odours emanating from indiscriminate waste disposal sites may cause nausea and vomiting to humans.

j. Increase in hospitalisation- solid waste containing hazardous materials if not properly managed may results toxicity to people that may be exposed to it leading to increased hospitalization especially of vulnerable people e.g. of diabetic residents living near hazard waste sites.

k. Mercury toxicity-toxicity may occur as a result of consumption of fish containing high level of heavy metals such as mercury leading to mercury poisoning.

l. Accidents- improper disposal solid wastes may lead to accidents on road causing loss of human lives and economic properties.

3.3.3 Occupational Hazards associated with Waste Handling

i. Infections

- Skin and blood infections resulting from direct contact with waste, and from infected wounds
- Eye and respiratory infections resulting from exposure to infected dust, especially during landfill operations
- Different diseases that results from the bites of animals feeding on the waste
- Intestinal infections that are transmitted by flies feeding on the waste.

ii. Chronic Diseases

- Incineration operators are at risk of chronic respiratory diseases, including cancers resulting from exposure to dust and hazardous compounds.

iii. Accidents

- Bone and muscle disorders resulting from the handling of heavy containers
- Infecting wounds resulting from contact with sharp objects
- Poisoning and chemical burns resulting from contact with small amounts of hazardous chemical waste mixed with general waste
- Burns and other injuries resulting from occupational accidents at waste disposal sites or from methane gas explosion at landfill sites.

3.3.4 Economic Effects

a. Municipal Wellbeing

Everyone wants to live and visit places that are clean, fresh and healthy. A city with poor sanitation, smelly and with waste matter all over the place does not attract good people, investors and tourists. Such cities tend to have poor living standards.

b. Recycling Revenue

Cities that do not invest in recycling and proper waste control miss out on revenue from recycling. They also miss out on job opportunities that come from recycling, composting and businesses that work with them.

4.0 CONCLUSION

The total effect of solid waste on the environment and consequently on public health must be considered so as to avert any danger that may arise. Poor solid waste handling poses serious health implications and hazards to man. Many problems have been associated with improper handling of waste in the environment like dumping of waste on land, indiscriminate disposal of waste into rivers and other surface waters, or into the air can cause environmental pollution and hazards to the living organisms resulting to destruction of life. Effective management of solid waste is therefore a key for sustainable development and environmental protection to ensure public health.

5.0 SUMMARY

Finally, in this unit we presented to you the effects of solid waste accumulation on the environment, the health of man and even his economy. You learned that solid waste not only pollute the soil, water and air in our surroundings, it is also a major cause of accidents, global warming and to a greater extend flooding and their associated health consequences. Solid waste accumulation also leads to spread of infections and chronic diseases as well as economic loss as it discourages tourism and its associated investment potential.

6.0 TUTOR-MARKED ASSIGNMENT

1 Outline the effects of solid waste in the environment.
2 Describe the impact of solid waste of human health.
3 Enumerate solid waste associated diseases.
4 Identify economic effects of solid waste accumulation.

7.0 REFERENCES/FURTHER READING

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UNIT 2 FIELD SAMPLING AND MONITORING OF WASTE SITES

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt the various waste management techniques and their strategies with the integrated waste management options. In this unit, you will focus attention on the assessment of waste sites for the quantification and qualification of wastes in terms of magnitude of deposits and physico/biochemical characteristics for a better appreciation of the properties and insight into the mode of handling and management. Thus, we shall be discussing the sampling and monitoring of waste sites.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- state the rational for waste sampling
- outline a sampling plan
- develop a checklist for waste sampling
- take waste samples and send to appropriate laboratory.

3.0 MAIN CONTENT

3.1 Rationale for Waste Sampling

Why collect waste samples? There are a wide variety of reasons for collecting samples and various sampling strategies for different situations. It is important that the purpose of the sampling and associated data quality objectives be identified before fieldwork begins. For example, samples may be collected to determine the existence and/or to define the extent of contamination at a site, to allow waste characterisation and classification for disposal or recovery, or to determine compliance with existing regulations. Once the objective is known, decisions about analytical parameter selection, national certified laboratory selection, quality control samples, sample location and frequency; etc. can be made more confidently. In sampling to assess permit compliance, some of these selections may have been mandated by the department.

Here, the permit applicant has the responsibility of assuring that any proposed requirements will be achievable if made mandatory. Defining sampling and data quality objectives is important to assure that the sampling plan is complete.

Environmental sampling is often conducted to gather data that will be the basis for remedial decisions. Because of the potential threat to health and environment and high costs usually associated with site remediation, strict adherence to quality assurance measures is strongly recommended. In such a case, the objective of the sampling helps to dictate what should be prescribed in the sampling plan.

3.2 Sampling Plan

An integral part of any sampling programme is planning. Before a plan can be written, site-specific information must be gathered to insure that the plan is logical, will meet the required objectives and the course of action is achievable. The purpose of developing a sampling plan is to detail a "plan of action." The person writing the plan must be very familiar with the site specific conditions and those implementing the plan must be very familiar with the plan's contents. A properly prepared sampling plan that is correctly implemented will allow the sampling objectives to be met, help avoid confusion in the field, preserve health and safety, and ultimately save time and money. In the development of the sampling plan, other pre-sampling activities must be heavily relied upon. Some factors to be taken into account will be discussed in the subsequent sections.

3.2.1 The Triad Approach

The commitment to a successful sampling is in streamlining the site investigation and remediation process at contaminated sites without compromising data quality and reliability. This goal can sometimes be better achieved by implementing the Triad approach, a process that integrates systematic planning, dynamic work plans, and real-time measurements to achieve more reliable, timely and cost-effective site characterisation and cleanup. The Triad approach seeks to recognise and manage the uncertainties involved in generating representative data from heterogeneous environmental matrices. The department supports and encourages the use of the Triad approach for sites undergoing investigation and remediation within the site remediation and waste management program.

3.2.2 Site History-Evaluating Existing Data/File Information

The first step in a site investigation should be the gathering of background information. information concerning the history of activity at a site (including locations and age of buildings, drainage pathways, contours, building layout, foundations, septic systems, tanks, etc.; processes and materials for manufacture, storage and disposal both past and present, or historical spills) can be extremely useful in planning sampling events. A file search may reveal areas of a site used for specific processes (aerial site history, site plans, area land use may also be useful) and will help in the logical placement of sampling locations. Data from the Nigerian Geographic Information System (GIS) are a valuable resource that can provide additional background information to investigators, enabling the ability to analyse mapped datasets on computer. GIS datasets relevant to the history of activity at a site include statewide land use, soils, geology, and digital aerial orthophotography.

By revealing what materials were handled on site, a file search may provide guidance in choosing which parameters to include for analysis. Additionally, while caution must still be used, judgments regarding health and safety requirements can be made. When no information is available, field personnel must consider that worst case conditions may exist and take proper precautions to insure safety.

3.2.3 Defining the Physical Environment

Equal in importance to finding out what may be on-site is determining where it is most likely to be located. A pre-sampling site visit should be conducted to gather additional background information.

Labels and dot numbers on drums and tanks may be useful. Files found on-site may include information about materials that were manufactured, stored or disposed of on-site. Product names may be determined from shipping labels or manifests. Any and all information will be useful in sampling plan preparation, and in formulating a site-specific health and safety plan.

The fate of environmental contaminants is dictated by the source, the characteristics of the contaminant itself, (i.e., persistency and toxicity) and perhaps most importantly, by the physical environmental system into which it is released. Contaminants move at varying rates and to varying degrees when released into different kinds of matrices.

Defining what kind of environmental system the site is a part of is extremely important to the success of achieving the sampling objectives.

An investigation into the local geology, hydrology (including flow rates of nearby surface waters, average depth to ground water and flow direction, identification of areas of recharge, etc.), and climatology is necessary. The biological system should also be assessed. The flora and fauna of the area (including identification of sensitive environments and/or species, stressed vegetation, potential for bioaccumulation and biotransformation in the plant and animal life, especially agricultural) are definite factors to be taken into account. Stressed vegetation may serve as an indicator for contaminant migration to a particular area. A GIS system and GIS data can assist investigators in defining both the environmental and biological systems. These data elements include soil type, hydrograph, land use, wetland delineation, surface contours and more.

Overall, by defining the physical environment, the fate of contaminants can be predicted. Migration pathways should also be identified assuring that samples will be collected in the most appropriate area. The factors addressed above offer an overview of considerations that must be evaluated for a sampling plan to be complete. The more information is obtained, the more that will be known about the source, movement, and concentrations of contaminants in the media to be sampled. With this knowledge, it will be easier to write a complete, site specific sampling plan.

Along with the historical and physical information needed prior to sampling plan development, the following topical areas of basic information are necessary components for an inclusive sampling plan.

3.2.4 Sample Locations and Numbers

The objective of the sampling event is important when choosing the location of sampling points. Samples are sometimes collected to characterise a site for which limited background information is available and/or obvious contaminated areas do not exist. In such a case, a random sampling scheme may be useful. Random sampling depends on the theory of random chance probabilities to choose the most representative sample. This process is utilised when there are numerous available sampling locations and there are no satisfactory reasons for choosing one location over another.

Tables of random numbers are readily available from many sources and should be used to eliminate any possible bias generated by those collecting the sample, assuming a random approach is used.

Also important when choosing sample locations is consideration of the site's physical environmental setting and how these factors can influence the concentration and movement of the material of concern.

Sampling at hazardous waste sites is usually conducted in an attempt to discover contamination and to define its extent and variability. With such an objective, it is most logical to choose sample locations that will yield the most information about site conditions. Here, judgment (or biased) sampling should be employed. Biased samples are those collected at locations that were chosen based on historical information, knowledge about the location and behavior of the contaminant(s), and/or knowledge about the effects of the physical system on the contaminants' fate.

Both biased and random sampling techniques can be used together to thoroughly address an entire site. Some samples may be biased to potentially contaminated areas (e.g., stained soil, former process or disposal areas) or potentially impacted areas (e.g., areas of stressed vegetation, sediment downstream from discharge pipe). In areas less likely to be contaminated or areas with little available background information, random samples may be used to allow adequate assessment of the entire site.

3.2.5 Sample Size Parameters

There are seven factors that determine the number of samples required for site characterisation:

- Exposure pathways
- Statistical performance objectives
- Data quality objectives
- Quality assurance objectives
- Background samples
- Sampling objectives
- Site specific conditions.

For example, if the objective of the event is to determine whether the site is contaminated, a limited number of samples, from properly chosen locations, will yield useful information. A greater number of samples may be needed however, if the site is known to be contaminated and delineation of the contamination is the objective. In many cases statistical considerations can be helpful in determining sampling strategy.

3.3 Sample Methodology and Matrix

Once the appropriate numbers and locations have been chosen, consideration must be given to what collection method will be used to assure that representative samples of site conditions are obtained. The selected sampling methodology will be matrix dependent. In some instances, there may be several acceptable options available for collecting a sample. In other instances, site-specific conditions may dictate that only one approach will work, even though that method may not be the preferred method. In all cases, the construction material of the sampling device, its design, decontamination, and proper use are critical factors and should be included in the proposed sampling plan.

3.3.1 Waste Sampling Equipment

3.3.1.1 General

Selecting appropriate equipment to sample wastes is a challenging task due to the uncertainty of the physical characteristics and nature of the wastes. It may be difficult to separate, homogenize and/or containerize a waste due to its physical characteristics (viscosity, particle size, etc.). In addition, the physical characteristics of a waste may change with temperature, humidity or pressure. Waste streams may vary depending on how and when a waste was generated, how and where it was stored or disposed and the conditions under which it was stored and disposed.

Also, the physical location of the wastes or the unit configuration may prevent the use of conventional sampling equipment.

Given the uncertainties that a waste may present, it is desirable to select sampling equipment that will facilitate the collection of samples that will meet the study's objective, and that will not unintentionally bias the sample by excluding some of the sample population that is under consideration. However, due to the nature of some waste matrices or the physical constraints of some waste units, it may be necessary to collect samples knowing that a portion of the desired population was omitted due to limitations of the equipment. Any deviations from the study plan or difficulties encountered in the field concerning sample collection that may have an effect on the study's objective should be documented in a logbook, reviewed with the analytical data and presented in the report.

3.3.1.2 Waste Sampling Equipment

Waste sampling equipment should be made of non-reactive materials that will neither add to nor alter the chemical or physical properties of the material that is being sampled. Table 2.1 lists some conventional equipment for sampling waste units/ phases and some potential limitations of the equipment. Another reference for selecting sampling equipment is the ASTM, standard guide for selection of sampling equipment for wastes and contaminated media data collection activities, d 6232, most recent version.

3.3.1.3 Ancillary Equipment for Waste Sampling

In addition to the equipment listed in Table 2.1 which provides the primary device used to collect various waste samples, ancillary equipment may be required during the sampling for safety and/or analytical reasons. Some examples of these types of equipment are glass mixing pans, particle size reducers, remote drum opening devices and spark resistant tools. Any influences that these types of ancillary equipment may have on the data should be evaluated and reported as necessary.

3.3.2 Waste Sampling Procedures

3.3.2.1 Waste Piles

Waste piles vary in size, shape, composition and compactness, and may vary in distribution of hazardous constituents and characteristics (strata).

These variables will affect safety and access considerations. The number of samples, the type of sample(s), the sample location(s) and interval(s) should be based on the study's objectives. Commonly used equipment to collect samples from waste piles is listed in Table 2.1. Specific procedures will vary depending on the equipment and objectives of the investigation. All equipment should be compatible with the waste and should be cleaned to prevent cross contamination of the sample.

3.3.2.2 Surface Impoundments

Surface impoundments vary in size, shape and waste content, and may vary in distribution of hazardous constituents and characteristics (strata).

The number of samples, the type of sample(s) and the sample location(s) and interval(s) should be based on the study's objectives.

Because of the potential danger of sampling waste units suspected of containing elevated levels of hazardous constituents, personnel should never attempt to sample surface impoundments used to manage potentially hazardous wastes from a boat. All sampling should be conducted from the banks or piers of surface impoundments. Any exception must be approved by the appropriate site safety officer and/or the occupational health and safety designee (OHSD).

Table 2.1: Sampling Equipment for various Waste Units

Equipment	Waste Units/Phases	Limitations
Scoop with bracket/conduit	Impoundments, piles, containers, tanks/liquids, solids, sludges	Can be difficult to collect deeper phases in multiphase wastes. Depth constraints
Spoon	Impoundments, piles, containers/solids, sludges	Similar limitations as the scoop. Generally not effective in sampling liquids.
Push tube	Piles, containers/cohesive solids, sludges	Should not be used to sample solids with dimensions >½ the diameter of the tube. Depth constraints.

Auger	Impoundments, piles, containers/solids	Can be difficult to use in an impoundment or a container, or for solidified wastes.
Sediment sampler	Impoundments, piles/solids, sludges	Should not be used to sample solids with dimensions >½ the diameter of the tube.
Ponar dredge	Impoundments/solids, sludges	Must have means to position equipment to desired sampling location. Difficult to decon.
COLIWASA or drum thief	Impoundments, containers, tanks/liquids	Not good with viscous wastes. Devices ≥ 7' require 2 samplers to use effectively.
Dipstick™/ Mucksucker™	Impoundments, containers, tanks/liquids, sludges	Not recommended for tanks >11 feet deep. Devices > 7' require 2 samplers to use effectively
Bacon bomb	Impoundments, tanks/liquids	Not good with viscous wastes
Bailer	Impoundments, tanks/liquids	Only if waste is homogeneous. Not good with viscous wastes
Peristaltic pump with vacuum jug assembly	Impoundments, tanks/liquids	Cannot be used in flammable atmospheres. Not good with viscous wastes.
Back-hoe bucket	Piles/solids, sludges	May be difficult to access desired sampling location. Difficult to decon. Can lose volatiles.
Split-spoon	Piles/solids	Requires drill rig or direct push equipment.
Tot-hammer	Piles, containers/solids	Physically breaks up sample. May release volatiles. Not for flammable atmospheres.

Source: http://www.epa.gov/region4/sesd/fbqstp/Waste-Sampling.pdf

3.3.2 Drums

Drums are the most frequent type of containers sampled by field investigators for chemical analyses and/or physical testing. Caution should be exercised by the field investigators when sampling drums because of the potential presence of explosive/flammable gases and/or toxic vapours. Therefore, the following procedures should be used when collecting samples from drums of unknown material:

1. Visually inspect all drums that are being considered for sampling for the following:

- pressurisation (bulging/dimples)
- crystals formed around the drum opening
- leaks, holes, stains labels, markings
- composition and type (steel/poly and open/bung)
- condition, age, rust and
- sampling accessibility.

Drums showing evidence of pressurization and crystals should be furthered assessed to determine if remote drum opening is needed. If drums cannot be accessed for sampling, heavy equipment is usually necessary to stage drums for the sampling activities.

Adequate time should be allowed for the drum contents to stabilise after a drum is handled.

2. Identify each drum that will be opened (e.g., paint sticks, spray paint, cones, etc.).
3. Before opening, ground each metal drum that is not in direct contact with the earth using grounding wires, alligator clips and a grounding rod or metal structure. If a metal drum is in an over-pack drum, the metal drum should be grounded.
4. Touch the drum opening equipment to the bung or lid and allow an electrical conductive path to form. Slowly remove the bung or drum ring and/or lid with spark resistant tools (brass/beryllium).
5. Screen drums for explosive gases and toxic vapour with air monitoring instruments as bung or drum lid is removed. Depending on site conditions, screen for one or more of the following:

- Radioactivity
- Cyanide fumes
- Halogen vapours
- Ph and/or

- Flash point (requires small volume of sample for testing).

6. Select the appropriate sampling equipment based on the state of the material and the type of container. Sampling equipment should be made of non-reactive material.
7. Place oil wipe (as necessary), sampling equipment and sample containers near drum(s) to be sampled.

3.3.2.4 Tanks

Sampling tanks is considered hazardous due to the potential for them to contain large volumes of hazardous materials and therefore, appropriate safety protocols must be followed. Unlike drums, tanks may be compartmentalised or have complex designs.

Preliminary information about the tank's contents and configuration should be reviewed prior to the sampling operation to ensure the safety of sampling personnel and that the study's objectives can be achieved. In addition to having discharge valves near the bottom of tanks and bulk storage units, most tanks have hatches at the top. It is desirable to collect samples from the top hatch because of the potential for the tank's contents to be stratified. Because wastes often stratify due to different densities of phases or settling of solids, it may be important to obtain a vertical cross section of the entire unit, or it may be desirable to collect grab samples from each strata. Additionally, when sampling from the discharge valve, there is a possibility of a stuck or broken valve which could cause an uncontrolled release. Investigators should not utilise valves on tanks or bulk storage devices unless they are operated by the owner or operator of the facility or a containment plan is in place should the valve stick or break. If the investigator must sample from a tank discharge valve, the valving arrangement of the particular tank must be clearly understood to ensure that the compartment(s) of interest is sampled.

Because of the many different types of designs and materials that may be encountered, only general sampling procedures that outline sampling a tank from the top hatch are listed below:

1. All relevant information concerning the tank such as the type of tank, the tank capacity, markings, condition and suspected contents should be documented in a logbook.
2. The samplers should inspect the ladder, stairs and catwalk that will be used to access the top hatch to ensure that they will support the samplers and their equipment.
3. Before opening, ground each metal tank using grounding wires, alligator clips and a grounding rod or metal structure.

4. Any vents or pressure release valves should be slowly opened to allow the unit to vent to atmospheric pressure. Air monitoring for explosive/flammable gases and toxic vapours should be conducted during the venting with the results recorded in a logbook. If dangerous concentrations of gases evolve from the vent or the pressure is too great, leave the area immediately.
5. Touch tank opening equipment to the bolts in the hatch lid and allow electrical conductive path to form. Slowly remove bolts and/or hatch with spark resistant tools (brass/beryllium). If a pressure build up is encountered or detected, cease opening activities and leave the area.
6. Screen tanks for explosive/flammable gases and toxic vapours with air monitoring instruments. Depending on the study objectives and site conditions, conduct characteristic screening (e.g., pH, halogen, etc.) as desired. Collect a small volume of sample for flash point testing, if warranted. Note the state, quantity, number of phases and colour of the tank contents. There should be a log book where records of all relevant results, observations, and information are kept. Compare the screening results with any pre-existing data to determine if the tank should be sampled.
7. Select the appropriate sampling equipment based on the state of the material and the type of tank. Sampling equipment should be constructed of non-reactive materials.
8. Place oil wipe (as necessary), sampling equipment and sample containers near tanks(s) to be sampled.
9. Close the tank when sampling is complete.

3.3.3 Waste Sample Handling Procedures

3.3.3.1 General

When collecting samples of concentrated wastes for laboratory analyses, field personnel are required to screen the waste materials to ensure safe handling and transportation of the samples.

Safety procedures, sampling and screening methods used to collect the samples must comply with those procedures/methods described in this protocol. It should be noted that waste samples should not be preserved because of the potential for an inadvertent chemical reaction with the preservative. Additionally, concentrated waste samples are not required to be cooled to 4°C.

After samples have been collected and containerized, the outside of the sample containers should be cleaned with water, paper towels and/or oil wipes to remove any spilled material from the exterior of the container. It should be noted that each sample container should be labeled.

Field investigators will use knowledge gained of site practices and processes, labels and marking on waste containers, field screening results and personal observations made during their investigation to determine the hazard potential of a sample. Samples considered to be hazardous by the field investigators or detected to have strong chemical odours will be placed in secondary containment for transport to the SESD laboratory and for subsequent handling upon arrival. The bagged samples will be placed in a plastic pail and sealed with a tight fitting lid.

The project number for the sampling investigation and the specific sample station number will be marked on the secondary container in indelible ink. A standard SESD hazard Communication Label will be affixed to the side of the secondary container. The appropriate hazard(s) for the sample (health, flammability, and/or reactivity) will be indicated with an "X." Additionally, an "X" will be placed in the "protective equipment" section of the label if protective equipment was required for collection of the sample. All secondary containing pails will be secured in the vehicles while transporting the samples from the field to the laboratory for analyses. In addition, each pail should indicate when protective equipment is recommended to handle the actual waste sample material.

3.3.2 Particle Size Reduction

Particle size reduction of waste samples is periodically required in order to complete an analytical scan or the toxicity characteristic leaching procedure (TCLP) test. samples that may require particle size reduction include slag, bricks, glass/mirror cullet, wire, etc. method 1311 (TCLP) states "particle size reduction is required, unless the solid has a surface area per gram of material equal to or greater than 3.1 cm2, or is smaller than 1 cm in its narrowest dimension (i.e., capable of passing through a 9.5 mm (0.375 inch) standard sieve). if the surface area is smaller or the particle size larger than described above, prepare the solid portion of the waste for extraction by crushing, cutting or grinding the waste to a surface area or particle size as described above" the method also states that the surface criteria are meant for filamentous (paper, cloth, etc.) waste materials, and that "actual measurement of the surface area is not required, nor is it recommended." also, the loss of volatile organic compounds could be significant during particle size reduction.

Waste samples that require particle size reduction are often too large for standard sample containers. If this is the case, the sample should be secured in a clean plastic bag and processed using normal chain-of-custody procedures (see http://www.epa.gov/region4/sesd/fbqstp/Waste-Sampling.pdf). Note that the sample labels or tags that will be required for the various containers should be prepared in the field and either inserted into or attached to the sample bag.

Because of the difficulty in conducting particle size reduction, it may be completed at a special center established for it at country level. The following procedure may be used for crushing and/or grinding a solid sample:

1. Remove the entire sample, including any fines that are contained in the plastic bag and place them on the standard cleaned stainless steel pan or cover the sample material with clean plastic.
2. Using a clean hammer, carefully crush or grind the solid material (safety glasses are required), attempting to minimise the loss of any material from the pan. Some materials may require vigorous striking by the hammer, followed by crushing or grinding. The material may be subject to crushing/grinding rather than striking.
3. Continue crushing/grinding the solid material until the sample size approximates 0.375 inch. Attempt to minimise the creation of fines that are significantly smaller than 0.375 inch in diameter.
4. Pass the material through a clean 0.375-inch sieve into a glass pan.
5. Continue this process until sufficient sample is obtained. Thoroughly mix the sample as described in the SESD operating procedure for soil sampling (SESDPROC-300). Transfer the contents of the glass pan into the appropriate containers.
6. Attach the previously prepared labels/tags and submit for analyses.

3.4 Laboratory Selection

Prior to submitting samples to a laboratory for analysis, the certification status of the laboratory must be determined. Laboratories submitting analytical data to the authority must hold current certification where applicable under the regulations governing the certification of laboratories and environmental measurements and/or under other relevant bodies. The offices concerned with quality assurance offers certification in the following categories:

- Drinking water program
- Oil spill and detection program
- Solid and hazardous waste programs etc.

The government certification program requires certification for the “analyse immediately” parameters under the safe drinking water, water pollution, and the solid and hazardous Water programs. Certification for those parameters can be obtained from the offices responsible with quality assurance.

Additionally, immunoassay methods that are considered laboratory or field methods require certification under the solid and hazardous waste program. Regardless of whether a company or organisation is or is not a laboratory, certification must be obtained. This includes but is not limited to responsible parties, contractors and facilities.

3.5 Quality Assurance Considerations

Quality assurance measures must be associated with each sampling and analysis event as an additional measure of control to assure that the sample delivered to the laboratory for analysis is representative of site conditions. The sampling plan should outline how the representative quality of the samples will be assured. This will include, but not be limited to: data quality objectives, laboratory SOPs, field SOPs, sample bottle preparation, equipment decontamination, trip blanks, field blanks, duplicates, split samples, performance evaluation samples, sample preservation and handling, chain of custody, analysis request, analytical methods, parameters, and deliverables.

3.6 Quality Assessments

The sample collection process should be coordinated with the laboratory so that analysts know how many samples will be arriving, the approximate time of their arrival and the analyses that are to be carried out, and can thus have appropriate quantities of reagents/chemicals prepared.

It is good practice to prepare a checklist such as the one on below, so that nothing is missing or forgotten before a sampling expedition is undertaken. Many of the items in the list are self-explanatory.
Personnel who will collect water, biota or sediment samples must be fully trained in both sampling techniques and field test procedures. They should also be aware of the objectives of the monitoring programme since these will have some influence on the sampling procedures. Obtaining a sample that is fully representative of the whole site is difficult and the collection and handling of samples are also frequent sources of error (often greater errors than those arising during analysis).

Thus the choice of a representative sampling point and the use of appropriate sampling techniques are of fundamental importance.

3.7 Checklist for Waste Sampling

Paperwork

- Itinerary
- Inventory details of sampling stations; maps
- List of samples required at each sampling station
- List of stations where water level readings are to be recorded.

Co-ordination

- Local co-ordination, for example, to ensure access to sites on restricted or private land
- Institutional co-ordination, for example, for travel arrangements or sample transport
- Notify laboratories of expected date and time of sample arrival
- Check any available sources of information on local weather conditions and feasibility of travel.

For sampling

- Sample bottles, preservatives, labels and marker pens
- Sample storage/transit containers and ice packs
- Filtering apparatus (if required)
- Samplers/sampling equipment
- Rubber boots, waders, etc.
- Standard operating procedures for sampling
- Spares of all above items if possible and when appropriate.

For documentation

- Pens/wax crayons
- Sample labels
- Field notebook
- Report forms.

For on-site testing

- List of analyses to be performed on site
- Check stocks of consumables (including distilled water, pH buffers, standards and blanks);replenish and refresh as appropriate
- Check and calibrate meters (pH, conductivity, dissolved oxygen, turbidity, thermometers)
- Other testing equipment according to local practice
- Standard operating procedures and equipment manuals
- Spares (e.g. batteries).

Safety

- First-aid kit
- Waders, gloves, etc.
- Fire extinguisher (if appropriate).

Transport

- Does assigned vehicle have sufficient capacity for personnel, supplies and equipment?
- Is vehicle road-worthy? Check battery, lubrication, coolant, windshield washer
- Is there sufficient fuel for the trip, either in the tank, in fuel cans, or available en route?
- Is the spare tyre inflated; is there a jack, wheel wrench and tool kit?

Double-check

- When was equipment last calibrated?
- Itinerary against travel details on inventory
- Accessories for equipment and meters (including cables, chargers and spare batteries) and consumables.

3.8 Health and Safety Concerns

Prior to any work being performed at a hazardous waste site, the organisation, or company, engaged for the work must develop a written health and safety program for its employees. As part of the overall health and safety program, a site-specific safety and health plan, which addresses the safety and health hazards at a particular site, must be developed and kept available at the site during the duration of all site work. Typically, a health and safety program will address the following areas: organisational responsibilities, risk analysis, underground utility mark outs, employee training, personnel protection, medical surveillance, air surveillance, site control, decontamination, site standard operating procedures, contingency planning, confined space operations, and spill containment. Depending on the types of contaminants and other hazards present and the type of work that is anticipated some of these concern areas may not be applicable all aspects of a particular sampling episode.

3.9 Waste Characterisation and Analysis

3.9.1 Waste Characterisation

Waste characterisation is a method used to determine the types of materials being discarded in a waste stream and in what proportion. Waste characterisation information can help policy makers and city planners reduce landfill waste, set up recycling programs, and conserve money and resources. In fact, a waste characterisation study typically precedes waste diversion studies and strategies.

3.9.2 Rationale of Waste Characterisation

Characterisation studies allow cities to map their entire waste stream and to identify gaps so that they can focus their efforts on diverting the most appropriate materials that will have the greatest impact. Depending on local conditions, material types selected for study can be based on volume generated difficulty of collection and processing, or recyclability and reuse potential. Each city will have to determine for themselves which material types and selection criteria make the most sense, but having this information will make the process easier and improve diversion efforts.

To conduct a characterisation study, data must be collected by taking representative samples of waste and sorting it into material types like newspaper and aluminum cans, and weighing each type. Samples can be taken from trucks delivering waste to landfills and transfer stations from residential, commercial, and self-haul sources. The following are the major steps to complete a waste characterisation study:

1. Select Approach: Landfill sampling, waste generator sampling, use of existing data, combination of approaches
2. Collect Representative Data: select samples for field studies, determine number of samples needed
3. Use Protocols: uniform field sorting protocols, material type definitions, lumping material categories, classifying composites
4. Health and Safety: determine safety protocol before conducting field studies
5. Data Analysis: random sampling (landfill) vs. subdivision of sectors (generator).

3.9.3 Why Waste Analysis?

Waste products must be used or disposed of with environmentally sound management practices in order to prevent damage to our natural resources. Farms' food-processing plants, textile manufacturers, pharmaceutical companies, wood and paper producers, and municipalities all generate a variety of waste products--the disposal of which must be managed somewhat differently depending upon the source and the intended use.

Waste managers therefore require sound knowledge of waste constituents before choosing and applying appropriate management procedure. Waste analysis also helps toxicologists to determine the individual constituents of waste and the potential toxic effects of the waste to both the environment and humans.

3.9.4 Planning Waste Analysis

The planning of waste analysis program or activity will take into account the following

- Type of sampling
- Number and type of stratum
- Level of sampling
- Type of sampling unit
- Calculation of sample size
- Generation of random sample plan, and
- Duration of waste analysis

3.9.5 Execution of Waste Analysis

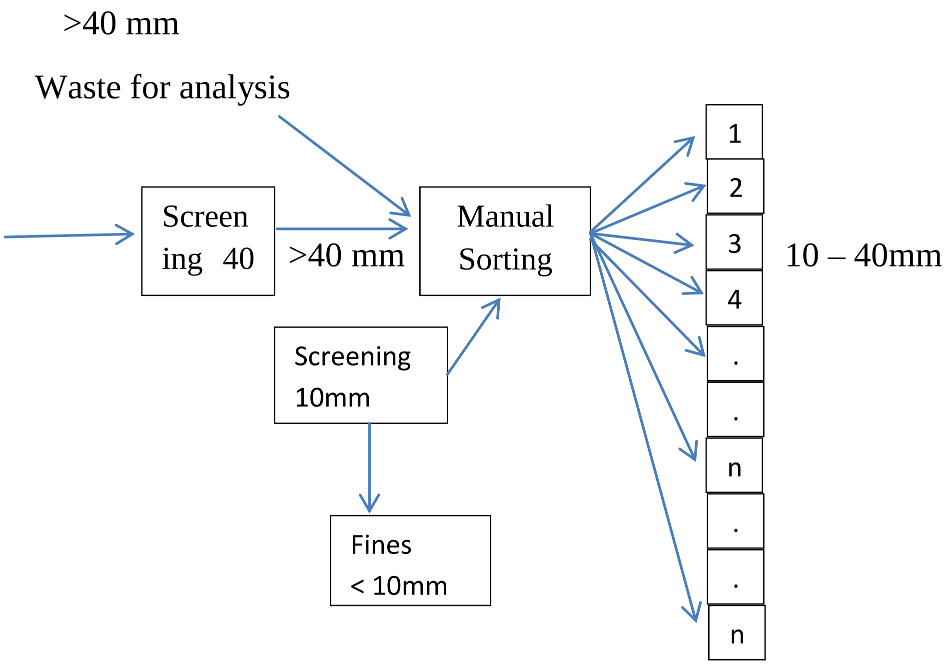

Fig. 2.2: A Summary of Waste Analysis Processes
Source:http://www.sustainablecitiesinstitute.org/view/page.basic/class/feature.class/ Lesson_Waste_Characterisation_Study

4.0 CONCLUSION

The fieldwork associated with the collection and transport of samples will account for a substantial proportion of the total cost of a monitoring programme. Sampling expeditions should, therefore, be planned and carried out in such a way that efforts are not wasted. If, for example, an essential piece of equipment is forgotten or an inadequately described sampling station cannot be found, the value of that particular sampling expedition is seriously compromised. Similarly, if unrealistic estimates of travel time are made and an expedition takes longer than intended, samples may be held longer than the maximum allowable storage time and the results of analyses will be of questionable value.

It is advisable to carry out a pilot programme before the routine monitoring programme begins. This can be used as a training exercise for new personnel and will provide the opportunity to make a final selection of sampling stations on the basis of whether they are representative of the whole site as well as readily accessible. Programme managers and laboratory personnel should accompany field personnel on field expeditions from time to time. This provides opportunities for field supervision as part of in-service training and for everyone working on the programme to appreciate the problems and needs of the field work.

5.0 SUMMARY

In this unit, you were exposed through the fascinating concept and practice of waste monitoring through environmental sampling for waste and laboratory analysis. In this you do appreciate the rationale for waste sampling and the rudiments of developing a waste sampling plan and checklist and indeed, determining the sample size and purpose of taking the sample. We have also gave a good outline of various waste sampling equipment and waste sampling procedures for different waste sites like waste piles, impoundments, drums, and tanks. Also highlighted are waste sample handling procedures including particle size reduction and finally the health and environmental considerations in waste sampling. Waste monitoring through regular sampling of waste sites is fundamental for the understanding of the nature, magnitude and management options for any category of waste.

6.0 TUTOR-MARKED ASSIGNMENT

1 State the rationale for waste sampling.
2 Outline the components of a sampling plan.
3 Enumerate the essential features of a checklist for waste sampling.

4 Outline five equipment for waste sampling and state one limitation of each.

7.0 REFERENCES/FURTHER READING

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