NATIONAL OPEN UNIVERSITY O F NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

COURSE CODE: SLM 509

COURSE TITLE: WASTE MANAGEMENT AND SOIL

Course Guide

SLM 509 WASTE MANAGEMENT AND SOIL

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INTRODUCTION

This course is primarily concern with waste generation and the impact of waste generally on environment and human in particular. The generation of waste is becoming a global concern and somewhat directly connected to the industrial development and population growth. Increase in population has led to the generation of waste faster than they are collected and disposed of in many cities and towns. The quantity and diversity of wastes generated by industries and municipalities pose serious risks to both human health and the environment. Apparently, there is ignorance in the part of populace about the deleterious effects on the waste generated and have resulted in the alarming increase of environmental pollution alongside the urbanization, industrialization and changing agricultural practices.

The day–to–day activities of human beings, particularly in the developing countries, cause more environmental pollution than industrial waste emissions because industrial pollution is concentrated in certain towns and cities and can be ordered to close but no such measure can be taken for the sudden prohibition of human- derived pollution occurring at all places. The solid waste, sewage and night soil pose the most intimidating and widespread of all environmental problems. The disposal of such waste requires proper solid and hazardous waste management.

It is imperative therefore to create awareness among local authorities and stakeholders on the menace of indiscriminate generation and disposal of these wastes to the environment and to proffer treatment technologies that will help manage, recycle and convert waste to wealth.

WHAT YOU WILL LEARN IN THIS COURSE

This course is a two credit unit. The course guide takes you through what you will learn by reading this material. The study of this course SLM 509 – "Waste Management and soil", generally teaches how human activities lead to generation of wastes and the consequences of the wastes on environment and human health. Many human activities both domestic and otherwise such as consumption of packaged food items, laundry, discharge of unwanted and general household chores, activities involving trades like distribution and retailing, on farm and farm gate activities and industrial operations all lead to generation of wastes. As a result, wastes accumulate to the level that endangers not only the human health but also other organisms in both terrestrial and aquatic ecosystem.

Wastes generated in environment are from different sources including residential, municipal commercial, agricultural, constructions and demolitions, institutional such as schools, hospitals and other governmental ministries and parastatals and of course industries. Others include various sources of wastewaters such as industrial wastewaters, agricultural slurry from livestock and abattoir, institutional wastewaters such as hospitals and schools, residential wastewaters, commercial wastewaters, etc. The nature of wastes and wastewaters generated by each source varied tremendously from place to place. For example the waste dumpsites in the landfill can generate gases that are of global warming potentials such as carbon dioxide, methane and other gases. The same dumpsite produces leachate that can percolate into the soil profile and eventually contaminate the ground water. Industrial wastewaters discharged into environment contain heavy metals such as Cd, Cu, As, Cr, Pb, Hg. The same wastewaters are used in irrigation to grow crops such as lettuce, tomato, onions and so forth. These crops are consumed by humans and animals and can have deleterious effect on health.

This course also teaches how these problems can be overcome by teaching different waste treatment and disposal techniques to mange the waste generated. These techniques involve the waste prevention at source, waste reduction, waste reuse and recycling, the conventional landfilling and incineration and improved technologies such as pyrolysis, gasification, anaerobic digestion and finally integrated method of waste management. Also, the course talked about composting which is another avenue of managing waste, especially agricultural wastes. The processes involved and the microbes that carry out the decomposition process were all well discussed.

COURSE AIM

The aim of this course is to create awareness on the waste generation in our environment and its associated deleterious impact on human health and environment in general. It also aims at proffering simple and different ways of managing the waste.

COURSE OBJECTIVES

After going through the course, you should be able to:

- Define wastes and know its sources.
- Know the effects of waste disposal on human and environments.
- Identify and describe wastes that are agriculturally based.
- Understand different sources of agricultural wastes.
- Understand the wastes that are generated from municipality and how they are managed.
- Understand the industrial sources of waste with their associated deleterious impact on environment.
- Classify and characterize wastes that are hazardous in nature.
- Know and understand the decomposition of organic matter; the series of microorganism involved in the decomposition process.
- Learn the simple way of carrying out the composting of organic wastes and residues
- Learn the general impact of various waste sources on the environment;
- Employ different waste management strategies to solve waste generation and its impact on environment.

WORKING THROUGH THIS COURSE

This course has been carefully put together bearing in mind the fact that it is an introductory course. However, efforts have been made to ensure adequate explanation of the concepts and issues treated in the work. Diagrams and tables have been used where necessary to enhance your understanding. You are advised to spend good time to study the work and ensure that you attend tutorial sessions where you can ask questions and compare your knowledge with that of your classmates.

COURSE MATERIALS

You will be provided with the following materials:

- A Course guide
- Study Units.

In addition, the course comes with a list of recommended textbooks, which are not compulsory for you to acquire or read, but are essential to give you more insight into the various topics discussed.

STUDY UNITS

The course is divided into 15 units. The following are the study units contained in this course:

Module 1

Unit 1: Wastes
Unit 2: Characteristics of Agricultural wastes
Unit 3: Municipal wastes
Unit 4: Industrial waste
Unit 5: Hazardous waste

Module 2

Unit 1: organic matter
Unit 2: Soil Biota
Unit 3: Role of organic matter in soil fertility
Unit 4: Effect of organic matter on soil properties
Unit 5: Composting

Module 3

Unit 1: General Impact of Waste on Environment
Unit 2: Waste Treatment and Disposal
Unit 3: Waste incineration
Unit 4: Waste Land filling
Unit 5: Other Technologies

Module 1

In unit one you will learn the definition of wastes as explained by professionals. You will also learn the composition wastes and how the wastes are generated. The effects of different waste disposal on environment are also discussed in this unit. Unit two discusses the characteristics of agricultural wastes, their sources and how they can be converted into useful materials such as fertilizers, biogas and animal feeds. Unit three explains what municipal solid wastes are; and different types of municipal soil wastes are elucidated in the unit. Physical, chemical and biological characteristics are also explained in the unit; and finally ways of transforming or managing municipal solid wastes are discussed. In unit four, the industrial wastes are defined and different examples are given. The sources of industrial wastes are highlighted and their deleterious impacts on environment are explained. Unit five of this module dwelled on the definition and characteristics of hazardous wastes, sources and classification. Also, sources and different types of household hazardous wastes and materials were elucidated.

Module 2

Module two generally explained the organic matter decomposition. In unit one, organic matter is described, the decomposition process and its components. Factors that affect organic matter decomposition are also described. In unit two, general soil biota is explained. The various classifications and categories are explained. You will also learn in this unit that soil biota generally are classified into three groups macrobiota, mesobiota and microbiota. Also this unit explains biogenic structures and differentiated the harmful microorganisms from beneficial ones. Unit three, the role of organic matter in soil fertility is explained. Unit four discussed the effect of organic matter on soil physical, chemical and biological properties. Finally, unit five of this module explained in detail how composting is carried out. The processes involved, material used, different types and benefits are all elucidated in this unit.

Module 3

Unit one of this module talked about the general impact of wastes and wastewaters on environment and risk of different waste sources and disposal and human health. Unit two discussed the different waste treatment and disposal techniques. It also discusses different waste reduction, reuse and recycling techniques. Unit three and four discussed landfilling and incineration of wastes, which are the conventional ways of waste treatment and disposal techniques. Unit five highlighted and discussed the modern ways of waste treatment and disposal, which include: pyrolysis, gasification, combined pyrolysis – gasification and anaerobic digestion. These are described as the alternative treatment and disposal technologies to the conventional technologies explained the previous units. Finally, the integrated waste management technology is discussed, which combines all the technologies in one system.

TEXT BOOKS AND REFERENCES

The following textbooks are recommended for further reading:

Hill, M. (2002). Handbook on solid waste management. Second edition. 834 pp.

ISWA. (2012). Globalization and Waste Management. International Solid Waste management (ISWA). A Global Perspective on Current Developments in Solid Waste Management", IFAT ENTSORGA, May 2012, Munich, Germany. 55 pp.

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Coleman, D.C., Crossley, D.A. and Hendrix, P.F. (2004). Fundamentals of Soil Ecology, 2nd Ed. Elsevier, Inc.

Jenny, H. (1980). The Soil Resource, Origin and Behavior, Ecological Studies 37 Springer-Verlag, New York.

Dalzell, H.W., Biddlestone, A.J., Gray, K.R. and Thurairajan K. (1987). Soil management: compost production and use in tropical and sub tropical environments. pp. 177.

IEA Bioenergy. (1996). Bioenergy, biogas from municipal solid waste: Overview of systems and markets for anaerobic digestion of MSW. IEA Bioenergy, Energy Recovery from MSW Task Anaerobic Digestion Activity. National renewable energy Laboratory, Harwell .

Paul T.W. (2005). Waste treatment and disposal. Second edition. pp. 391.

ASSESSMENT

There are two components of assessment for this course. They are the Tutor-Marked Assignment (TMA), and the end of course examination.

TUTOR-MARKED ASSIGNMENT

The TMA is the continuous assessment component of your course. It accounts for 30% of the total score. Your facilitator will give the TMAs to you and you will return it after you have done the assignment.

FINAL EXAMINATION AND GRADING

This examination concludes the assessment for the course. It constitutes 70% of the whole course. You will be informed of the time for the examination.

SUMMARY

This course provides the knowledge of waste generation and its impact on environment in general and human health in particular. It also gives how these generated can be treated, disposed of and managed using both convention methods and alternative technology. At the end of this course, you should be able to answer the following questions:

- How waste generation and its disposal affects the environment and human health.
- What wastes are of agricultural origin and do these wastes daunt our immediate environs and ways of making the useful
- How the discharged industrial effluents and emissions pollute our environments and their impacts on human health.
- How the legislators define, characterize and classify wastes that are considered hazardous.
- How organic matter is decomposed in the soil
- What are organisms responsible for organic matter decomposition
- What are the roles played by organic matter in the soil
- How does soil organic matter influence the physical, chemical and biological properties of soil
- How are organic residues are composted and put into use
- What are the benefits of composting
- What are the general impact of waste discharges on our environments and heaths
- What are the conventional ways of treating and disposing wastes
- Why do we need alternatives techniques in managing and disposing of wastes
- How do we integrate waste treatment techniques into a unified system of waste management?

We wish you success in this course and hope that you will have a better understanding of how wastes affects your environs and offer a simple way of combating the challenges that might have arisen as regards to health issues and environmental safety. Remember that Waste is Wealth, so value it.
Best wishes.

MAIN
COURSE

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MODULE 1

Unit 1: Wastes
Unit 2: Characteristics of Agricultural wastes
Unit 3: Municipal wastes
Unit 4: Industrial waste
Unit 5: Hazardous waste

UNIT 1: WASTES

CONTENTS

1.0 INTRODUCTION

Waste is defined as any substance, solid, liquid or gaseous that remains as residue or an incidental by-product of the processing of a substance or for which no use can be found by the organism or system that produces it. According to United Nation Environmental Program (UNEP), Wastes are substances or objects, which are disposed of or are intended to be disposed of or required to be disposed of by provision of national laws. The World Health Organization refers to waste as something, which the owner no longer wants at a given time and space and which has no current or perceived market value. However, what one regards as waste may not be totally useless as much can be recycled to produce new products.

Waste includes all items that people no longer have any use for, which they either intend to get rid of or have already discarded. Many items can be considered as waste e.g., household rubbish, sewage sludge, wastes from manufacturing activities, packaging items, discarded cars, garden waste, old paint containers etc.

Waste can be photodegradable, e.g. broken down by sunlight after a time like plastic, non-bio-degradable, e.g. steel, biodegradable e.g. broken down by bacteria on exposure, like organic matter. Examples of waste include household waste, industrial (which often contain toxic chemicals), medical waste (which may contain organism that cause disease) and nuclear waste (which is radioactive).

2.0 OBJECTIVES

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

- Define waste as described by professional bodies
- Understand different items that are considered wastes
- Classify wastes
- Know various ways of waste generations

- Have knowledge on how different waste disposal affects our environment as well as human health.

3.0 MAIN CONTENT

3.1 Waste Generation

Every human activity generates waste but it is the accumulation of wastes that constitute environmental health hazards. Waste generation occurs through domestic, commercial, industrial, agricultural and other social activities. The composition of the various wastes that are generated in Nigeria include but not limited to: Household waste – 85%; Commercial waste - 8%; sewage Sludge – 3.5%; Industrial Waste – 1.6%; Agricultural waste – 1.1%; Mini waste – 0.5%; and Hazardous waste – 0.3%.

Domestically, human activities such as environmental sanitation, food preparation, consumption of packaged foods, laundry, washing of utensils, discharge of unwanted household items or unserviceable household equipment and old furnishing all lead to huge volume of waste. Activities like retailing and distributive trade, small, medium and large-scale industrial operations also bring about the generation of both solid and liquid waste. On-farm operation and in-farm gate activities are usually characterized by waste generation. Typical examples include timber and wood-processing industry, which generate large quantities of waste in form of sawdust and shavings.

Waste generation and disposal is a growing problem worldwide and is directly connected to industrial development and population growth. Wastes, both from domestic and commercial sources have grown significantly in Nigeria over the past decade. Currently, as a result of industrialization and rapid population growth in many cities and towns, wastes are generated faster than they are collected, transported and disposed. It is difficult to quantify the volume of waste generated from each household in Nigeria, but merely from observation, it shows that the generation of waste amounts to millions of tons. It has been observed that about 75% of the total wastes generated each month are mainly from the urban centers (Nnamani, 2000). Several researchers have studied the volume of waste generated in Nigerian cities; for example, Maclaren International Ltd (1970) estimated this volume at 182.900 tones. The study concluded by Haskoning and Konsadem Associates (1994) estimated the per capita rate at 0.6kg/day, with a density of 300kg/m^3.

3.2 Effect of Waste on Environment

The world's accelerated economic development in recent decades has led to a rapid urbanization and an uncontrolled population growth in urban centers. Changes in the consumption patterns of the urban dwellers have resulted in an excessive generation and disposal of waste. Disposing of waste has huge environmental impacts and can cause serious problems.

Landfill is the most widely employed for waste disposal worldwide. The dumps do not have bottom liners to prevent the seepage of leachate. During degradation process, one tone of land filled waste generates about 0.2m^3 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 landfill. A landfill site may still produce leachate with a high concentration of NH_3-N 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.

Also, the dumps do not have a top cover or other preventive measures to reduce methane emission into the atmosphere. Methane and carbon dioxide are two major gases produced from the decomposition of the organic 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 mega tones 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, 2005). 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, 2005).

Incinerating waste also causes problems, because plastics tend to produce toxic substances, such as dioxins, when they are burnt. Gases from incineration may cause air pollution and contribute to acid rain, while the ash from incinerators may contain heavy metals and other toxins. In addition, there are a substantial number of uncontrolled disposal sites that contain hazardous wastes and that could present serious environmental or public health problems. For example, municipal waste sludge and incinerator ash can contain toxic heavy metals such as lead, cadmium, mercury, and other toxic materials. Heavy metals such as chromium and lead have been long contaminants of soil. Chromium (IV) was found to cause throat and lung cancer, shortened lifespan, reproductive problems and lower fertility. Lead causes plumbism (lead poisoning), anemia, effects on the intestines and central nervous system. Also in children (generally having a less well-developed blood brain barrier than adults), Pb causes behavioral changes; decreased intelligence, brain damage and even death have been observed. Other heavy metals such as copper, mercury, and selenium, get into water from many sources including industries, exhaust pipes, mines, and even natural soil (Encarter, 2007).

Nitrates, which are commonly associated with fertilizers and agricultural waste runoff, can seep into groundwater. Well water contaminated with nitrates is hazardous to humans, particularly the infants, as it results in oxygen depletion in the blood. Once ingested into the human body, nitrate is converted into compound known as nitrosoamines, which are known carcinogens. Moreover, nitrates could be chemically reduced in the body of infant humans to nitrites, which reduces the oxygen carrying capacity of hemoglobin. The current WHO public health standard for safe drinking water requires that nitrates levels in drinking water should be less than 50 mgl^{-1}. When nitrate level in drinking water exceeds this standard, costly measures have to be taken to make water safe for drinking. Nitrates in the agricultural waste runoffs also contaminate surface water, which leads to Eutrophication thereby killing aquatic life.

4.0 CONCLUSION

Considering the consequence of excessive waste generation worldwide, an integrated management plan and its implementation need to be undertaken consistently. The outcomes of the scheme may provide inputs for local government and relevant stakeholders to formulate and implement integrated waste management in a holistic manner. These strategies may provide a policy framework to accomplish the target of reducing waste generation worldwide by 1% annually. This will facilitate ways to achieve an environmental sustainability, one of the UN Millennium Development Goals (MDG) in 2015.

5.0 SUMMARY

At the end of this unit, we understand that:

- Waste is any substance – (solid, liquid or gaseous) in which no use can be found by the organism or system that produces it and is required to be disposed of by provision of law. However, what one regards as waste may not be totally useless as much can be recycled to produce new products.
- Waste can be photodegradable i.e. broken down by sunlight e.g. plastic. Non-bio-degradable e.g. steel and biodegradable i.e. broken down by bacteria on exposure e.g. organic matter.
- Waste generation and disposal is a growing problem worldwide and is directly connected to industrial development and population growth.
- Waste disposal has huge environmental impacts and can cause serious problems.

6.0 TUTOR MARKED ASSESSMENT

Disposing of waste has huge environmental impacts and can cause serious problems. Explain how various ways of waste disposal have impact on *environment.*

7.0 REFERENCES/ FURTHER READING

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UNIT 2: CHARACTERISTICS OF AGRICULTURAL WASTES

CONTENTS

1.0 INTRODUCTION

Agricultural waste is defined as unwanted waste produced as a result of agricultural activities (i.e., manure, oil, silage plastics, fertilizer, pesticides and herbicides; wastes from farms, poultry houses and slaughterhouses; veterinary medicines or horticultural plastics). The by-products of agricultural activities are usually referred to as "agricultural waste". These wastes take the form of crop residues (residual stalks, straw, leaves, roots, husks, shells etcetera) and animal waste (manures). Agricultural wastes are widely available, renewable and virtually free, hence they can be an important resource. They can be converted into heat, steam, charcoal, methanol, ethanol, biodiesel as well as raw materials (animal feed, composting, energy and biogas construction etcetera).

Compositions of agricultural wastes depend on the system and type of agricultural activities. They can be in form of liquids, slurries or solids. Agricultural wastes include: animal waste (manure and animal carcasses), food processing waste (only 20% of maize is canned and 80% is waste), crop waste (corn stalks, sugarcane bagasse, drops and culls from fruits and vegetables, prunings) and hazardous and toxic agricultural waste (pesticides, insecticides and herbicides, etc).

Expansion of agricultural production has naturally resulted in increased quantities of agricultural wastes such as livestock waste, crop residues and agro-allied industrial by-products. There is therefore significant increase in agricultural wastes globally as a result of intensification of farming systems. It is estimated that about 998 million tones of agricultural waste is produced yearly (Agamuthu, 2009). It was also reported that organic wastes amount to 80% of the total solid wastes generated in any farm (Brown and Root Environmental consultancy, 1997).

2.0 OBJECTIVES

- To identify and describe wastes that are agriculturally based.
- To understand different sources of agricultural wastes.
- To understand ways on how agricultural wastes are utilized.

3.0 MAIN CONTENT

3.1 Agricultural waste generation

3.1.1 Waste from application of chemicals during Cultivation practices

Most crops in tropics do well because of the favorable weather conditions. Likewise generation and development of insects and weeds are also favored by the tropical climates. As a result, there is high demand for pesticides and insecticides as well as herbicides in order to kill insects and protect plants against the spread of epidemic diseases and weed infestation. These needs often lead to the abuse of the chemicals by farmers. After use, most of the containers holding these chemicals are usually pitched into fields or surrounding water bodies. These wastes have the potential to cause environmental hazards such as food poisoning and contamination of the farmland due to their potential to last in the soil.

Also, application of fertilizers plays an important role in maintaining the productivity and quality of plants. However, most farmers apply more fertilizer to their crops than recommended rate in order to boost production (Hai and Tuyet, 2010). The implication of such excessive application of fertilizer is that portion is retained in the soil, a portion enters in to water bodies as a result of either surface runoff or the irrigation system (which results in the pollution of surface water); while portion enters ground water and a portion escapes into atmosphere and denitrified thus causing air pollution.

3.1.2 Waste from livestock production

Waste from livestock activities include solid waste such as manure and organic materials in the slaughterhouse; wastewater such as urine, cage wash water, wastewater from the bathing of animals; from maintaining sanitation in slaughterhouses; and air pollutants and odors. The pollution caused by livestock production is therefore a serious problem since most of them are usually built around residential areas. Air pollution includes odors emanating from cages resulting from the digestion process of livestock wastes; the putrefaction process of organic matter in manure; animal urine, and/or from redundant foods. This untreated and non-reusable waste source can generate greenhouse gases while also having negative effects on the fertility of the soil and causing water pollution. In livestock waste, water volume accounts for 75–95% of total volume, while the rest includes organic matter, inorganic matter, and many species of microorganisms and parasite eggs (Hai and Tuyet, 2010). Those germs and substances can spread diseases to humans and cause many negative effects on the environment.

3.1.3 Waste from Aquaculture

Aquaculture production requires the use of inputs, especially feed per unit area of land (Henriksson *et al*., 2018) leading to an increase in waste generation from the production systems. These wastes have little or no economic value and are often a nuisance to the environment. The waste generation from aquaculture has made its sustainability a public concern (Martins *et al*., 2010). Reports indicated that metabolic wastes discharged by 63,000 tons of fish produced in Japan in 1999 were equivalent to the waste generated by 5 million people (Suzuki *et al*., 2003). This underscores the need for proper methods to ensure the sustainable intensification of aquaculture.

3.2 Uses of agricultural wastes

There are a number of applications to which agricultural wastes can be used. These include:

3.2.1 As source of fertilizer

The use of animal manures as a source of fertilizer has impact on input energy requirements at the farm level (Timber and Downing, 1977). Animal manure could supply 19% N, 38% P and 61% K (Council for Agricultural Science and Technology, 1975). However, fertilizer use of manures from large confinement is associated with high costs for transport, distribution, storage facility requirements, odor problems and possibility of groundwater contamination. Mokwunye (2000) reported that poultry manure contain high phosphorus which has positive effect on the growth and productivity of crops. It is also effective when combined with mineral phosphorus fertilizer for farm use. Adding manure to soil increases its fertility because it increases the nutrient retention capacity (or cation exchange capacity), improves the physical condition, the water- holding capacity and the structural stability of soil.

3.2.2 As source of biogas

Agricultural waste, particularly the manures, can be used to produced methane gas. The gas can be used for heating purposes as in broiler operation, water heating, grain drying, etc. The acid-forming bacteria break down the volatile solids from organic waste to organic acids, which are then utilized by methanogenic organisms to yield methane-rich gas (Figure1). The composition of the typical gas produced is: methane, 50-70%; CO_2, 25-45%; N_2, 0.5-3%; H_2, 1-10% with traces of H_2S; and the heating value of the gas is in the range of 18-25 M J m^{-3}. Anaerobic digestion makes the treatment and disposal of large poultry, swine and diary waste feasible, minimizing the odor problem. It stabilizes the waste and the digestion sludge is relatively odor-free and yet retains the fertilizer value of the original waste.

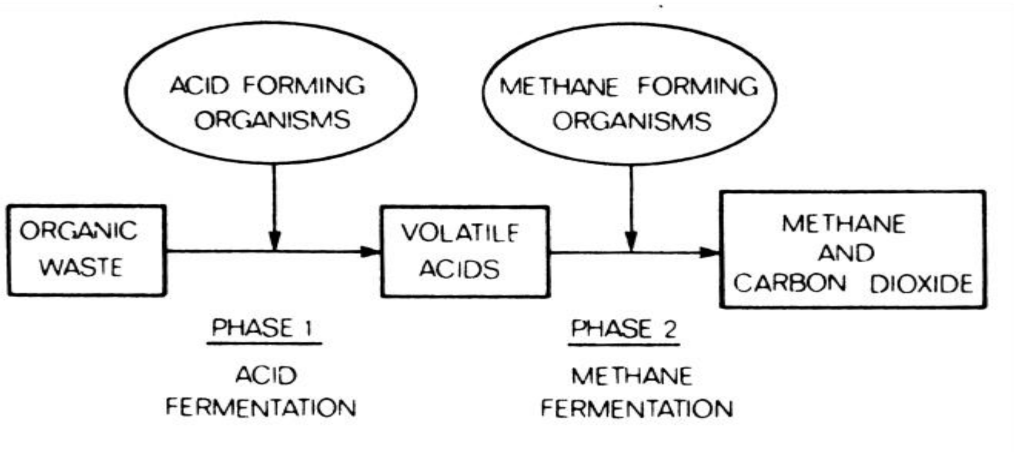

Figure 1: Methane production by microbial fermentation (Adapted from Obi et al. (2016)).

3.2.3 As heavy metal adsorbent

The release of excessive heavy metals to environment as a result of industrialization is of great concern world wild. Heavy metal ions such as copper, cadmium, mercury, zinc, chromium and lead ions do not degrade into harmless end products easily and therefore pose danger to environment as a result of their toxicity to many life forms. Studies on the treatment of effluent having heavy metal revealed that adsorption is highly effective technique for the removal of heavy metal from waste stream and activated carbon has been widely used (Ghand *et al*., 1994). Recently, agricultural wastes have been proven to be a low cost alternative for the treatment of effluents containing heavy metals through the adsorption process. The low cost agricultural waste such as sugarcane bagasse (Mohan *et al*., 2002), rice husk (Ayub *et al*., 2002), sawdust (Ajmal *et al*., 1996), coconut husk (Tan *et al*., 1993), oil palm shell (Khan *et al*., 2003), neem bark (Ayub *et al*., 2001), etc., have been investigated for elimination of heavy metals from wastewater.

3.2.4. As source of animal feeds

Agricultural wastes from both crop residues and animal waste can be used as animal feed. The use of broiler litter in cattle feeding is a widely applied practice. Animals, especially ruminants are useful in converting crop residues into food, hence contributing substantially to reducing potential pollutants. The rumen contains the microbial enzyme cellulase, which is the only enzyme to digest the most abundant plant product, cellulose (CAST, 1975). With ruminants, nutrients in by-products are utilized and do not become a waste-disposal problem (Oltjen and Beckett, 1996).

4.0 CONCLUSION

Agricultural wastes are valuable resource and can be useful of raw material for fertilizer production, animal feeds, biogas as well as sources for improving food security. However, if not treated, kept or disposed of properly, agricultural wastes are likely to cause pollution to the environment or even harm to human health. This calls for increased public awareness on the benefits and potential hazards of agricultural wastes, especially in developing countries.

5.0 SUMMARY

At the of this unit, we learnt that:

- The by-products of agricultural activities are usually referred to as “agricultural waste”.
- Agricultural wastes take the form of crop residues and animal manures.
- Quantities of agricultural wastes increased as a result of expansion of agricultural production, which include agro-allied industries.
- Agricultural wastes are usually generated from farming activities.
- Importance of agricultural wastes includes: sources of fertilizer, biogas, heavy metal adsorbent and animal feeds.

6.0 TUTOR MARKED ASSESSMENT

Explain the various uses of Agricultural wastes.

7.0 REFERENCES/ FURTHER READING

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UNIT 3: MUNICIPAL SOLID WASTES

CONTENTS

1.0 INTRODUCTION

Municipal solid waste (MSW) can be defined as non-air and sewer emission created within and disposed of by a municipality including household garbage, commercial refuse, construction and demolition debris, dead animals and abandoned vehicles. Municipal solid waste, also called garbage or trash, is non-hazardous refuse generated by households, institutions, industries, agriculture, and sewage. It is made up of waste, both compostable and recyclable materials, with the municipality overseeing its disposal. Typically, this refuse is collected, separated and sent to either a landfill or a municipal recycling center for processing. The united State Environmental Protection Agency (USEPA) observed that the majority of substances that are MSW include: paper, vegetable matter, plastics, metals, textiles, rubber and glass. It is estimated that in 2006 the total amount of municipal waste generated globally reached 2.02 billion tones, representing a 7% annual increase since 2003. It is further estimated that between 2007 and 2011, global generation of MSW raised by 37.3%, equivalent to roughly 8% increase per year. It is estimated that an average Nigerian generates about 0.49kg of solid waste per day with household and commercial center contributing almost 90% of total.

Municipal Solid Waste has changed alongside with society and time. In the past, refuse from community was mostly made up of ash, wood, bone, and vegetable Waste. Dumps were mainly filled with pottery or tools that could no longer be repaired as early humans would feed most biodegradables to their livestock or leave it to decompose. As humanity continued to develop, the refuse created by communities became more complicated with the introduction of metals like copper, aluminium, and steel; new materials like plastic; and the introduction of hazardous substances. Fortunately, humanity has been able to answer to this shift for the most part with programs that combat the various types of litter through recycling, compost and developing landfills that will protect the environment from pollution.

2.0 OBJECTIVES

- To define and identify wastes that are municipal based.
- To know the composition of municipal solid wastes.
- To understand the types of municipal solid waste
- To know the characteristics of municipal solid waste
- To understand different ways of managing municipal wastes

3.0 MAIN CONTENT

3.1 Types of MSW

3.1.1 Residential and Commercial MSW

These are solid wastes that are organic (combustible) or inorganic (non-combustible) from residential areas and commercial establishments. They do not include solid special or hazardous material. Typical examples of organic fraction of residential and commercial MSW include food waste (garbage), paper of all types, plastics, textiles, rubber, leather, wood and yard wastes. The inorganic fraction consists of items such as glass, crockery aluminum etc. If the waste components are not separated when discarded, they are known as commingled residential and commercial MSW.

3.1.2 Special Wastes

These are residential and commercial MSW that are bulky items, consumer electronics, white goods, yard wastes that are collected separately, batteries, oil and tyres- all handled separately.

- Bulky items can be large worn out or broken household, commercial and industrial items such as furniture, lamps, bookcases, filing carbonates etc.
- Consumer electronics include worn out, broken and other no longer wanted items such radios, stereos and television sets.
- White goods are large worn out or broken household, commercial and industrial appliances such as stove, refrigerators, dish washers and clothes washers and dryers.
- The principal sources of batteries are households, automobiles and other vehicle servicing facilities. Household batteries com from varying sources such as alkaline, mercury, silver, zinc, nickel and cadmium. Household battery can cause contamination of groundwater when found in leachate. Land filling of household should be discouraged as each automobile battery contains 8 kg of lead and 4 liters of sulphuric acids- all HAZMATs.
- Principal sources of oil is from servicing of motor and other moving vehicles. Waste oil discharged to the ground water or into municipal sewers often contaminate surface and ground waters as well as soil.
- About 230 to 240 million rubber tyres are produced in landfill or stockpiles. Stockpiling of tyers in the tropics is used in some advantage of erosion control in the shorelines- otherwise they pose serious aesthetic and environmental problem in case of fire outbreak.

3.2 Characteristics of Municipal Solid Waste

3.2.1 Physical Characteristics

Specific weight

This is weight of waste material per unit volume (kg/cm^3 or kg/m^3)

Moisture content

Moisture content of MSW is expressed in two ways: wet weight method and dry weight method. In the wet weight method, the moisture in a sample is expressed as percentage of wet weight while in the dry weight method, the waste is expressed as the dry weight of the material. The wet weigh is the most commonly use in field for waste management. It is expressed thus:

$$M = (w-d)/w * 100$$

Where M= moisture content (%), w = initial waste sample as delivered (kg) and d = weight of sample after drying at 105^0C

Example: The dry weight of waste sample after drying at 105^0C is 22372 g. If the moisture content of the waste was 65%, what would be the initial weight of waste (in kg) sample as delivered?

Solution:

$$m = (w-d)/w*100$$

Where m = moisture content; w = initial weight of waste; d = weight of waste sample after drying

$$65 = (w-22.372)/w * 100$$
$$65w = 100w-2237.2$$
$$65w-100w = -2237.2$$
$$-35w = -2237.2$$
w = **63.92kg**

Particle size and size distribution

These are important properties for recovery of materials. The size of waste component may be defined by the following measures:

$$Sc = L, Sc = (L+ W)/2 , Sc = (L+W+H)/3$$

Where Sc = size of component (mm), L= length (mm), W= width (mm), H= height (mm).

Field capacity

This is the amount of moisture that can be retained in a waste sample subject to downward pull of gravity. FC is important in determining the formation of leachate in landfill.

Permeability of compacted waste

The hydraulic conductivity of compacted waste is an important physical property that governs the movement of liquid and gases in a landfill.

3.2.2 Chemical Characteristics

Information on the chemical composition of MSW is important for evaluating alternative processing and recovery options. If solid wastes are to be used as fuels, four most important properties to be determined are:

1. Proximate analysis
2. Fusing point of ash
3. Ultimate analysis

Proximate Analysis

This involves

- Moisture (loss of moisture when heated to 105^0C)
- Volatile combustible matter (additional loss of weight on ignition at 950^0C in a covered crucible).
- Fused carbon (combustible residue left after volatile matter is removed)
- Ash (weight of sample after combustion in an open crucible).

Table 1. Typical example of proximate analysis and energy data for materials found in residential, commercial and industrial solid wastes

Types of waste	Proximate Analysis (% by weight)				Energy Content (KJ)		
	Moisture	Volatile Matter	Fixed carbon	Non Combust.	As collected	Dry	Dry ash free
Food waste	70	21.4	3.6	5	1.88	6.27	7.51
Meat waste	38.8	56.4	1.8	3.1	8.03	13.13	13.86
Cardboard paper	5.2	77.5	12.3	5	7.42	7.82	8.23
Plastic	0.2	95.8	2	2	14.98	15.18	16.82
Leather	10	68.5	12.5	9	7.91	8.48	9.42
Yard wastes	60	30	9.5	0.5	2.76	6.82	9.42
Wood	20	68.1	11.3	0.6	6.97	8.81	8.79

Source: Isirimah (2002).

Fusing point of Ash

Is defined as that temperature at which the ash resulting from the burning of waste will form a solid (Clinker). Typical temperatures for the formation of clinker range from 110 to 1200^0C.

Ultimate analysis of solid waste

This is the analysis of waste components. It involves the determination of % C, N, S, O, H and ash. Halogens are often included because of their importance. The result of ultimate analysis is used to characterize chemical composition of organic matter in MSW. They are also used to define proper mix of waste material to achieve suitable C/N ratio for biological conversion processes. An example is given in table below.

Table 2: Typical date on ultimate analysis of the combustible materials found in residential, commercial and industrial solid wastes

Type of waste	Percentage by weight (dry basis)					
	Carbon	Hydrogen	Oxygen	Nitrogen	Sulphur	Ash
Food waste	48	6.4	37.6	2.6	0.4	5
Meat waste	59.6	9.4	24.7	1.2	0.2	4.9
Cardboard paper	43	5.9	44.8	0.3	0.2	5
Plastic	60	7.2	22.8	-	-	10
Leather	60	8	11.6	10	0.4	10
Yard wastes	46	6	38	3.4	0.3	6.3
Wood	49.5	6	38	0.1	<0.1	0.9

3.2.3 Biological characteristics

Biodegradability of organic waste components

This is a biological characteristic of organic fraction of MSW that is measured by Volatile solid (VS) content (determined by ignition at 550^0C). This method of biodegradable is misleading because some organic fractions of MSW are highly volatile but low in biodegradability e.g. certain plant trimmings. Alternatively, lignin content of a waste can be used to estimate the biodegradable fraction using the following relationship:

$$BF = 0.83 - 0.028\ LC$$

Where BF = biodegradability fraction expressed on VS basis
LC = lignin content of the VS expressed as percentage dry weight.

Production of odors

Formation of odor results from the decomposition of organic compound found in MSW. When under anaerobic condition, sulphate is reduced to sulfide. The latter combined with hydrogen to form hydrogen sulphide.

$$2CH_3CHOHCOOH + SO_4^{2-} \rightarrow 2CH_3COOH + S^{2-} + H_2O + CO_2$$

Lactate sulphate Acetate sulphide ion

$$S^{2-} + 2H^+ \rightarrow H_2S$$

S^{2-} can also combine with metal salts such as Fe to form metal sulphides

$$S^{2-} + Fe^{2+} \rightarrow FeS$$

The black color of solid waste is due to production of FeS.

The biochemical reduction of an organic compound containing sulphur radical can lead to the formation of malodorous compound such as methyl mercaptan and amino butynic acid. The reduction of methionine (an amino acid) is an example.

$$CH_3SCH_2CH_2CH(NH_2)COOH \xrightarrow{2H} CH_3SH + CH_3CH_2CH_2(NH_2)COOH$$

Methionine Methyl mercaptan aminobutynic acid

Methyl mercaptan can also be hydrolyzed biochemically to methanol and hydrogen sulphide.

$$CH_3SH + H_2O \rightarrow CH_3OH + H_2S$$

Breeding of flies

Fly breeding is important during storage of waste. Flies develop in less than 2 weeks after the eggs are laid. Life of common housefly from egg to adult can be described as follows:

Eggs development ---------8-12 hours
First stage of larval --------20 hours

Second stage of larval -----24 hours
Third stage of larval -------3 days
Pupa stage ------------------ 4-5 days
Total ---------------------- 9-11 days.

3.3 Treatment/Transformation of MSW

3.3.1 Physical Transformation

In physical transformation, no change in physical state is involved. These include: Component separation, mechanical volume reduction and mechanical size reduction.

Component separation: - term used to describe the process of separation by manual and /or mechanical means. It is necessary operation in the recovery of reusable and recyclable for MSW.

Mechanical volume reduction:- is the term used to describe the process whereby an initial volume of waste is reduced using force or pressure. It is also known as **densification.**

Mechanical size reduction:- is the term used to describe the process whereby size of the waste is reduced. It does not necessarily reduce the volume of the waste. Examples are shredding, grinding and milling.

3.3.2 Chemical Transformation

These transformations that involve change of phase (e.g. solid to liquid or solid to gas) in reducing the volume and/or recovering products. The principal processes in chemical transformation include:

- Combustion/chemical oxidations
- Pyrolysis
- Gasification

3.3.3 Biological Transformation

This is transformation that involves the use of microorganisms in converting waste to useful materials such as compost and to produce methane. Principal organisms involve in the transformation are bacteria, fungus, yeast and actinomycetes. Two processes are involved during biological transformation:

- Aerobic composting
- Anaerobic digestion

4.0 CONCLUSION

Municipal solid wastes are non-hazardous materials produced by households, commercial and institutional activities that include paper, vegetable matter, plastics, metals, textiles, rubber and glass. Municipal solid wastes changes with society and time as developments brings about changes in the waste created by communities. More complicated wastes are usually introduced into the community like heavy metals, plastic and hazardous substances. However, with technology available, various techniques can be used to combat the different types of municipal solid wastes produced in order to protect the environment from pollution.

5.0 Summary

At the end of this unit, we have learnt that:

- Municipal solid waste, also called garbage or trash, is non-hazardous refuse generated by households, institutions, industries, agriculture, and sewage.
- Municipal solid waste changes with society and time.
- Municipal solid waste can broadly be classified into Residential/ commercial and Special wastes.
- The characteristics of municipal solid waste are physical, chemical and biological
- Municipal solid waste can be treated through physical, chemical and biological transformations.

6.0 Tutor Marked Assessment

- What do you understand by MSW?
- Give a concise note on the different types of MSW.
- Highlight three characteristics of
  - Physical MSW;
  - Chemical MSW; and
  - Biological MSW.
- What are the three ways through which you can transform MSW?
- The dry weight of waste sample after drying at 105^0C is 332373 g. If the moisture content of the waste were 85%, what would be the initial weight of waste (in kg) sample as delivered?

7.0 REFERENCES/ FURTHER READING

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UNIT 4: INDUSTRIAL WASTES

CONTENTS

1.0 INTRODUCTION

These are wastes from light and heavy manufacturing, fabrication, construction sites, power and chemical plants. They include: housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes etc. It is the waste produced by industrial activity, which includes any material that is rendered useless during a manufacturing process such as that of factories, industries, mills, and mining operations. Industrial waste include dirt and gravel, masonry and concrete, scrap metal, oil, solvents, chemicals, scrap lumber, even vegetable matter from restaurants. Industrial waste may be solid, liquid, gaseous, hazardous or non-hazardous waste. Hazardous waste may result from manufacturing or other industrial processes. Certain commercial products such as cleaning fluids, paints or pesticides discarded by commercial establishments or individuals can also be defined as hazardous waste. Non-hazardous industrial wastes are those that do not meet the EPA's definition of hazardous waste - and are not municipal waste.

Industrial waste, if improperly managed, can pose dangerous health and environmental consequences. The introduction of many new products for the home and office - computers, drugs, textiles, paints and dyes, plastics - also introduced hazardous waste, including toxic chemicals, into the environment. The human health and environmental impacts of many of these chemicals are largely unknown. High levels of toxic contaminants have been found in animals and humans, particularly those, like farm workers and oil and gas workers, who are continually exposed to such waste streams.

2.0 OBJECTIVES

- To define and identify wastes that are industrial based
- To know the sources and types of industrial wastes
- To understand the impact of industrial wastes on human and environment

3.0 MAIN CONTENT

3.1 Sources of Industrial waste

The wastes produced in industries are heterogeneous and each category of industries differs in the amount and type of waste it produces. Industrial wastes may be solids or liquids. Industrial solid wastes include: solid wastes generated from mining and tailings; solid wastes from metallurgical industries which include – varies of slag from metallurgical procedure and processing of metal and non–metal; solid waste from power industries: coal fly ash, coal slag, fuel ash, gangue generated from coal excavating and coal washing; solid wastes from chemical industries: inferior products, outgrowth, disabled catalyst, waste additives, raw materials that have not reacted etc.; solid wastes from oil chemical industries: oil mud, tar shale slag, waste catalyst, waste organic solvent; solid wastes from light industries: sludge, animal residue, waste acids, waste alkali, others from food processing such as food industries, paper making and printing industries, spinning and dye – printing industries and leather industries; other industrial solid wastes include: metal dross from mechanical processing, plant sludge, construction and demolition wastes and slags from other processing industries.

Industrial liquid wastes are generally divided into two: organic and inorganic industrial liquid wastes. In organic liquid wastes, the effluents contain organic substances having various origins and properties. Most organic industrial wastewaters are produced by the following industries and plants: factories manufacturing pharmaceuticals, cosmetics, organic dye-stuffs, glue and adhesives, soaps, synthetic detergents, pesticides and herbicides; tanneries and leather factories; textile factories; cellulose and paper manufacturing plants; factories of the oil refining industry; brewery and fermentation factories; metal processing industry. The inorganic industrial wastewater is produced mainly in the coal and steel industry, in the nonmetallic minerals industry and in commercial enterprises and industries for the surface processing of metals (iron picking works and electroplating plants). These wastewaters contain a large proportion of suspended matter, which can be eliminated by sedimentation, often together with chemical flocculation through the addition of iron or aluminum salts, flocculation agents and some kinds of organic polymers.

3.2 Impact of industrial wastes on human and environment

Most factories and power plants are located near water bodies because they need large amounts of water as input for manufacturing process. Most of these factories do not yet have the resources or technology to dispose of waste with lesser effects on the environment. Both untreated and partially treated wastewaters are commonly discharged into a near lying water body. Metals, chemicals and sewage released into water bodies directly affect marine ecosystems and the health of those who depend on the waters as food or drinking water sources. Toxins from the wastewater can kill off marine life or cause varying degrees of illness to those who consume these marine animals, depending on the contaminant. Wastewater containing nitrates and phosphates often causes eutrophication, which can kill off existing life in the water.

Another obvious effect of industrial waste is air pollution resulting from fossil fuel burning. This affects the lives of many people because this spreads illnesses. Over time, this issue that has been widespread. Several environmental issues have a devastating effect on third world countries because they don't have sufficient resources to solve this particular issues. This also affects the quality of soil because farmers have to try and deal with this massive issue (Aivalioti 2014). In addition, nitrogen dioxide is a common air pollutant found in the air. Air pollutants have a devastating effect on the human population because it causes sicknesses. Ammonia also causes a lot of respiratory problems that can be contracted from the air. "Illnesses that can occur from air pollution range from irritation to eyes, skin, nose, or throat. There is also a chance to get Pneumonia or Bronchitis both being very dangerous. Commonly, people have reported to have gotten headaches, nausea and dizziness from air pollution (Richie and Roser, 2019). WHO stated that air pollution is the worst risk in terms of human health.

On the other hand, one of the most devastating effects of industrial waste is water pollution. Farmers rely on this water but if the water is polluted, then crops that are produced can become polluted. This affects not only the society and humans but also animals. Water pollution can have devastating effects on the human body majorly from infection of bacteria, parasites and chemicals. Diseases that humans can be exposed from drinking unsafe water range from cholera, typhoid or Giardia.

4.0 CONCLUSION

Industrial wastes come from various types and forms of industries but mostly are hazardous in nature. The industrial waste generated can cause both air and water pollution, which do not only have devastating effect on humans but also to animals, fish, and birds. Polluted water is unsuitable for drinking, recreation, agriculture, and industry. It diminishes the aesthetic quality of lakes and rivers. More seriously, contaminated water destroys aquatic life and reduces its reproductive ability. Eventually, it is a hazard to human health.

5.0 SUMMARY

This unit can be summarized thus:

- Industrial wastes are waste from Light and heavy manufacturing, fabrication, construction sites, power and chemical plants.
- Industrial wastes can be to dangerous health and environmental consequences when not properly managed.
- Sources of industrial wastes may be generally solids or liquids arising from different manufacturing process.
- The major impacts of industrial wastes are water and air pollution.

6.0 Tutor Marked Assessment

Discuss impact of industrial wastes on environment and human health.

7.0 REFERENCES/ FURTHER READING

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UNIT 5: HAZARDOUS WASTES

CONTENTS

1.0 INTRODUCTION

The simple definition of hazardous waste that "Any waste that has the potential to harm human health or the environment is hazardous waste" is not adequate from a legal standard point. Therefore, the Resource Conservation and Recovery Act (RCRA) legislation in the US defined hazardous waste as a waste, or combination of waste, which because of its quantity, concentration, or physical, chemical or infectious characteristics may:

- Cause or significantly contribute to an increase in mortality or increase in serious irreversible illness; and
- Pose a substantial present or potential hazard to human health or environment when improperly treated, stored, transported or disposed of.

According to EPA, waste is hazardous if it meets one or more of the following criteria.

- It exhibits the characteristic of hazardous waste
- It is a non-specific source waste.
- It is a specific commercial chemical product or intermediate.
- It is a mixture containing a listed hazardous waste.
- It is a substance that is not excluded hazardous waste RCRA.

2.0 OBJECTIVES

- To have clear definition on hazardous waste
- To know the characteristics of hazardous wastes
- To identify the sources of hazardous wastes
- To classify hazardous waste into different classes

3.0 MAIN CONTENT

3.1 Characteristic of Hazardous Waste

Available procedures are accurate enough to enable definition of the four characteristic of hazardous waste i.e. ignitability, corrosivity, reactivity and toxicity. However, test protocol and data interpretation for measuring carcinogenicity, mutagenicity, phytotoxicity and potential bioaccumulation are either poorly developed or too complex and require high level of expertise.

3.1.1 Ignitability

Ignitability is the characteristic used to define hazardous waste as those waste that could cause a fire during transport, storage or disposal. Examples of ignitable waste include waste oils and used solvent. It has the following properties;

1. It is a liquid, other than aqueous solution containing less than 24% alcohol by volume and has flash point less than 60˚C (140˚F).
2. It is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture, or spontaneous chemical changes, and when ignited, burns so vigorously and persistently that it creates a hazard.

3.1.2 Corrosivity

This is a characteristic of hazardous waste that is measured by pH. Waste containing materials of very high or very low pH can produce dangerous reaction with other materials in the waste or cause toxic contaminants to migrate from certain waste. Examples are acidic wastes from many industrial processes. The corrosive materials have the following properties.

1. It is aqueous and has the pH of <2 or > 12.5 as determine by pH meter
2. It is a liquid and corrodes steel at rate >6.35mm per year at a test temperature of 55^{o}C (130^{o}F).

3.1.3 Reactivity

Some constituents of a waste may be unstable and may have the potential to cause explosion at any state of the waste management cycle. Used cyanide solvents and water from TNT operation are example of reactive waste.

1. It is normally unstable and readily undergoes violent changes without detonating.
2. It reacts violently with water.
3. It forms potentially explosive mixture with water.
4. When mixed with water, it generates toxic gases, vapors or fumes sufficiently enough to endanger human health or environment.
5. It is cyanide or sulfide bearing waste which when exposed to pH condition between <2 and >12.5, can generate toxic gases, fumes and vapors that can endanger human health and environment.

3.1.4 Toxicity

Is the ability of a substance to cause death, injury, or impairment to an organism that comes in contact with it. Modes of contact are ingestion, inhalation and dermal contact. A waste will be considered as toxic if, using the standard test method, the extract from the representative sample of the waste contains the following at greater or equals to respective value.

Table 1

Chemical	Maximum allowable concentration (mg/L)
As	5
Ba	100
Cd	1
Cr	5
Pb	5
Hg	0.2
Se	1
Ag	5

Concept of toxicity

Adverse effect such as carcinogenicity, mutagenicity and teratogenicity are generally linked to contact with toxic materials and may also be used as a criteria in a listening of hazardous wastes. However, the term ‘toxic’ and ‘hazardous’ are not interchangeable. Toxic denotes the capacity of a substance to produce injury while hazardous denotes the probability that injury will result from the use of (or contact with) a substance.

Acute toxicity refers to the toxic effects that have rapid onset, a short course and pronounced symptoms. Acute toxic waste may injure human and mammals when inhaled or ingested or upon contact with skin. Acute toxicity is typically measured in terms of lethal dose concentration (LD_{50}) in which 50% of the test population will die from the exposure to a particular substance under prescribed condition.

Chronic toxicity refers to the effect that persists over a long period of time. Chronic toxicity measurements are not nearly as standardized as acute measurements due to inability to maintain human being or mammal under long term controlled condition.

3.2 Sources of Hazardous Waste

Petrochemical industries: phenols, acids, caustic and organic compounds

Metal industries: heavy metals, fluorides, cyanide, acids, alkali, solvents and phenols

Leather industries: heavy metals and sulfides

Others that generate partial hazardous waste: rubber, batteries, pharmaceutical, textiles, dyeing and finishing, leather tanning and finishing, special machinery, plastics etc.

3.3 Classification of Hazardous Waste

3.3.1 EPA classifications

a). Hazardous waste from non-specific sources: - these are generic waste commonly produced by manufacturing and industrial processes e.g. halogenated solvent used in degreasing. Examples include tetrachloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, chlorinated fluorocarbons etc.

b). Hazardous waste from specific sources: - these wastes are produced by specific industrial processes such as wood preserving (such as creosote and pentachlorophenol), petroleum refining (e.g. Dissolved air floatation (DAF)), and organic chemical manufacturing (distillation bottoms from production of acetaldehyde from ethylene). Others include inorganic chemicals.

c). Commercial chemical products: - this consists of specific commercial products like chloroform, creosote, acids, pesticides etc.

d). Hazardous constituents: - these are hazardous constituent capable of producing toxic, carcinogenic, mutagenic, or teratogenic effect on human and other lives e.g. tetrachloroehylene, methylene chloride trichloroethylene, 1,1,1-trichloroethane etc.

3.3.2 Industrial classifications

The hazardous waste management industries recognizes five categories of waste

1. Metal/metal finishing
2. Paints/solvents/coatings
3. Organic
4. Petroleum
5. Inorganic

3.3.3 Classification based on quantity produced

a). Small quantity generators (SQG): - if the total quantity of the hazardous waste produced is <100 kg/month of none acutely hazardous waste or < 1 kg of acutely hazardous waste.

b). Medium quantity generators (MQG): - if the total quantity of the hazardous waste produced is between 100-1000 kg/month of none acutely hazardous waste.

c). Large quantity generators (LQG): - if the total quantity of the hazardous waste produced is between 1000 kg/month or more of none acutely hazardous waste and > 1 kg/month of acutely hazardous waste.

3.4 Household Hazardous Waste (HHW)

Household Hazardous Waste is a subgroup of solid waste commonly found in MSW as well as in wastewater streams. As the name implies, these special wastes originate from households. HHW are any household wastes, which are generated from the disposal of substances identified as hazardous household substances including, but not limited to the following listed waste sources and types:

(i) **Repair and Remodeling wastes including**: adhesives, glues, cements, roof coatings and sealants, epoxy resins, solvent based paints, solvents, painter removers and strippers.

(ii) **Cleaning Agent wastes including**: *oven cleaners*; degreasers and spot removers; septic *cleaners*; polishes, waxes, and *strippers;* solvent cleaning fluids.

(iii) **Pesticide wastes including**: insecticides, fungicides, rodenticides, molluscides, wood preservatives, moss retardants and chemical removers, herbicides, and fertilizers containing pesticides.

(iv) **Automotive maintenance wastes including**: batteries, waxes and cleaners, paints, solvents, cleaners, additives, gasoline, flushes, auto repair materials, motor oil, diesel fuel, and antifreeze,

(v) **Hobby and recreation wastes including**: paints, solvents, photo chemicals, pool chemicals, glues, adhesives and cements, inks, dyes, chemistry sets, pressurized gas containers and household batteries.

(vi) **Other household wastes including**: ammunition, asbestos, fireworks, and any other household wastes identified as moderate-risk waste in the planning area’s local hazardous waste plan.

4.0 CONCLUSION

The management of hazardous waste requires high degree of knowledge over very broad technical and legal area. Hazardous wastes are diverse with compositions and properties that not only vary significantly from one industry to another but within the industries and indeed the househol3. Proper management therefore requires understanding the numerous and complex regulations governing the hazardous waste streams and knowledge of the treatment and waste minimization technologies.

At the end of this unit, we learnt that:

- Definition of hazardous that "any waste that has the potential to harm human health or the environment is hazardous waste" is not adequate from a legal standard point.
- Certain criteria are needed to describe waste as hazardous
- Characteristics of hazardous waste are: ignitibility, corrosivity, reactivity and toxicity
- Classification of hazardous waste is based on EPA, industrial and quantity generated.
- Household hazardous waste is generated from the disposal of substances identified as hazardous from household.

6.0 Tutor Marked Assessment

1. Define hazardous waste based on the **RCRA** legislation
2. Give one feature of each of the followings:
   i. Ignitability
   ii. Corrosivity
   iii. Reactivity
   iv. Toxicity.
3. What are the three (3) classes of hazardous wastes? Explain one (1).
4. List the different household hazardous waste (HHW).

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Module 2:

UNIT 1: ORGANIC MATTER

CONTENT

1.0 INTRODUCTION

Many a times, organic matter is considered as the plant and animal residues incorporated into the soil. This is actually organic material, not organic matter. Organic material is anything that was alive and is now in or on the soil. For it to become organic matter, it must be decomposed. Organic material is unstable in the soil, changing form and mass readily as it decomposes. As much as 90 % of it disappears quickly because of decomposition. Organic matter is stable in the soil. It has been decomposed until it is resistant to further decomposition.

Organic matter in soil has been described as “the most complex and least understood component of soils” (Magdoff and Weil, 2004). According to SSSA (1987), organic matter in the soil is defined as the organic fraction of the soil exclusive of undecayed plant and animal residue. However, organizations and individual researchers differ in their opinion about whether undecayed plant and animal tissues (e.g. stover, dead bugs, earthworms, etc.) should be included in the definition of soil organic matter.

A broader definition of soil organic matter is adopted as proposed by Magdoff (1992), which consider soil organic matter to be the diverse organic materials, such as living organisms, slightly altered plant and animal organic residues, and well-decomposed plant and animal tissues that vary considerably in their stability and susceptibility to further degradation. Simply put, soil organic matter is any soil material that comes from the tissues of organisms (plants, animals, or microorganisms) that are currently or were once living.

Soil organic matter is any material produced originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process. Most soil organic matter originates from plant tissue. Plant residues contain 60–90% moisture. The remaining dry matter consists of carbon, oxygen, hydrogen and small amounts of sulphur, nitrogen, phosphorus, potassium, calcium and magnesium.

2.0 OBJECTIVES

- To define organic matter
- To understand how organic matter is decomposed in the soil
- To the components of organic matter
- To know the factors that influence organic matter decomposition

3.0 MAIN CONTENT

3.1 Organic Matter Decomposition in Soil

Decomposition is a biological process that includes the physical breakdown and biochemical transformation of complex organic molecules of dead material into simpler organic and inorganic molecules (Juma, 1998). Its speed is determined by three major factors: soil organisms, the physical environment and the quality of the organic matter (Brussaard, 1994). In the decomposition process, different products are released: carbon dioxide, energy, water, plant nutrients and re-synthesized organic carbon compounds. Successive decomposition of dead material and modified organic matter results in the formation of a more complex organic matter called humus (Juma, 1998). This process is called humification.

Decomposition of organic matter occurs when an organism dies (or parts of it die) and is on or in the soil. The invertebrates, fungi, and bacteria living in and on the soil consume it. By so doing, they assimilate many of its nutrients into themselves. This process is called "nutrient immobilization." As long as these nutrients are in the bodies of the decomposers, they are not available for plant uptake, hence the term "immobilization;" they are temporarily unavailable. When the nutrients are immobilized, they are in organic form. Decomposers can also immobilize nutrients that are applied inorganically and tie them up temporarily in organic form. This is particularly common with nitrogen, and particularly when the carbon: nitrogen ratio of the litter is very high, such that nitrogen is in great demand.

The decomposers all tend to be short-lived. They die and are consumed by others, often through a complex succession of organisms. However, gradually, the nutrients that they contained are converted to inorganic forms either through biological action or by leaching by water. This process is called mineralization; the conversion of organically bound forms of nutrients to inorganic forms as result of inorganic or biological chemical reactions. At this point, the nutrients are available for plant uptake.

Thus, in soils, death, immobilization and mineralization, coupled with plant uptake, are constantly occurring. Nutrients gradually become available from the decay of organic inputs, which act essentially like timed-release fertilizers. This is the nutrient cycling. By breaking down carbon structures and rebuilding new ones or storing the C into their own biomass, soil biota plays the most important role in nutrient cycling processes and, thus, in the ability of a soil to provide the crop with sufficient nutrients to harvest a healthy product.

3.2 Components of Soil Organic Matter

Most soil organic matter originates from plant tissue. Plant residues contain 60-90 percent moisture. The remaining dry matter consists of carbon (C), oxygen, hydrogen (H) and small amounts of sulphur (S), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). Although present in small amounts, these nutrients are very important from the viewpoint of soil fertility management.

Soil organic matter consists of a variety of components. These include, in varying proportions and many intermediate stages, an active organic fraction including microorganisms (10-40 percent), and resistant or stable organic matter (40-60 percent), also referred to as humus.

Organic matter may be divided into aboveground and belowground fractions. Aboveground organic matter comprises plant residues and animal residues; belowground organic matter consists of living soil fauna and microflora, partially decomposed plant and animal residues, and humic substances. The C:N ratio is also used to indicate the type of material and ease of decomposition; hard woody materials with a high C:N ratio being more resilient than soft leafy materials with a low C:N ratio.

Although soil organic matter can be partitioned conveniently into different fractions, these do not represent static end products. Instead, the amounts present reflect a dynamic equilibrium. The total amount and partitioning of organic matter in the soil is influenced by soil properties and by the quantity of annual inputs of plant and animal residues to the ecosystem. For example, in a given soil ecosystem, the rate of decomposition and accumulation of soil organic matter is determined by such soil properties as texture, pH, temperature, moisture, aeration, clay mineralogy and soil biological activities. A complication is that soil organic matter in turn influences or modifies many of these same soil properties.

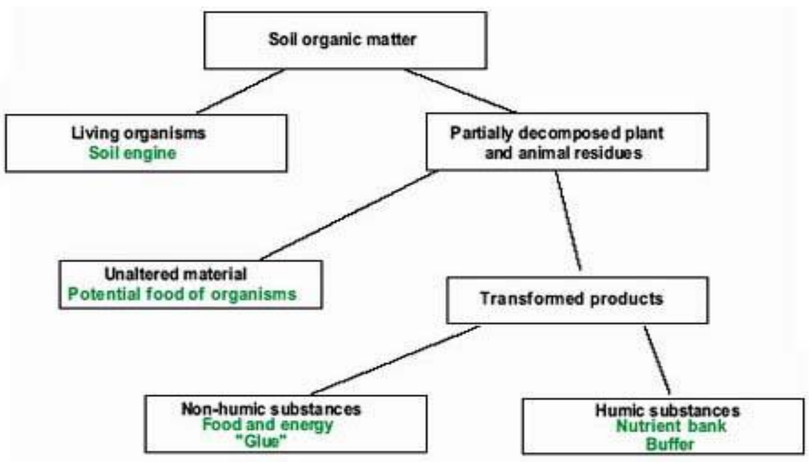

Fig 1: Components of soil organic matter and their functions

3.3 Factors Affecting Organic Matter Decomposition

Climate

Climate, i.e. precipitation and temperature, influence the amount and type of vegetation as well as the rate of decomposition. The organic matter content of a soil increases with increasing decomposition up to the limit set by temperature. In soils, every 10^{o}C increase in mean annual temperature results in the organic matter content being reduced by about 1/3 to 1/2, if all other factors are constant. Generally, cold and arid climate tends to slow down the microbial processes within soil and thus decomposition and mineralization. Also, the warmer the climate, the higher the rates of microbial process, i.e., the lower the organic matter content in those soils.

The soil moisture content also has a remarkable effect of soil organic matter decomposition and accumulation. Waterlogged soils tend to accumulate organic matter because the microbial processes, in particular decomposition and mineralization, are slowed down. In aquic moisture regimes, the drainage and soil aeration is poor thereby creating anaerobic conditions. Anaerobic oxidation of organic residues is less efficient than aerobic oxidation. If organic matter is accumulated the soil development is towards organic soils (Histosols).

Vegetation

The rate of soil organic matter accumulation depends largely on the quantity and quality of organic matter input. Under tropical conditions, applications of readily degradable materials with low C: N ratios, such as green manure and leguminous cover crops, favor decomposition and a short-term increase in the labile nitrogen pool during the growing season. On the other hand, applications of plant materials with both large C: N ratios and lignin contents such as cereal straw and grasses generally favor nutrient immobilization, organic matter accumulation and humus formation, with increased potential for improved soil structure development. Generally, when the C: N ratio is > 25, net immobilization occurs, whereas at ratios < 25 net mineralization is likely.

Soil Structure

Soil organic matter tends to increase as the clay content increases. This increase depends on two mechanisms. First, bonds between the surface of clay particles and organic matter retard the decomposition process. Second, soils with higher clay content increase the potential for aggregate formation. Macro aggregates physically protect organic matter molecules from further mineralization caused by microbial attack (Rice, 2002). For example, when earthworm casts and the large soil particles they contain are split by the joint action of several factors (climate, plant growth and other organisms), nutrients are released and made available to other components of soil microorganisms.

Salinity and Acidity

Salinity, toxicity and extremes in soil pH (acid or alkaline) result in poor biomass production and, thus reduced additions of organic matter to the soil. For example, pH affects humus formation in two ways: decomposition and biomass production. In strongly acid or highly alkaline soils, the growing conditions for microorganisms are poor, resulting in low levels of biological oxidation of organic matter (Primavesi, 1984). Soil acidity also influences the availability of plant nutrients and thus regulates indirectly biomass production and the available food for soil biota. Fungi are less sensitive than bacteria to acid soil conditions.

Topography

Organic matter accumulation is often favored at the bottom of hills. There are two reasons for this accumulation: conditions are wetter than at mid- or upper-slope positions, and organic matter is transported to the lowest point in the landscape through runoff and erosion. Similarly, soil organic matter levels are higher on north- facing slopes (in the Northern Hemisphere) compared with south-facing slopes (and the other way around in the Southern Hemisphere) because temperatures are lower (Quideau, 2002).

4.0 CONCLUTION

Soil organic matter plays a vital role in nutrient retention and availability in the soil. This is as a result of decomposition of plant and animal matters brought about by soil organisms, physical environment and the quality of the organic residue. There are several factors however, that affect decomposition of the organic residue in soil.

5.0 SUMMARY

At the end of this unit, we learnt that:

- Soil organic matter is any material produced originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process.
- Decomposition of organic matter occurs when an organism dies (or parts of it die) and is on or in the soil. The decomposed organic matter can either be immobilized or mineralized in soil depending on the prevailing condition
- Organic matter may be divided into aboveground and belowground fractions. Aboveground organic matter comprises plant and animal residues; belowground organic matter consists of living soil fauna and microflora, partially decomposed plant and animal residues, and humic substances.
- Factors that affect organic matter decomposition are generally climatic and edaphic factors.

6.0 Tutor Marked Assessment

Explain the various factors that can influence the decomposition of organic residues in soil

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UNIT 2: SOIL BIOTA

CONTENT

1.0 INTRODUCTION

Soil organisms represent a large fraction of global terrestrial biodiversity. They carry out a range of processes important for soil health and fertility in soils of both natural ecosystems and agricultural systems. Soil biodiversity is comprised of the organisms that spend all or a portion of their life cycles within the soil or on its immediate surface including surface litter and decaying logs (Table 1)

Table 1: Categories and characteristics of soil organisms

Category	Characteristics	Organisms
Permanent	Whole life cycle in the soil	Mites, collembola, earthworms
Temporal	Part of life cycle in the soil	Insect larvae
Periodical	Frequently enter into the soil	Some insect larvae
Transitory	An inactive phase in the soil (e.g. eggs, pupae, hibernation) but the active period not in the soil	Some insects
Accidental	Organisms fall down or they are drawn along	Insect larvae

The community of organisms living all or part of their lives in the soil constitutes the soil food web. The activities of soil organisms interact in a complex food web with some subsisting on living plants and animals (herbivores and predators), others on dead plant debris (detritivores), on fungi or on bacteria, and others living off but not consuming their hosts (parasites). Plants, mosses and some algae are autotrophs; they play the role of primary producers by using solar energy, water and carbon (C) from atmospheric carbon dioxide (CO_2) to make organic compounds and living tissues. Other autotrophs obtain energy from the breakdown of soil minerals, through the oxidation of nitrogen (N), sulphur (S), iron (Fe) and C from carbonate minerals. Soil fauna and most fungi, bacteria and actinomycetes are heterotrophs, they rely on organic materials either directly (primary consumers) or through intermediaries (secondary or tertiary consumers) for C and energy needs.

A food web is a series of conversions of energy and nutrients as one organism eats another. In a healthy soil, there are a large number of bacteria and bacterial feeding organisms. Where the soil has received heavy treatments of pesticides, chemical fertilizers, soil fungicides or fumigants that kill these organisms, the beneficial soil organisms may die (impeding the performance of their activities), or the balance between the pathogens and beneficial organisms may be upset, allowing those called opportunists (disease-causing organisms) to become problems.

2.0 OBJECTIVES

- To know the various types of soil organism and their function in ecosystem.
- To classify soil organisms based on their sizes.
- To identify the organisms that are beneficial and harmful to agriculture.

3.0 MAIN CONTENT

3.1 CLASSIFICATION OF SOIL ORGANISMS

The easiest and most widely used system for classifying soil organisms is by using body size and dividing them into three main groups: macrobiota, mesobiota and microbiota (Swift *et al.*, 1979). The ranges that determine each size group are not exact for all members of each group.

3.1.1 MICROORGANISMS

These are the smallest organisms (<0.1 mm in diameter) and are extremely abundant and diverse. They include algae, bacteria, cyanobacteria, fungi, yeasts, myxomycetes and actinomycetes that are able to decompose almost any existing natural material. Microorganisms transform organic matter into plant nutrients that are assimilated by plants. Two main groups are normally found in agricultural soils: bacteria and mycorrhizal fungi.

Bacteria

Bacteria are very small, one-celled organisms that can only be seen with a powerful light (1000×) or electron microscope. They constitute the highest biomass of soil organisms. They are adjacent and more abundant near roots, one of their food resources. There are many types of bacteria but the focus here is on those that are important for agriculture, e.g. Rhizobium and actinomycetes.

Bacteria are important in agricultural soils because they contribute to the carbon cycle by fixation (photosynthesis) and decomposition. Some bacteria are important decomposers and others such as actinomycetes are particularly effective at breaking down tough substances such as cellulose (which makes up the cell walls of plants) and chitin (which makes up the cell walls of fungi). Land management has an influence on the structure of bacterial communities as it affects nutrient levels and hence can shift the dominance of decomposers from bacterial to fungal.

One group of bacteria is particularly important in nitrogen cycling. Free-living bacteria fix atmospheric N, adding it to the soil nitrogen pool; this is called biological nitrogen fixation and it is a natural process highly beneficial in agriculture.

Actinomycetes are a broad group of bacteria that form thread-like filaments in the soil. The distinctive scent of freshly exposed, moist soil is attributed to these organisms, especially to the nutrients they release as a result of their metabolic processes. Actinomycetes form associations with some non-leguminous plants and fix N, which is then available to both the host and other plants in the near vicinity.

Fungi

These organisms are responsible for the important process of decomposition in terrestrial ecosystems as they degrade and assimilate cellulose, the component of plant cell walls. Fungi are constituted by microscopic cells that usually grow as long threads or strands called hyphae of only a few micrometers in diameter but with the ability to span a length from a few cells to many meters. Soil fungi can be grouped into three general functional groups based on how they source their energy:

Decomposers – they are also known as **saprophytic fungi** – they convert dead organic material into fungal biomass, CO_2 and small molecules such as organic acids. These fungi generally use complex substrates, such as the cellulose and lignin, in wood. They are essential for decomposing the carbon ring structures in some pollutants. Like bacteria, these fungi are important for immobilizing or retaining nutrients in the soil.

Mutualists – they are also known as **mycorrhizal fungi** – they colonize plant roots through a symbiotic relationship. Mycorrhizae increase the surface area associated with the plant root, which allows the plant to reach nutrients and water that otherwise might not be available. Mycorrhizae essentially extend plant reach to water and nutrients, allowing plants to utilize more of the resources available in the soil. Mycorrhizae source their carbohydrates (energy) from the plant root they are living in/on and they usually help the plants by transferring phosphorus (P) from the soil into the root. Two major groups are identified:

(i) **Ectomycorrhizae**: that grow on the surface layers of the roots and are commonly associated with trees.
(ii) **Endomycorrhizae:** such as arbuscular mycorrhizal fungi and vesicular mycorrhizal fungi, that grow within the root cells and are commonly associated with grasses, row crops, vegetables and shrubs.

Arbuscular mycorrhizal fungi can also benefit the physical characteristics of the soil because their hyphae form a mesh to help stabilize soil aggregates. Vesicular-arbuscular mycorrhizae are the most widespread mycorrhizal fungi. Mycorrhizae are particularly important for phosphate uptake because P does not move towards plant roots easily. These organisms do not harm the plant, and in return, the plant provides energy to the fungus in the form of sugars. The fungus is actually a network of filaments that grows in and around the plant root cells, forming a mass that extends considerably beyond the root system of the plant (Figure 2).

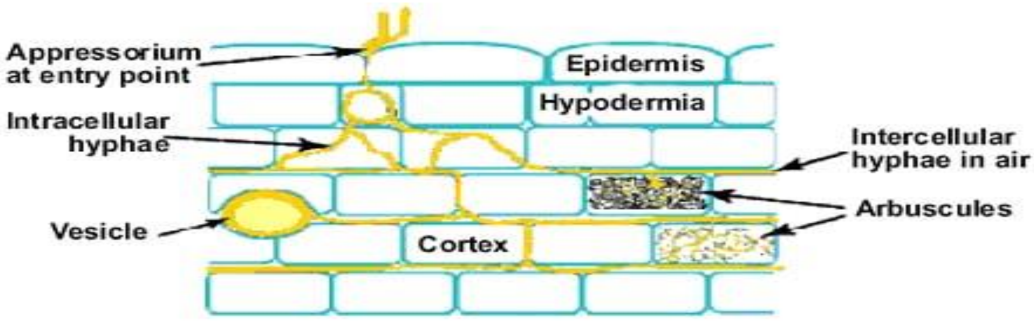

Fig 2: Mycorrhizal roots and the associated networks of hyphae are a major component of most soils

Pathogens or Parasites: they cause reduced production or death when they colonize roots and other organisms. Root-pathogenic fungi, such as *Verticillium*, *Pythium* and *Rhizoctonia*, cause major economic losses in agriculture each year.

Many fungi help control diseases, e.g. nematode-trapping fungi that parasitize disease-causing nematodes, and fungi that feed on insects may be useful as bio-control agents.

3.1.2 MICROFAUNA

The microfauna (<0.1 mm in diameter) includes *inter alia* small collembola and mites, nematodes and protozoa that generally live in the soil water films and feed on microflora, plant roots, other microfauna and sometimes, larger organisms (e.g. entomopathogenic nematodes feed on insects and other larger invertebrates). They are important to release nutrients immobilized by soil microorganisms.

Nematodes

Nematodes are tiny filiform roundworms that are common in soils everywhere. They may be free-living in soil water films; beneficial for agriculture or phytoparasitic (Figure 2), and live at the surface or within the living roots (parasites). Free-living nematodes graze on bacteria and fungi, thus they control the populations of harmful microorganisms. These nematodes are 0.15-5 mm long and 2-100 mm wide; an exception are Mermithidae nematodes, which may be 20 cm long and are very common in tropical soils, being parasites of some arthropods such as locusts. Nematodes can only move through the soil where a film of moisture surrounds the soil particles. They live in the water (they are hydrobionts) that fills spaces between soil particles and covers roots. In hot and dry conditions, they enter into a dormant stage, and as soon as water becomes available, they spring back to activity.

Nematodes are recognized as a major consumer group in soils and are generally grouped into four to five trophic categories based on the nature of their food, the structure of the stoma (mouth) and oesophagus and the method of feeding (Yeates and Coleman, 1982): **bacterial feeders, fungal feeders, predatory feeders, omnivores,** and **plant feeders. T**he bacterial feeders prey on bacteria (bacterivores) and may ingest up to 5 000 cells/minute, or 6.5 times their own weight daily. This helps disperse both the organic matter and the decomposers in the soil. Bacterial- and fungal-feeding nematodes release a large percent of N when feeding on their prey groups and are thus responsible for much of the plant available N in the majority of soils (Ingham *et al*., 1985). The annual overall consumption may be as much as 800 kg of bacteria per hectare and the amount of N turned over in the range of 20-130 kg (Coleman et al., 1984).

Phytophages or plant-feeding nematodes damage plant roots, with important economic consequences for farmers. They possess stylets with a wide diversity of size and structure, and they are the most extensively studied group of soil nematodes because of their ability to cause plant disease and reduce crop yield.

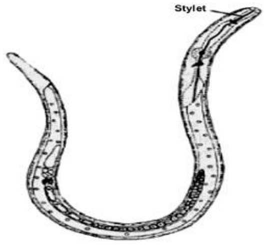

Fig 3: Parasitic nematode

3.1.3 MESOFAUNA

Mesofauna (0.1-2 mm in diameter) includes mainly microarthropods, such as pseudoscorpions, springtails, mites, and the worm-like enchytraeids. Mesofauna have limited burrowing ability and generally live within soil pores, feeding on organic materials, microflora, microfauna and other invertebrates.

Collembola

Collembola or "springtails" are micro arthropods that live in the litter or in the pore space of the upper 10-15 cm of soil. They are saprophagous and feed mainly on fungi, bacteria and algae growing on decomposing plant litter (Ponge, 1991). They are important as epigeic decomposers. Unlike most insects, they have no wings at any stage. They measure a few millimeters in length (Figure 4) and elongate with a characteristic salutatory organ, a forked "tail" which enables them to spring when in danger. Springtails are probably the most abundant group of insects on Earth.

Fig 4: springtail

Pseudoscorpions

Pseudoscorpions are tiny arachnids rarely longer than 8 mm. They live in litter, decaying vegetation, and the soil. Pseudoscorpions superficially resemble true scorpions, bearing relatively large chelae on the pedipalps, but they do not have a telson or stinger. Pseudoscorpions feed on very small arthropods such as springtails and mites.

3.1.4 MACROFAUNA

Members of species classed as macrofauna are visible to the naked eye (generally> 2 mm in diameter). Macrofauna includes vertebrates (snakes, lizards, mice, rabbits, moles, etc.) that primarily dig within the soil for food or shelter, and invertebrates (snails, earthworms and soil arthropods such as ants, termites, millipedes, centipedes, caterpillars, beetle larvae and adults, fly and wasp larvae, spiders, scorpions, crickets and cockroaches) that live in and feed in or upon the soil, the surface litter and their components. In both natural and agricultural systems, soil macrofauna are important regulators of decomposition, nutrient cycling, soil organic matter dynamics and pathways of water movement as a consequence of their feeding and burrowing activities.

Earthworms

The effects of earthworms in the soil differ according to the ecological category of the species (Lavelle, 1981) involved:

Epigeic: they live in the litter layers, a very changing environment, subject to drought, high temperatures and predator presence. These earthworms are generally small and pigmented (green or reddish) with rapid movements.

Endogeic: these are unpigmented (with no color) worms that live and feed in the soil. This group is further divided into three subgroups: oligohumic, mesohumic and polyhumic, depending on the organic matter content of the soil ingested.

Anecic: these earthworms feed on the surface litter that they generally mix with soil, but they spend most of their time in the soil. They are large, with dark anterodorsal pigmentation, and they dig sub vertical burrows.

As a result of this wide range of adaptations, earthworms have diverse functions in the soil. Epigeic worms can be used as compost makers with no impact on soil structure. Anecics and endogeics do have an impact on soil structure owing to their mixing and burrowing activities, and on soil organic matter.

Termites

Termites are important members of soil macrofauna in various regions of the world. They are social insects, living in organized colonies with a number of castes (different individuals) with a set of morphological and physiological specializations. The main castes are: queen (the termite that founds the colony), worker and soldier.

Neither individual termites nor colonies normally travel long distances as they are constrained to live within their territorial border or within their food materials. A number of species feed on living plants and some may become serious pests in agricultural systems where dead residues are scarce (Wood, 1996). Most species feed on dead-plant materials above and below the soil surface. Their food sources include plant-decaying materials, dead foliage, woody materials, roots, seeds and the faeces of higher animals (Lavelle and Spain, 2001). There are also soil-wood feeders and soil feeders, which means that they ingest a high proportion of mineral material. Their nutrition derives mainly from well-decayed wood and partly humified soil organic matter. Another group of termites grow fungi in their nests (fungus-growing termites). Termites may be classified by their feeding habits: grass harvesters, surface litter feeders, wood feeders, soil-wood feeders, soil feeders (humivores).

Ants

Ants build a large variety of structures in the soil. However, because of their feeding habits, they are of less importance in regulating processes in the soil than termites or earthworms.

Beetles

Beetles (Coleoptera) are diverse taxonomically and differ widely in size and in the ecological role they perform in soil and litter. They are either saprophagous, phytophagous or predators. Two groups are of particular relevance in agricultural soils: larvae from the family Scarabeidae (dung-beetles), crucial to burying cow dung in natural savannahs and grasslands used for cattle grazing; and Melolonthinae beetles, whose larvae may be abundant in grasslands and affect crop production by feeding on living roots (Villalobos and Lavelle, 1990).

3.1.5 Biogenic structures

Biogenic structures are those structures created biologically by a living organism. Three main groups of biogenic structures are commonly found in agricultural systems: earthworm casts and burrows, termite mounds and ant heaps. The biogenic structures can be deposited in the soil surface and in the soil, and generally they have different physical and chemical properties from the surrounding soil. The color, size, shape and general aspect of the structures produced by large soil organisms can be described for each species that produces it. The form of the biogenic structure can be likened to simple geometric forms in order to facilitate evaluation of the volume of soil moved through each type of structure on the soil surface.

3.2 BENEFICIAL VERSUS HARMFUL ORGANISMS IN AGRICULTURAL SOILS

Agricultural practices can have either positive or negative impacts on soil organisms. Land management and agricultural practices alter the composition of soil biota communities at all levels, with important consequences in terms of soil fertility and plant productivity. There are examples of both positive and negative effects of some groups of soil organisms, particularly microorganisms, phytoparasites/pathogens or rhyzophages, plant roots, and macrofauna on plant production.

The different agricultural practices used by farmers also exert an important influence on soil biota, their activities and diversity. Clearing forested or grassland for cultivation has a drastic effect on the soil environment and, hence, on the numbers and kinds of soil organisms. In general, such activity reduces the quantity and quality of plant residues and the number of plant species considerably. Thus, the range of habitats and foods for soil organisms is reduced significantly. Through changing the physical and chemical environment, agricultural practices alter the ratio of different organisms and their interactions significantly, for example, through adding lime, fertilizers and manures, or through tillage practices and pesticide use.

The beneficial effects of soil organisms on agricultural productivity that may be affected include:

1. Organic matter decomposition and soil aggregation;
2. Breakdown of toxic compounds, both metabolic by-products of organisms and agrochemicals;
3. Inorganic transformations that make available nitrates, sulphates and phosphates as well as essential elements such as Fe and Mn;
4. N fixation into forms usable by higher plants.

However, other soil organisms are detrimental or harmful to plant production. For example ants, aphids and phytophagous nematodes can be serious pests, and some microorganisms, bacteria and actinomycetes cause also plant diseases. However, most damage is caused by fungi, which account for most soil-borne crop diseases.

Humans generally begin their influence on soil biodiversity with naturally present communities at a particular site (resulting essentially from ecological and evolutionary forces). However, they also have the ability to introduce new organisms and, through imposition of different management practices, put selective pressures on the naturally present or introduced soil biota. This provides the opportunity to manage soil organisms and their activities in order to enhance soil fertility and crop growth.

4.0 CONCLUSION

Soil biota represents large part of terrestrial ecosystem and carry out functions that are important to agricultural and natural systems. Some are vital to the improvement of soil health and fertility while others are less important as they are parasitic to important crops. The bioturbating activities of the soil microorganism bring about decomposition and turn over of organic matter in the soil. However, changes in agricultural practices can engender their existence and can cause marked changes in both the pool size and turnover rate of soil organic matter. It is therefore important to analyze the nature and impacts of these practices.

5.0 SUMMARY

At the end of this unit, we learnt that:

- Soil organisms carry out a range of processes important for soil health and fertility in soils of both natural ecosystems and agricultural systems.
- The widely used system for classifying soil organisms is by using body size and dividing them into three main groups: macrobiota, mesobiota and microbiota.
- **Microorganisms** in soil are made of bacteria, actinomycetes and fungi; **Microfauna** are primary the nematodes; **Mesofauna** consists of microarthropods, such as pseudoscorpions, springtails, mites, and the worm-like enchytraeids; and **Macrofauna** are visible to the naked eye which include vertebrates that primarily dig within the soil for food or shelter and invertebrates that live in and feed in or upon the soil, the surface litter and their components.
- Some microorganisms create structures called biogenic structures that are deposited in the soil surface and in the soil.
- The different agricultural practices used by farmers exert an important influence on soil biota, their activities and diversity.

6.0 TUTOR MARKED ASSESSMENT

Explain in details how soil microbes are classified. What are the benefits of soil microbes in agriculture?

7.0 REFERENCES/ FURTHER READING

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UNIT 3: ROLE OF ORGANIC MATTER IN SOIL FERTILITY

CONTENT

1.0 INTRODUCTION

Organic matter affects soil properties of the soil and its overall health. Properties influenced by organic matter include: soil structure; moisture holding capacity; diversity and activity of soil organisms, both those that are beneficial and harmful to crop production; and nutrient availability. It also influences the effects of chemical amendments, fertilizers, pesticides and herbicides.

When crops are harvested or residues burned, organic matter is removed from the system. However, the loss can be minimized by retaining plant roots in the soil and leaving crop residues on the surface. Organic matter can also be restored to the soil through growing green manures, cuttings from agroforestry species and the addition of manures and compost.

2.0 OBJECTIVES

The objective of this unit explains how organic matter

- Influences nutrient management in soil
- Stabilizes the soil particles
- Influences the infiltration in the soil

3.0 MAIN CONTENT

3.1 Cation Exchange Capacity (CEC)

The stable fraction of soil organic matter (humus) is the most important fraction contributing to the CEC of a soil. Cation exchange capacity is the total sum of exchangeable cations that a soil can hold (Brady and Weil, 2004). Cation exchange capacity determines a soil's ability to retain positively charged plant nutrients, such as NH_4^+, K^+, Ca^{2+}, Mg^{2+}, and Na^+. As CEC increases for a soil, it is able to retain more of these plant nutrients and reduces the potential for leaching. Soil CEC also influences the application rates of lime and herbicides required for optimum effectiveness.

3.2 Nutrient Retention and Release

Humus plays an important role in regulating the retention and release of plant nutrients. Humus has a highly negatively charged soil component, and is thus capable of holding a large amount of cations. The highly charged humic fraction gives the soil organic matter the ability to act similarly to a slow release fertilizer. Over time, as nutrients are removed from the soil cation exchange sites, they become available for plant uptake.

3.3 Soil Structure and Bulk Density

Soil structure refers to the way that individual soil mineral particles (sand, silt, and clay) are arranged and grouped in space. Soil structure is stabilized by a variety of different binding agents. Soil organic matter is a primary factor in the development and modification of soil structure (Coleman *et al*., 2004). While binding forces may be of organic or inorganic origins, the organic forces are more significant for building large, stable aggregates in most soils. Examples of organic binding agents include plant- and microbially derived polysaccharides, fungal hyphae, and plant roots. Inorganic binding agents and forces include charge attractions between mineral particles and/or organic matter and freezing/thawing and wetting/drying cycles within the soil as well as compression and deformation forces. Both the stable and the active fraction of SOM contribute to and maintain soil structure and resist compaction.

3.4 Water Holding Capacity

Soil organic matter affects the amount of water in a soil by influencing: water infiltration and percolation; evaporation rates; and increasing the soil water holding capacity. Factors that reduce water infiltration and percolation are compaction in surface soils, lack of surface residue, poor soil structure, surface crusting due to salinity, and steep slopes that facilitate high volumes of water runoff. Surface residues physically impede water runoff, resulting in reduced velocity of water movement. As water movement across the soil surface slows down, water has more time to move downward into the soil profile, rather than across the soil surface. In this way, increasing soil organic matter and leaving residue on the soil surface can increase water infiltration. Surface residues also slow the rate of water evaporation from the soil and improve soil structure, which helps prevent soil crusting. Crusting can result in significant losses to crop stand.

The result of increasing soil organic matter is greater in soil pore space, which provides an area for water to be stored during times of drought. A unique characteristic of the pore space in soil organic matter is that the pores are found in many different sizes. The large pores do not hold water as tightly and thus will drain more readily. The medium and small-sized pores will hold water more tightly and for a longer period of time, so that during a dry period the soil retains moisture and a percentage of that water is made available over time for plant uptake. The benefit of leaving residue on the soil surface and increasing soil organic matter is that water infiltration is increased, soil crusting is decreased and the soil can hold more of the water that infiltrates and will eventually make it available for plant use.

3.5 Biological Activity

While microorganisms make up a small portion of the SOM (less than 5%) they are imperative to the formation, transformation, and functioning of the soil. In the soil, they conduct indispensable processes such as decomposition, nutrient cycling, degradation of toxic materials, N fixation, symbiotic plant relationships, and pathogen control. About soil fauna, Jenny said, "They break up plant material, expose organic surface areas to microbes, move fragments and bacteria-rich excrement around, up, and down, and function as homogenizers of soil strata" (Jeny, 1980). Soil fauna play an important role in the initial breakdown of complex and large pieces of organic matter, making it easier for soil microorganisms to release carbon and plant nutrients from the material as they continue the process of decomposition.

4.0 CONCLUSTION

Soil fertility is very important in agriculture and has to be maintained in order to have continuous crop production. Soil organic matter is the key to soil life and the diverse functions provided by the range of soil organisms. Soil organic matter improves the fertility of soil in many ways such as improving CEC, water and nutrient retention, stabilizing soil structure and improving microbial activities.

5.0 SUMMARY

At the end of this unit, we learnt that:

- Soil properties are affected by the level of organic matter in the soil
- Organic matter content of soil improves the diversity and activities of microorganisms
- Organic matter also influences the effects of other amendments such as fertilizers and pesticides

6.0 TUTOR MARKED ASSESSMENT

Discuss how soil organic matter contributes to soil fertility.

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UNIT 4. EFFECT OF ORGANIC MATTER ON SOIL PROPERTIES

CONTENT

1.0 INTRODUCTION

Organic matter affects both the biological, chemical and physical properties of the soil and hence its fertility and health. Some of the soil properties influenced by organic matter are: diversity and activity of soil organisms (beneficial and harmful ones); nutrient availability; soil structure; and water holding capacity. It also influences the effects of chemical amendments, fertilizers, pesticides and herbicides.

Freshly added or partially decomposed plant residues and their non-humic decomposition products usually constitute labile organic matter pool. The labile soil organic matter pool regulates the nutrient supplying power of the soil, particularly of nitrogen, whereas both the labile and stable pools affect soil physical properties, such as aggregate formation and structural stability. When crops are harvested or residues burned, organic matter is removed from the system. However, retaining plant roots in the soil and leaving crop residues on the surface can minimize the loss. Organic matter can also be restored to the soil through growing green manures, cuttings from agroforestry species and the addition of manures and compost. Soil organic matter is the key to soil life and the diverse functions provided by the range of soil organisms.

2.0 OBJECTIVES

- To learn the influence of organic matter on soil biological properties
- To learn the influence of organic matter on soil chemical properties
- To learn the influence of organic matter on soil physical properties

3.0 MAIN CONTENT

3.1 Effect of organic matter on soil biological properties

Soil microorganisms are of great importance for plant nutrition as they interact directly in the biogeochemical cycles of the nutrients. Agricultural production systems in which residues are left on the soil surface and roots left in the soil and the use of cover crops stimulate the development and activity of soil microorganisms. It has been reported that the incorporation of crop residues into soil is beneficial to soils, improving one or more essential soil attributes. It has been shown that incorporating crop residue in a 19-year experiment in Brazil resulted in a 129% increase in microbial biomass carbon and a 48% increase in microbial biomass nitrogen (Fig 1)

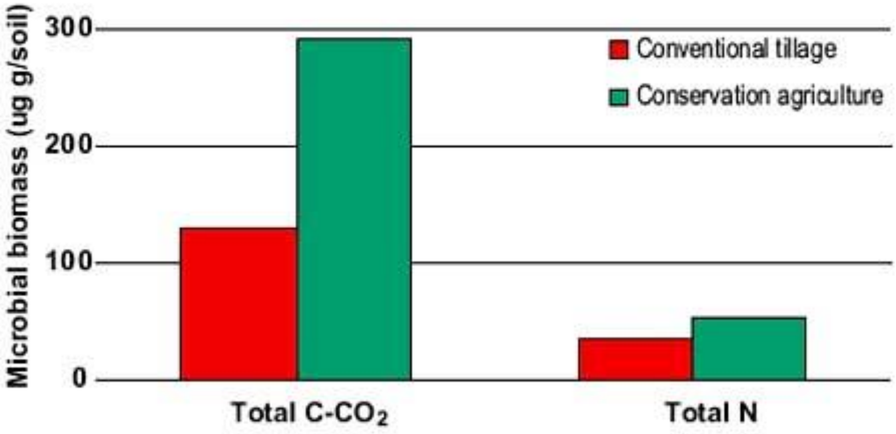

Fig 1: Microbial biomass C and N under conventional tillage and conservation agriculture.
Source: Balota et al., (1996).

The roots of most plants are colonized by Arbuscular mycorrhizal fungi (AMF), which form a network of mycelia or threads on the roots and extend the surface area of the roots. This allows absorption of water and nutrients by the plants beyond the depleted zone. Factors that might stimulate the AMF development are the increase in organic carbon in soil and the rotation of crops with cover crop/green manure species. In an undisturbed soil ecosystems, e.g. in conservation agriculture, colonization with AMF increases strongly with time compared with colonization under natural vegetation (Fig 2). Fine roots are the primary sites of mycorrhizal development as they are the most active site for nutrient uptake. This partly explains the increase in mycorrhizal colonization under undisturbed situations, as rooting conditions are far better than under conventional tillage.

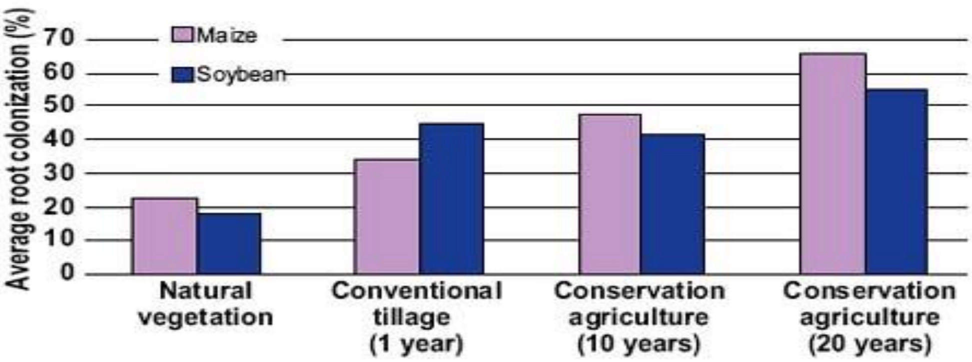

Fig 2. Root colonization of crop roots with AMF.
Source: Venzke *et al*., (1999).

Another effect of increased organic matter content in soil is increase in the earthworm population. Soil moisture is one of the most important factors that determine the presence of earthworms in the soil. Through cover crops and crop residues, evaporation is reduced and organic matter in the soil is increased, which in turn can hold more water.

Residues on the soil surface induce earthworms to come to the surface in order to incorporate the residues in the soil. The burrowing activity of earthworms creates channels for air and water; this has an important effect on oxygen diffusion in the root zone and the drainage of water from it. Furthermore, nutrients and amendments can be distributed easily and the root system can develop, especially in acid subsoil in the existing casts. The shallow-dwelling earthworms create numerous channels throughout the topsoil, which increases overall porosity, and thus bulk density.

3.2 Effect of organic matter on soil chemical properties

Many important chemical properties of soil organic matter result from the weak acid nature of humus. The ability of organic matter to retain cations for plant use while protecting them from leaching is due to the negative charges created as hydrogen is removed from weak acids during neutralization. Many acid-forming reactions occur continually in soils. Some of these acids are produced as a result of organic matter decomposition by microorganisms, secretion by roots, or oxidation of inorganic substances.

When acids or bases are added to the soil, organic matter reduces or buffers the change in pH. This is why it takes tones of limestone to increase the pH of a soil significantly compared with what would be needed to simply neutralize the free H present in the soil solution. All of the free hydrogen ions in the water in a very strongly acid soil (pH 4) could be neutralized with less than 6 kg of limestone per hectare. However, from 5 to more than 24 tones of limestone per hectare would be needed to neutralize enough acidity in that soil to enable acid sensitive crops to grow.

Organic matter may provide nearly all of the CEC and pH buffering in soils low in clay or containing clays with low CEC. Organic matter releases many plant nutrients as it is broken down in the soil, including N, phosphorus (P) and sulphur (S). Leguminous species are very important as part of a cereal crop rotation in view of their capacity to fix N from the atmosphere through symbiotic associations with root dwelling bacteria.

3.2 Effect of organic matter on soil physical properties

Organic matter influences the physical conditions of a soil in many ways. Crop residues that cover the soil surface protect the soil from sealing and crusting by the impact of raindrop thereby enhancing rainwater infiltration and reducing runoff. Increased organic matter also contributes indirectly to soil porosity (via increased soil faunal activity). Fresh organic matter stimulates the activity of macrofauna such as earthworms, which create burrows lined with the glue-like secretion from their bodies and intermittently filled with worm cast material. Surface infiltration depends on a number of factors including aggregation and stability, pore continuity and stability, the existence of cracks, and the soil surface condition.

Organic matter also contributes to the stability of soil aggregates and pores through the bonding or adhesion properties of organic materials, such as bacterial waste products, organic gels, fungal hyphae and worm secretions and casts. Moreover, organic matter intimately mixed with mineral soil materials has a considerable influence in increasing water holding capacity.

4.0 CONCLUSION

Organic matter plays an important and multi-faceted role in soil. Physically, organic matter influences soil structure and all associated properties. Chemically, soil organic matter affects the cation exchange capacity and the capacity for buffering changes in soil pH. Biologically, organic matter acts as the nutrient and energy supply for microbial biomass and higher plants. A soil which is biologically and chemically fertile but which cannot physically support crop development will not fulfill its agronomic potential. Soil productivity is, therefore, determined by a combination of organic matter's influence on physical, chemical, and biological properties of soil.

5.0 SUMMARY

At the end of this unit, we learnt that soil organic matter:

- Affects the biological, chemical and physical properties of soils.
- Biologically influences the activity of microorganisms, which results in higher microbial biomass in soil and hence serves as repository of nutrient.
- Chemically, improves CEC of soil for plant use while protecting the cations from leaching.
- Physically, improves soil structure and aggregate stability.

6.0 TUTOR MARKED ASSESSMENT

Discuss the effect of organic matter on soil physical, chemical and biological properties.

7.0 REFERENCES/ FURTHER READING

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UNIT 5: COMPOSTING

CONTENT

1.0 INTRODUCTION

The decomposition of organic wastes in soil occurs naturally at ambient temperature to produce humus. The humification process occurs very slowly in soil. It takes nature 2000 years to produce 10 cm high of humus. This natural decomposition process in the soil can be regulated and speeded up by man. Here, organic materials are collected and gathered together into a heap so that the heat that evolved from the process is saved. As a result, the temperature of the heat rises thereby speeding up the basic degradation process of nature, which normally occurs slowly in organic wastes that fall on the surface of the ground. The final product of the process is called compost or humus.

Therefore, **Composting** is the decomposition or breakdown of organic waste materials by mixed population of microorganisms in a warm, moist and aerated environment. It involves creating humus-like organic materials outside the soil by mixing, piling or storing organic materials under conditions conducive to aerobic decomposition and nutrient conservation. Basic reaction for organic matter decomposition is

$$C_6H_{12}O_6 + 6O_2 \xrightarrow[\text{Oxidation}]{\text{Enzymatic}} 6CO_2 + 6H_2O + \text{Energy}$$

2.0 OBJECTIVES

- To define and understand what is composting
- To conceptualize the processes involved during composting
- To understand the art of composting
- To understand different methods of composting
- To know the benefits of composting

3.0 MAIN CONTENT

3.1 Process of Composting

Composting process is most commonly used to change waste organic materials into useful products. The waste material will normally have within it a variety of microorganism capable of carrying out the process. When the material is exposed to the air and moisture content brought to the suitable level, the microorganisms begin their work. In addition to oxygen from the air and moisture, the microorganism require, for their growth and reproduction, a supply of food containing carbon and nutrient such as nitrogen, phosphorus and potassium (Fig 1). Waste materials usually provide these food requirements.

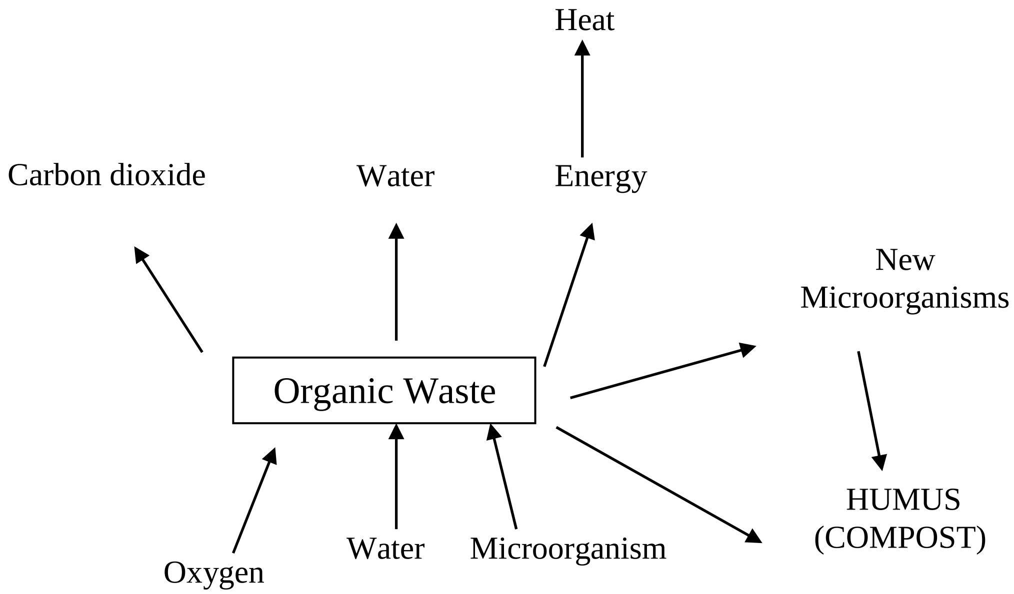


Fig 1: Composting Process

A good composting process should pass through 3 consecutive stages:

- ✓ Heating phase (fermentation)
- ✓ Cooling phase
- ✓ Maturation phase.

– Heating phase

During this stage, which is the first stage of composting, the heap starts to build up considerably (Fig 2). This is known as fermentation and is the result of breaking down of complex and tough fibrous material of organic matter. For effective fermentation:

1. Compost heap should be made of all sort of materials;
2. Right microorganisms have to be present;
3. Adequate air and water

If the above three condition are met heat will be generated quickly. During fermentation, the microorganisms multiply and change rapidly which adds up to the heating process. Fermentation may reach 60 – 70˚C in the compost heap. Fermentation has hygienic effects as it destroys pathogens. It is important that temperature of the heap be tested to make sure that fermentation is taking place. A simple way of testing if fermentation process is taking place is by putting a stick at the center of the heap after completion and leaving it until next day. After taking it out, feel it immediately. It should be considerably warmer than body temperature. If not, then this is an indication that something is wrong with the heap.

– Cooling down phase

During this stage, temperature drop to near ambient because of exhaustion of high energy compounds in compost pile. Compost is recolonized by new microorganisms Including beneficial organisms producers of plant-growth stimulating compounds or antagonistic to plant pathogens. The decomposition process is slower but the chemical reactions continue which stabilize the humus. This phase of composting can last several weeks to months (Fig 2).

– Maturation phase

This is last stage of composting. Here the temperature drops to soil temperature depending on the climate. Apart from the soil microorganism such as bacteria and fungi, large soil micro fauna are also active at this stage. In temperate environment, earthworms feed strongly on the decomposed organic material and this helps in the decomposition process. In the tropical environment, termites play an important role in the decomposition process. Compost is ready for use if it feels crumbly or looks like brown or black organic soil. It also has the earthy aroma, which smells good (Fig 2).

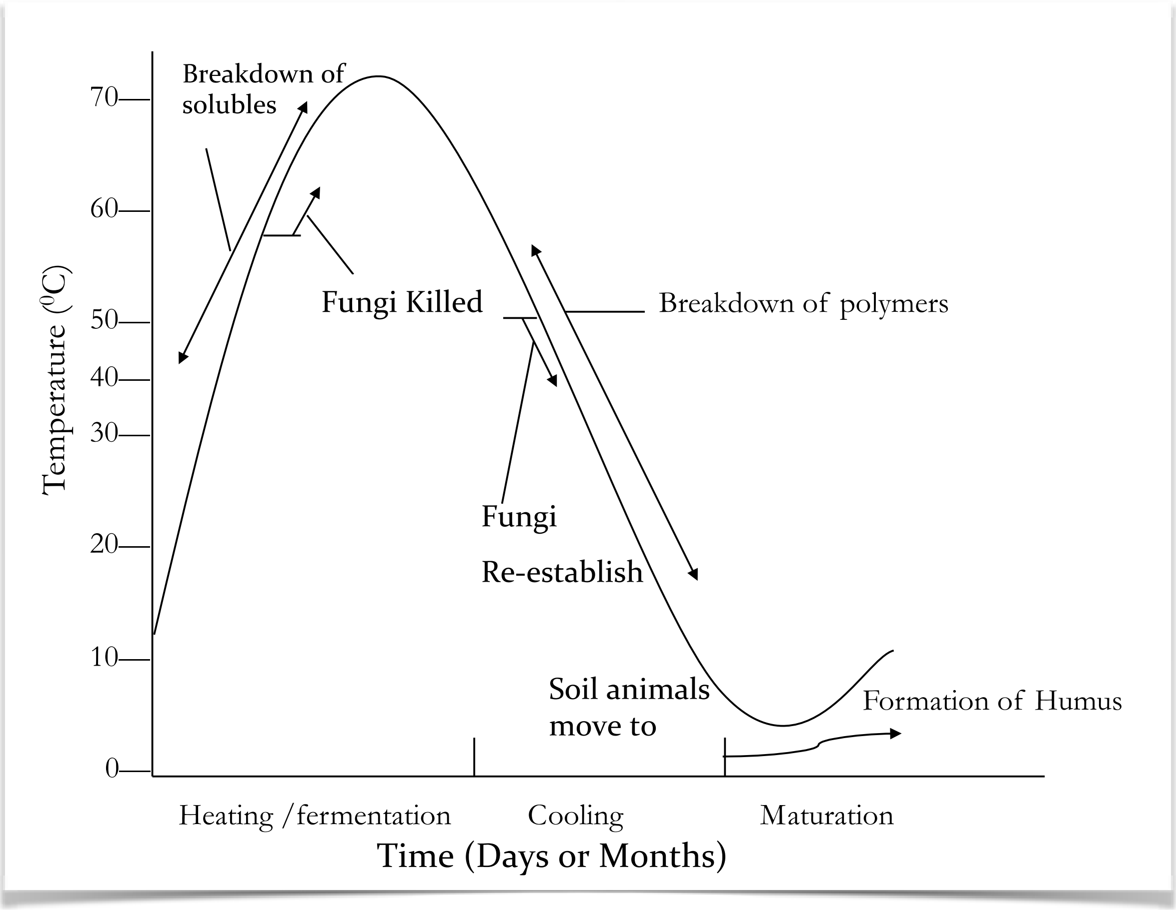


Fig 2: Temperature variation in Compost heap

3.2 The Practice of Composting

3.2.1 Materials for composting

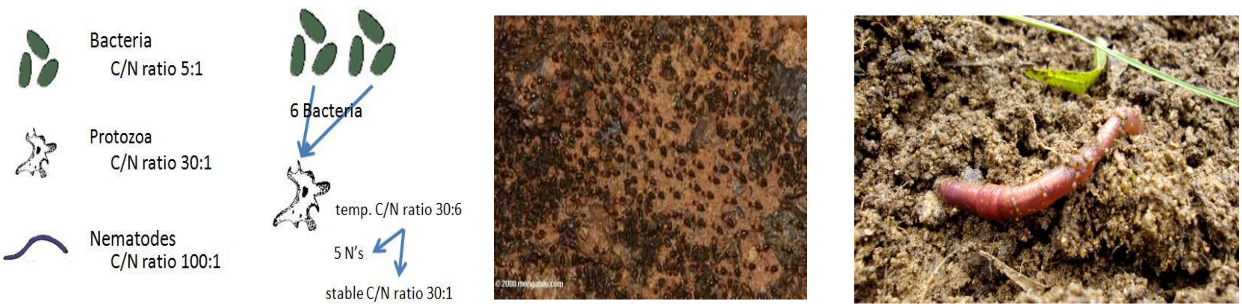
Materials used for composting should be all organic materials. In general any type of organic materials that are of plant and animal origin can be used. All non-biodegradable and organic matter containing heavy metals or that can transmit human disease should be avoided. It is important to use both high carbon containing material and high nitrogen containing materials. This is because different organic matters have different proportion of Carbon and Nitrogen and microorganisms need them both to function well. In general, young living materials that decompose fast contains low level of C and high level N whereas tough, dead materials decompose slowly and have large amount of C but low amount of N. Too little of N – rich material means the composting will be slow whereas too much of it will result in the heap becoming too acidic and smelly. Hence there is need to have a mixture of materials that have right proportion of C and N. Table 1 below gives example of high N and High C containing materials.

Table 2.4.1: Materials high in Carbon and Nitrogen.

High Carbon Materials	***C: N***	***High Nitrogen Materials***	***C: N***
Leaves and Foliage	40-80:1	Grass Clippings	19:1
Bark	100-130:1	Sewage Sludge	16:1
Paper	170:1	Poultry carcass	4:1
Wheat Straw	127:1	Food Wastes	15:1
Wood and Sawdust	300-700:1	Cow Manure	20:1
Rice Straw	100:1	Horse Manure	25:1

3.2.2 Microorganisms

Composting process occurs as a result of activity of microorganism and other larger organism like earthworms and termites (Fig 3). The first condition for composting is the presence of microorganism. So adding these microorganisms in the compost heap is necessary. One of the sources of these microorganisms is soil. Thus adding soil to the compost heap will increase microbial activity of the compost. It is important to collect soils from shady and humid place e.g. from below tree. Soils that contains moisture also contains microorganism while soils that are dried out by sun usually do not contain many microorganisms. Decaying leaf litters are also very good sources of microorganisms (see Fig 4).



Termites Earthworms

Fig 3: Examples of some microorganisms that help in decomposition in compost heap.

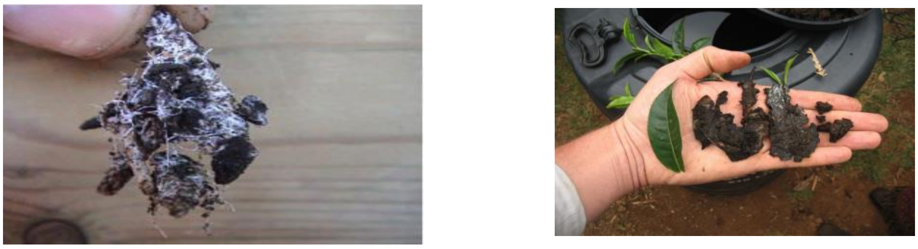


Fig 4: Examples of decaying leaf litters that can be added to the compost heap.

3.2.3 Air

The microorganisms in the heap require oxygen to survive and do their work of converting organic materials. The carbon dioxide produced by microorganisms as a result of their activity also needs to be flushed out by the flow of air. If there is no air in the pile the important microorganisms will not survive. In this situation, only the microorganisms that do not need oxygen will survive and the decomposition of organic material will slow down. In order to get enough air in the heap, do not put the compost heap right against the wall. It is good to put air channels into the heaps. This can be done effectively done by putting stakes, twigs, straws or any other firm material upright in the heap when composting it. The air channel should be removed after 4 – 5 days in order to avoid too much ventilation during fermentation, which can cause combustion.

3.2.4 Moisture

Microorganisms need moisture to live and to spread through the heap. The activity of organism will slow down if the heap is too dry. If it is too wet, then there will be no air and the composting organism will die. This will cause the heap to ferment rather than compost. Moisture level of compost can be tested by putting a straw in the heap. If after 5 minutes it feels damp, the moisture content is good; but if it dries after 5 minutes, then the moisture is too low. Dry compost has to be sprinkled uniformly with water using watering can or perforated tin, which ensures uniform distribution of water. A mixture of urine and water can be used in the ratio 1:4 because urine can enhance growth of microorganisms. On the other hand, if a water droplet is observed in the heap, it means the water is too much and the heap should be opened up straightaway. The materials can be allowed to dry up in the sun or can be mixed with drier materials and the heap is made again. If it becomes too wet by rain, then it is better to cover it with plastic cover. The moisture test is repeated after few days.

3.3 Methods of Composting

There are different methods of composting organic materials. For the purpose of this class we are going to concentrate only on Indore method. Here, compost are produced in:

- ✓ Pit – during the dry part of the year; and
- ✓ Stacks on surface or aboveground – during the rainy season.

In either of the method, the heap is built to a height of 1.5 m and having a base of about 40 m^2 (Fig 5). A heap with such dimension will require nearly 20 tons of organic waste material and should produce 6 to 8 tons of compost per batch. It should be possible to produce 2 – 3 bathes per year in a pit and normally one batch for a stack. A smaller dimension can be adopted depending on the available materials to be composted. A good basic size is 2 to 2.5 wide and 1.5 to 2 m height while the length will depend on the quantity of the available organic materials. It is strongly advised to start with a heap greater than 1 cubic meter otherwise the temperature in the heap remains low and the decomposition is too slow and incomplete.

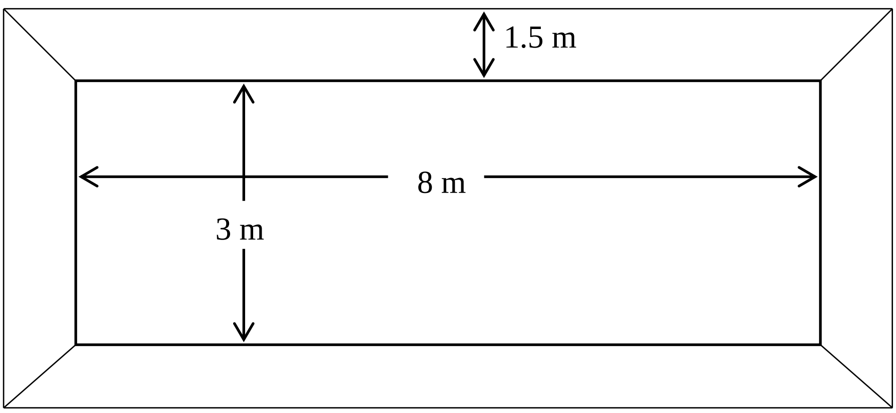


Fig 5: Detailed plan view of standard composting pit.

3.3.1 Setting up the heap

In setting up compost heap, it is important to start the heap with a foundation of coarse materials such as twigs and sugar cane stalks. The outside can easily flow in under and the excess water flows away more quickly. Materials such as straws and dried leaves are then added on top of the coarse materials. These materials are called the ***brown materials***. Next is to add materials that are easily decomposed such as fresh leaves, weeds grasses, etc. these materials are called the ***green materials***. In good composting practice, the ratio of brown materials to green materials should be 1:2. That means to each part of brown material you add two parts of green material. This is then followed by addition of animal manure. After this, water is sprinkled on top of the set up before another set of layer is built up. The individual layer should not be more than 10 cm of the plant materials and 2 cm for the manure (Fig 6).

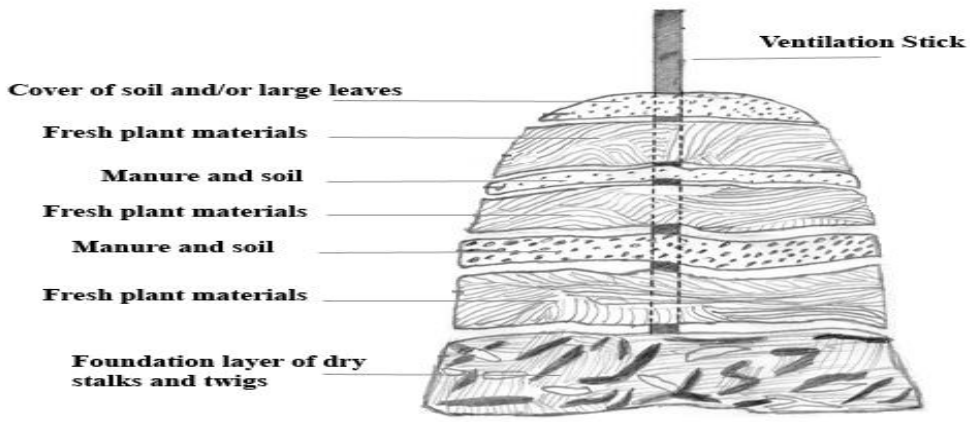


Fig 6: Example of Indore compost heap with layers.

As stated earlier, air channels should be inserted in the heap by putting twigs upright in the heap as indicated in figure 5 above. It should be remembered microorganisms are the ones that carry out this decomposition process. Hence it is necessary to add them in the heap.

3.3.2 Additives

Compost is essentially soil conditioner containing fairly low level of plant nutrient. Where food production needs to be increased and mineral fertilizer can be afforded, then there is incentive passing it through composting process. Care must be taken to avoid adding excessive nitrogenous fertilizer is not added which can lead to nitrogen loss as ammonia. Addition of phosphorus has beneficial effect on compost heap. The composting process makes phosphate more water soluble and hence more available to plants. Cheap phosphate rock can be used instead of more expensive superphosphate, which has been chemically treated to make it more water-soluble. Moreover, addition of phosphate rock or calcium phosphate of 2 to 3 % by weight has been found to be beneficial in speeding up the composting process and in nitrogen conservation.

Addition of inoculants such as bacterial culture will be beneficial to the compost heap as it adds microorganisms to the heap. It has been indicated that inoculating compost heap with suitable nitrogen fixing bacteria, *Azotobacter*, in the presence of phosphate rock will significantly increase the nitrogen content of the final compost.

3.3.3 Covering the heap

In times of heavy rain or in an area of heavy rains, the heap has to be protected against excess water. This can be done by covering with a simple roof above the heap or even simpler by covering with layers of leaves, cloth, plastic materials and so on. If plastic materials are used, then cover the top only so that air can penetrate through the sides. Trenches around the heap should be created to facilitate run off of excess rainwater. Covering the heap with material mentioned can also be advantageous in dry areas. It prevents excess evaporation of moisture from the heap and it dries out less quickly.

3.4 Benefits of Composting

1. Safe storage and handling – Composting provides a mean of storing organic materials until they are applied. It makes easier handling because of volume reduction (30-50%)
2. Supply of a variety of macro and micronutrients.
3. Nitrogen competition avoidance –For high C: N residues, nitrate depression occurs in compost pile, not in the field
4. Nitrogen stabilization – Composting can reduce nitrate leaching from low C: N residues particularly co-composting low C: N materials with high C: N materials.
5. Improves soil cation exchange capacity (CEC).
6. Improves soil structure and related physical properties.
7. Sterilization – High temperature during the thermophilic phase in well-managed compost piles kills most seeds and pathogenic organisms.
8. Detoxification – Most toxic compounds in organic waste (pesticides, natural phytotoxic chemicals etc.) are destroyed by the time compost matures.
9. Supplies beneficial organisms to soil.
10. May suppress some soil-borne diseases (through microbial antagonisms).

4.0 CONCLUSION

Compost is of high value in agriculture and horticulture for improving soil structure and water retention property of the soil and for supplying plant nutrients as compost finally breaks down to mineral matter. Compost is a good fertilizer that can be used to increase soil fertility in long-term basis. This is because it contains both nutrients and organic matter. Using compost as means to improve soil fertility is possible but in that case you need a large quantity of compost.

5.0 SUMMARY

At the end of this unit, we learnt that:

- Composting is decomposition of organic materials by microorganisms to produce a stable substance called humus.
- There are three stages that are involved in composting: heating, cooling and maturation; each stage catalyzed by different microorganism.
- Good composting practice entails the use of materials that have both high and low C/N ratios.
- The art of composting involves providing conditions that are conducive for microorganism to thrive.
- There are two main types of composting: pit and surface/stack also similar principles are employed.
- Compost has benefits in many ways in soil.

6.0 TUTOR MARKED ASSESSMENT

1. (a) What do you understand by composting?
   (b) Draw a simple diagram showing composting process.
   (c) (i) what are the importance of C and N in composting?
   (ii) What will be the consequence in a compost pile if:
   - N is Limiting?
   - N is in excess?

   (iii) What happens if:
   - C/N ratio is < 20:1?
   - C/N ratio is > 40:1?

   (d) Highlight six (6) benefits of Composting.

7.0 REFERENCES/ FURTHER READING

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MODULE 3

UNIT 1: GENERAL IMPACT OF WASTES ON ENVIRONMENT

CONTENTS

1.0 INTRODUCTION

Industries are the major sources of pollutants in both terrestrial and aquatic environments and various levels of the pollutants are discharged into the environment either directly or indirectly (Glyn and Garry, 1996). For example, discharged effluents from industries have been found to be carcinogenic (Tamburline, *et al*., 2002), while other chemicals present are poisonous to humans and toxic to aquatic life (WHO, 2002). Effluents from industries were found to alter the physical, chemical and biological nature of receiving water bodies (Kanu *et al*., 2006). These effluents contain substances that range from chlorides, phosphates, oil and grease, nitrates, heavy metals, among others (Ekiye and Luv 2010). The levels of the concentrations in these effluents, especially of heavy metals, have been found to be above acceptable and permissible levels (Emiola *et al*., 2010).

The degradation of the organic portion of the municipal solid wastes in the presence of percolating rainwater leach down to soil layer and eventually reaches and contaminate the underground water body making it unsuitable for drinking. If not properly treated, leachate seeping from a landfill can pose 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. Methane and carbon dioxide are two major gases produced from the decomposition of the organic waste in the landfill.

Agricultural wastes such as packages and bottles of pesticides are indiscriminately thrown to water bodies. These waste have the potential to cause unpredictable environmental consequences such as food poisoning, unsafe food hygiene and contaminated farmland due to their potentially lasting and toxic chemicals. The pollution caused by livestock production is a serious problem causing air pollution which includes odors emanating from cages resulting from the digestion process of livestock wastes; the putrefaction process of organic matter in manure; animal urine, and/or from redundant foods. This results in the generation of greenhouse gases while also having negative effects on the fertility of the soil and causing water pollution.

2.0 OBJECTIVES

- To give general insight on effect of wastes on human and environment
- To learn the impact of industrial effluent on human and environment
- To also learn the impact of agricultural waste on human and environment

3.0 MAIN CONTENT

3.1 Impact of industrial effluents on human and environment

Industrial activities particularly the tanning industry is considered to be a major source of pollution and tannery wastewater in particular, is a potential environmental concern. Tanning industry wastes poses serious environmental impact on water with its high oxygen demand, discoloration and toxic chemical constituents, terrestrial and atmospheric systems. Tannery waste characteristically contains a complex mixture of both organic and inorganic pollutants. For example, chlorinated phenols and chromium were found to be closely associated with the tannery waste. Chromium as inorganic pollutant is a transition metal and exists in several oxidation states, with trivalent Cr^{3+} and hexavalent Cr^{6+} species being the most common forms. Indeed chlorinated phenols (e.g. 3,5-dichlorophenol) as an organic pollutant associated with the tanning industry have been found to be highly toxic and affect the cellular compounds of organisms exposed to such waste.

The effluents from tanning industry adversely affect human life, agriculture and livestock. The residents, especially the tannery workers have been the victims of this pollution, which has led to severe ailments such as eye diseases, skin irritation, kidney failure and gastrointestinal problems. Chromium, extensively used in tanning process, is carcinogenic. Cancer found as cause of death in some cases can be linked to chromium pollution in the groundwater. Water with a low pH is corrosive to water- carrying systems and in unfavorable circumstances, can lead to the dissolution of heavy metals in the wastewater. The high pH in tannery wastewater is produced by lime because it is used in excess quantities and this causes scaling in sewers. A large fluctuation in pH exerts stress on aquatic environment, which may kill some sensitive species of plant and animals living there. Large quantities of proteins and their degraded products form the largest single constituent group in the effluent.

Due to sulfide discharged from the unhairing process, hydrogen sulfide is released at a pH value lower than 8.5. This gas has an unpleasant smell even in trace quantities and is highly toxic to many forms of life. In higher concentrations, fish mortality may occur at a sulfide concentration of 10 mg/L Sulfide in public sewer can pose structural problems due to corrosion by sulphuric acid produced as a result of microbial action. Sewage contains sulfide in the range of 15-20 mg/L and composite tannery wastewater contains 290 mg/L. Suspended solids, apart from being societal nuisance, have their main effect when they settle. The layer so formed on the bottom of the watercourse, covers the natural fauna on which aquatic life depends. This can lead to a localized depletion of oxygen supplies in the bottom waters. A further secondary effect is the reduced light penetration and consequent reduction in photosynthesis due to the increased turbidity of water.

3.1 Impact of Agricultural wastes on human and environment

The impact of agricultural waste on the environment depends not only on the amounts generated but also on the disposal methods used. Some of the disposal practices pollute the environment.

For example, agricultural waste burning is a common practice in the undeveloped countries, but it is a source of atmospheric pollution. According to (Ezcurra, 2001), agricultural waste burning releases pollutants such as carbon monoxide, nitrous oxide, nitrogen dioxide and particles (smoke carbon). These pollutants are accompanied by the formation of ozone and nitric acid, hence contributing to acid deposition thereby posing risk to human and ecological health.

Environmental pollution from animal waste (faeces, urine, and respiration and fermentation gases) is a global concern and is much more acute and serious in countries with high concentrations of animals on a limited land base for manure disposal. Animal wastes are excreted in solid, liquid, and gaseous forms. Respiration and fermentation gases are lost to the environment soon after being produced by the animal. After excretion, solid and liquid animal waste is subjected to microbial conversion (mainly anaerobic), which converts organic substrates into microbial biomass and soluble and gaseous products. Some of these products have an impact on the environment, as well as water quality, soil deterioration, and air pollution.

Odor pollution was reported to contribute highly to social tensions among urban livestock farmers. Additionally, the application of excessive animal wastes on land as fertilizer and soil conditioner is subject to surface run-off and leaching that may contaminate ground or surface waters. For that reason, nitrate leaching is considered a major nitrogen pollution concern on livestock farms. When phosphorus (P) enters the surface waters from land application of excessive animal manure it can stimulate the growth of algae and other aquatic plants. Their subsequent decomposition results in an increased oxygen demand that interferes with the welfare of fish. Manure decomposition can be a major source of methane (CH_4), ammonia (NH_3) and nitrogen oxides, which contribute to accumulation of greenhouse gases.

Synthetic fertilizers have been at the core of the Green Revolution, but there is awareness that their widespread and intensive use represents a serious threat for the environment. Global data for maize, rice and wheat indicate that crops take up only 18% to 49% of N applied as fertilizer; the remainder is lost to run-off, leaching or volatilization. Widespread use of pesticides on crops has led to the emergence of many pesticide-resistant pests and pathogens. Paradoxically, research demonstrated that insecticides, by suppressing the natural enemies of pests, lead to increased pest damage in crops. Moreover, pesticides also have a major impact on animal and human health. People can be exposed to excessive pesticide levels while working, via food, soil, water, air or by directly ingesting pesticide products. Along with other synthetic chemicals, some pesticides have a direct effect on the reproductive system of many higher organisms, acting as endocrine disruptors and inducing severe reproductive problems and modifying sexual behavior. It is demonstrated that an organic diet provides a dramatic and immediate protective effect against exposures to organo-phosphorus (pesticides that are commonly used in agricultural production) in children who are most likely exposed to these organo-phosphorus pesticides exclusively through their diet.

Agriculture is also responsible for 30–35% global greenhouse gases (GHGs) emission, largely from tropical deforestation, methane emission from livestock and rice cultivation and NOx from fertilized soil and its energetic efficiency, as output/input, is steadily decreasing. Agricultural activities (excluding forest conversion) account for approximately 5 percent of anthropogenic emissions of CO_2 and the 10–12% of total global anthropogenic emissions of GHGs accounting for nearly all the anthropogenic methane and one- to two-thirds of all anthropogenic nitrous oxide emissions are due to agricultural activities.

4.0 CONCLUSION

The discharge of effluent to environment increasingly affects the natural ecosystem and human health and his environment. On the other hand, agricultural wastes contribute tremendously to the effervescence of greenhouse gas, which is of global concern. This calls for approach toward environmental pollution abatement; prevention at the source is the best alternative.

5.0 SUMMARY

- Industrial effluents are the major sources of pollutants environments.
- Municipal solid waste in the landfill accompanied by percolating rainwater leach in the soil profile and contaminate underground water.
- Agricultural wastes burning and decomposition can lead to generation of greenhouse gases, which are of global warming concerns.

6.0 TUTOR MARKED ASSESSMENT

What are the effects of releasing industrial effluent on human and natural ecosystem?

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UNIT 2: WASTES TREATMENT AND DISPOSAL

CONTENTS

1.0 INTRODUCTION

The hierarchy of waste management, places waste reduction at the top, followed by re-use, recycling, recovery and finally disposal. Waste reduction is synonymous with waste prevention or waste minimization and has been defined as any technique, process or activity which either avoids, eliminates or reduces a waste at its source, usually within the confines of the production unit. This is sometimes known as 'clean technology' or producing 'clean' products. Clean technology is about minimizing the environmental impact of releases from processes. The philosophy behind it is the prevention of waste rather than the cure. Every aspect of a process needs to be optimized to minimize waste in any form.

The basic options to achieve this philosophy are relatively few and can be summarized in order of preference as:

(i) Reduction at Source The most effective way to prevent a material from entering the environment is to stop using or making it.

(ii) Product Changes Suitable alternative materials that may perform the same function with less environmental consequences.

(iii) Process Changes A process should be designed or changed in such a way that potentially polluting materials are not made or isolated, minimizing the possibility of a release.

(iv) Re-use of a material is an alternative way of preventing release to the environment.

(v) On-site Recycling Using a by-product of one process as a raw material for another disposes of it without an environmental impact.

(vi) Off-site Recycling Sending a by-product of a process to be used elsewhere is similar to on-site recycling, but the pollution and cost of transport, handling, etc. makes this less desirable.

2.0 OBJECTIVES

- To learn how to minimize waste production
- To know the processes of waste reuse
- To learn how to recycle waste

3.0 MAIN CONTENT

3.1 Waste Reduction

Waste reduction is both environmentally and economically beneficial both to society as a whole, and to businesses and the community. Waste reduction at source involves good practice, input material changes, product changes and technological changes. **Good practice** can be as simple and effective as good housekeeping, maintaining production procedures, minimizing spillages and proper auditing of input and final destination of raw materials. There are many examples of where a **change in input** material has resulted in a reduction of waste in the production process. For example, the replacement of organic solvents with water based types, or the replacement of hazardous solvents, such as benzene and chlorinated organic solvents, with less hazardous solvents. **Product changes** can be used to reduce the production of waste or materials used within the manufacturing process. Examples include the reduction in the weight of packaging, e.g. the thickness and therefore weight of drinks cans have shown a reduction of more than 50%. Plastic items, such as carrier bags and yoghourt pots, have similarly shown a reduction in thickness and therefore weight. A **change in technology** can mean a fundamental change in the process, a change in the process conditions, a change to an automated system or re-engineering of the process

Another option of waste reduction is waste re-use. Re-use involves using a product or package more than once or re-using it in another application. Examples include re-using plastic supermarket carrier bags, glass milk bottles, reuse of partly worn tyres and car parts via car scrap merchants.

3.2 Waste recycle

Recycling is the collection, separation, clean up and processing of waste materials to produce a marketable product. Recycling can take place within the manufacturing process, such as in the paper industry, mill off-cuts and damaged paper rolls are recycled back into the pulping process. Alternatively, recycling takes place at the post-consumer stage where paper can be collected separately or extracted from the waste and can then re-enter the paper making process. The advantages of using recyclable materials are that there is a reduced use of virgin materials, with consequent environmental benefits in terms of energy savings in the production process and reduced emissions to air and water and onto land.

Theoretically, recyclable components of municipal solid waste include paper, plastics, glass, metals and organic or putrescible materials, made up of garden and food wastes, which are suitable for composting. However, in some cases it is not possible to recycle some of the wastes due to contamination. Figure below shows an estimation of the potentially recyclable components of household. Approximately 60% of all household waste in the form of paper, plastics, textiles, glass, metals and organic waste, is potentially recyclable after discounting the contaminated materials.

While the recyclable materials are found in household waste, they are present in a very heterogeneous matrix and the segregation of the materials is one of the major factors involved in waste recycling. Two types of system exist to reclaim the materials separately, the ‘bring’ and the ‘collect’ systems (Hogg and Hummel 2002). The ‘bring’ systems involve the segregation of recyclable materials, for example, paper, plastic and glass bottles, metals and textiles, from household waste by the public and delivery to a centralized collection site. This system has the advantage of being low in capital costs, easily accessible and can also provide an easy method of segregating clean readily marketable materials. The ‘collect’ systems involve house-to-house collection of designated recyclable materials source separated by the householder and placed in separate containers. There are a number of varieties of the ‘collect’ system. For example, the recyclable materials such as paper, plastics and metal cans are all placed in one container, therefore the mixture has to be sorted, either by processing equipment or by hand at the central materials recycling facility. Alternatively, the collector may sort the materials. The advantages of the ‘collect’ system include convenience for the householder and higher recovery rates of recyclable materials. However, collection costs are higher in that separate collections or purpose-built vehicles, with separate enclosures, are required.

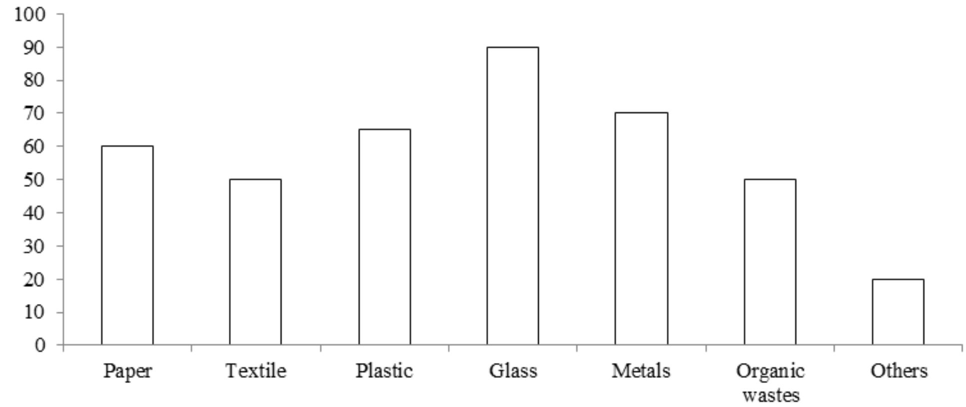

Fig 1: Potentially recyclable components of household waste.

An important aspect of materials recycling, which is often not considered, is the occupational health risks of the workers employed to sort, often by hand, the municipal solid waste in the materials recycling facility. The potential risks to the workforce include accidents from hand sorting due to broken bottles, sharps and tin cans, exposure to electromagnetic fields, used for sorting metals, and chemical hazards from garden and household chemicals, paint vapors and batteries (Gladding 2002). Biological hazards result from the vapors arising from biodegradation and also airborne bacteria and fungi and, potentially, viruses from the collection and sorting of household waste. Reported adverse symptoms in the workforce who are working in materials recycling facilities included pulmonary disorders, organic dust-like symptoms, gastrointestinal problems, eye inflammation and irritation of the skin and upper airways.

4.0 CONCLUSION

Waste management is an organized system of treatment, which starts with reduction at source in order to prevent material from entering environment. Other ways of waste reduction may involve simple practice of good housekeeping, input change, change in production technology and even reuse of a produce.

5.0 SUMMARY

– There is hierarchy in waste management, which places waste reduction at the top, followed by reuse, recycling, recovery and finally disposal
– Waste reduction at source involves good practice, input material changes, product changes and technological changes.
– Reuse of products is another option for waste reduction
– Waste recycling is the collection, separation, clean up and processing of waste materials to produce a marketable product.
– There are two types of recycling system that exist to reclaim the materials separately, the **‘bring’** and the **‘collect’** systems.

6.0 TUTOR MARKED ASSESSMENT

Explain the various ways involved in the waste reduction technology.

7.0 REFERENCES / FURTHER READING

Hogg D., Barth J., Favoino E., Centemero M., Caimi V., Amlinger F., Devliegher W., Brinton W. and Antler S. (2002). Comparison of compost standards within the EU, North America and Australasia. Waste and Resources Action Program, Banbury, UK.

Paul T.W. (2005). Waste treatment and disposal. Second edition. pp. 391.

UNIT 3: WASTE LANDFILLING

CONTENTS

1.0 INTRODUCTION

Land filling is an economical method of waste disposal in developing countries, which involves pitching refuses into depression, mining void, excavated land or borrowed pits. It is the most traditional way of waste disposal practiced in many countries. The great majority of waste generated in developing countries is mainly of domestic origin consisting of mostly food waste, green waste and relatively low concentrations of toxic materials. Consequently, there is less of a need for a sophisticated landfill liner system of the type required for the waste generated from industrialized countries.

2.0 OBJECTIVES

- To learn about landfilling as waste management technology.
- To learn the advantages and disadvantages of landfills over other waste treatment technologies.
- To be able to differentiate between different types of landfills.

3.0 MAIN CONTENT

3.1 Advantages and disadvantages of landfills

The major advantage associated with land filling of wastes is the low cost of landfill compared with other disposal options and the fact that a wide variety of wastes are suitable for landfill. Also, in many cases, there is a strong interaction of the minerals extraction process with the infilling of the void space with waste. Extraction of rock materials has produced and continues to produce large holes in the ground, which at some stage require infilling. Mineral extraction plans usually include the restoration of the site after completion of the extraction. Infilling of the mineral workings by waste is therefore an economical advantage for the site developer. The collection and utilization of landfill gas as a fuel for energy generation is also an advantage. However, landfill achieves a lower conversion of the wastes into energy with about one-third less energy recovery per ton from landfill gas than incineration. This is mainly due to the conversion of the organic materials in the waste into non-combustible gases and leachate and general losses from the system.

There are however, some disadvantages with landfill. Older sites which are, in some cases, still under current use or have long been disused, were constructed before the environmental impacts of leachate and landfill gas were realized. Many of these sites are now sources of pollution with uncontrolled leakages. Landfill gas in particular can be hazardous since the largest component, methane, can reach explosive concentrations. Landfill gas methane is also a 'greenhouse gas', leading to the problems of global warming. The contribution to total methane emissions from landfill gas has been estimated by the European Commission to be 32%.

3.2 Types of landfills

3.2.1 Hazardous waste landfill

These are landfills, also known as secured landfill that allows disposal of only hazardous wastes. Hazardous waste is defined as waste, which is dangerous or difficult to keep, treat or dispose of and may contain substances which are corrosive, toxic, reactive, carcinogenic, infectious, irritant and harmful to human health or which may be toxic to the environment. Some types of hazardous waste are however, not permitted to go to landfill sites, even hazardous waste landfill sites, and these include liquid waste, flammable waste, explosive or oxidizing wastes, infectious clinical or hospital wastes. Hazardous wastes are deposited into designated and permitted 'hazardous waste landfill sites' with a high specification containment barrier liner system to contain the derived leachate and landfill gas and to allow for their collection and treatment.

3.2.2 Non-hazardous waste landfill

Non-hazardous waste includes municipal solid waste and a wide range of industrial wastes, such as organic and inorganic wastes, provided that they are non-hazardous. Significant features of non-hazardous wastes are that many are 'bioreactive wastes' which undergo biodegradation within the landfill environment. Non-hazardous wastes are permitted to be deposited into 'non-hazardous waste landfill' sites. However, stable, non-reactive hazardous wastes, for example, those that are solidified or vitrified, are also permitted to be deposited into non-hazardous waste landfills, provided that their leaching behavior is equivalent to the general category of non-hazardous waste. There is also the requirement that such non-reactive hazardous wastes are deposited in cells within the landfill that do not contain biodegradable wastes. The site requires a containment barrier liner system to control, contain and collect and then treat the produced leachate and landfill gas.

3.2.3 Inert waste landfill

Inert waste is defined as waste that does not undergo any significant physical, chemical or biological transformations. In addition, inert waste will not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm human health. The total leachability and pollutant content of the inert waste and the ecotoxicity of the leachate must be insignificant and, in particular, not endanger the quality of surface water and/or groundwater. Inert wastes are therefore deemed not to pose a significant environmental risk either now or in the future since, as their name suggests, they are wastes of no or low reactivity. As such, inert wastes do not undergo significant chemical, biological or physical degradation to yield polluting materials and consequently, only the minimum barrier containment system is required. Typical inert wastes include bricks, glass, tiles and ceramic materials, concrete, stones, etc.

4.0 CONCLUSTION

Landfilling of wastes appears to be easy and cheap way of managing waste. There is however problem as regards the leachate that is produced in many of the older sites where houses are already built on the disused landfill sites or close to areas of housing. Another issue is continual emission of greenhouse gases from the landfill, which is of serious concern. To contain the landfill gas and leachate, a barrier system which lines the landfill and acts as a barrier to the outside environment is required. The landfill gas should be collected via a system of porous pipe work within the landfill site and then treated and used or flared. The leachate should be collected and treated to remove pollutants to environmentally acceptable levels. There is call for increasing need for modern landfill as a fully designed and engineered process with high standards of management.

5.0 SUMMARY

- Land filling is an economical method of waste disposal in developing countries.
- The major advantage associated with land filling of wastes is the low cost of landfill compared with other disposal options.
- Many of the wastes disposed are suitable for landfills
- The collection and utilization of landfill gas as a fuel for energy generation is also an advantage.
- However, landfill gas in particular can be hazardous since the largest component, methane, can reach explosive concentrations.
- There are three different types of landfills: hazardous, non – hazardous and inert landfills.

6.0 TUTOR MARKED ASSESSMENT

What are the advantages and disadvantages of landfilling wastes? Describe the different types of landfills you have learnt.

7.0 REFERNCES / FURTHER READING

Paul T.W. (2005). Waste treatment and disposal. Second edition. pp. 391.

UNIT 4: WASTE INCINERATION

CONTENTS

1.0 INTRODUCTION

As an alternative to landfill, wastes containing combustible material may be incinerated or combusted. Incineration is the oxidation of the combustible material in the waste to produce heat, water vapor, nitrogen, carbon dioxide and oxygen. Depending on the composition of the waste, other emissions may be formed including, carbon monoxide, hydrogen chloride, hydrogen fluoride, nitrogen oxides, sulphur dioxide, volatile organic carbon, dioxins and furans, polychlorinated biphenyls, heavy metals, etc. (European Commission 2004). Municipal solid waste incineration has historically been seen in terms of a means of waste disposal. However, modern incinerators would now include a means of energy recovery as an economic necessity. Energy recovery is usually by the generation of electricity from high-temperature steam turbines or through district heating schemes.

2.0 OBJECTIVES

- To learn about incineration of waste as an alternative to landfilling.
- To compare incineration with landfill
- To learn the advantages and disadvantages of incineration over landfills

3.0 MAIN CONTENT

3.1 Advantages of incineration over landfill

Incineration of waste has a number of advantages over landfill.

- Incineration can usually be carried out near the point of waste collection. In some cities, the number of landfill sites close to the point of waste generation is becoming scarcer, resulting in transport of waste over long distances.
- The waste is reduced into a biologically sterile ash product, which for municipal solid waste is approximately 10% of its pre-burnt volume and 33% of its pre-burnt weight.
- Incineration produces no methane, unlike landfill. Methane is a ‘greenhouse gas’ and is a significant contributor to global warming.
- Waste incineration can be used as a low-cost source of energy to produce steam for electric power generation, industrial process heating or hot water for district heating, thereby conserving valuable primary fuel resources.
- The bottom ash residues can be used for materials recovery or as secondary aggregates in construction.

- Incineration is the best practicable environmental option for many hazardous wastes such as highly flammable, volatile, toxic and infectious waste.

3.2 Disadvantages of incineration over landfill.

- Generally there are much higher costs and longer payback periods, due to the high capital investment.
- The incinerator is designed on the basis of a certain calorific value for the waste. Removal of materials such as paper and plastics for recycling may reduce the overall calorific value of the waste and consequently may affect incinerator performance.
- Whilst modern incinerators comply with existing emissions legislation there is some public concern that the emitted levels may still have an adverse effect on health.
- The incineration process still produces a solid waste residue which requires management.

4.0 CONCLUSION

Incineration is an alternative method of waste treatment to the landfilling, which can be carried out near the point of waste collection. Incinerating waste does not lead to production of gases such as methane and is a source of low-cost energy. However, it may be a more expensive compared to landfilling.

5.0 SUMMARY

- Incineration of waste is an alternative method of waste disposal to landfilling
- Incineration does not produce methane
- Waste is reduced to ash
- Wastes can be incinerated near the point of collection
- More expensive compared to landfilling

6.0 TUTOR MARKED ASSESSMENT

Highlight the advantages and disadvantages of incineration over landfill.

7.0 REFERENCES/ FURTHER READING

Paul T.W. (2005). Waste treatment and disposal. Second edition. pp. 391.

UNIT 5: OTHER WASTE TREATMENT TECNOLOGIES

CONTENTS

1.0 INRODUCTION

The hierarchy of waste management and the concept of sustainable waste management have led to the development of alternative waste treatment and disposal options rather than the traditional reliance on the options of landfill and incineration. Alternatives, which have a minimal environmental impact, with a view to recycling or energy recovery with low pollution, have received particular attention.

2.0 OBJECTIVES

- To learn different methods of waste management strategies that are safer than conventional ways
- To learn how to use all the technologies available as an integral unit for waste management strategies

4.0 MAIN CONTENT

3.1 **Pyrolysis**

Pyrolysis is the thermal degradation of organic waste in the absence of oxygen to produce a carbonaceous char, oil and combustible gases. How much of each product is produced is dependent on the process conditions, particularly temperature and heating rate. Figure below characterizes the main differences between pyrolysis, gasification and incineration.

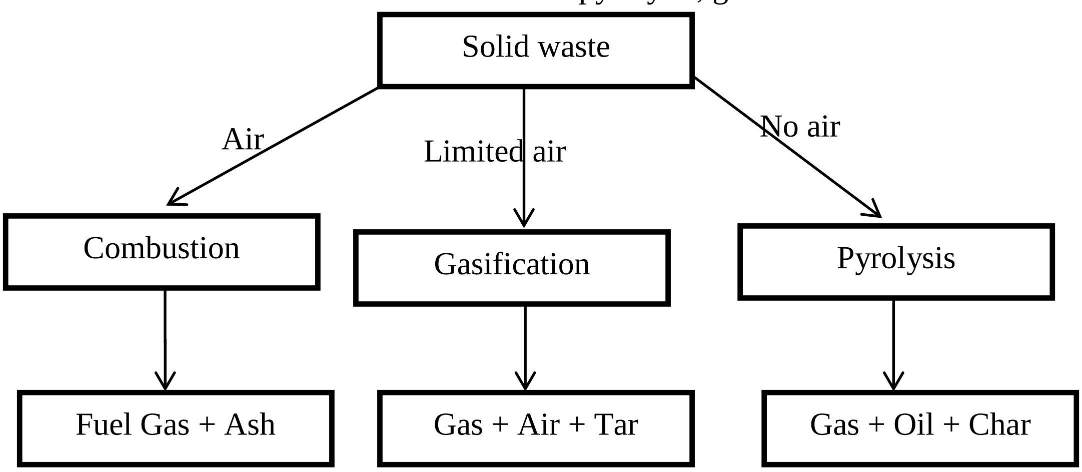

Fig 1: The main difference between pyrolysis, gasification and incineration.

The key difference is the amount of oxygen supplied to the thermal reactor. For Pyrolysis there is an absence of oxygen, and for gasification there is a limited supply of oxygen, such that complete combustion does not take place, instead the combustible gases; carbon monoxide and hydrogen are produced. The oxygen for gasification is supplied in the form of air, steam or pure oxygen. Incineration involves the complete oxidation of the waste in an excess supply of oxygen to produce carbon dioxide, water and ash, plus some other products such as metals, trace hydrocarbons, acid gases, etc.

3.2 Gasification

Gasification differs from pyrolysis in that oxygen in the form of air, steam or pure oxygen is reacted at high temperature with the available carbon in the waste to produce a gas product, ash and a tar product. Partial combustion occurs to produce heat and the reaction proceeds exothermically to produce a low to medium calorific value fuel gas. The operating temperatures are relatively high compared to pyrolysis, at 800–1100°C with air gasification, and 1000–1400 °C with oxygen.

The principle reactions occurring during gasification of waste in air are (Whiting 2003; Francis and Peters 1980)

$$C + O2 \longrightarrow CO_2 \quad \text{Oxidation exothermic}$$

$$C + CO2 \longrightarrow 2CO \quad \text{Boudouard reaction – endothermic}$$

$$2C + O2 \longrightarrow 2CO \quad \text{Exothermic}$$

3.3 Combined Pyrolysis-Gasification

Some modern developments in thermo-chemical processing of waste have utilized both pyrolysis and gasification in combined technologies, which may then involve a further combustion step to combust the gases produced in the first two stages. Such pyrolysis/ gasification/combustion technologies are, in effect, incinerators, but each step is separated into a separate temperature and pressure-controlled reactor rather than in an incinerator, where the three thermal degradation steps are combined in a one-step grate (furnace) combustion system.

3.4 Anaerobic Digestion

The anaerobic degradation processes found in landfills which lead to the formation of methane and carbon dioxide from organic waste are utilized in anaerobic digestion but in an enclosed, controlled reactor. The better control of the process means that all of the gas is collected for utilization unlike landfills where collection efficiencies are relatively low at 50% or less. In addition, the process in a waste landfill typically takes many years to anaerobically degrade the biodegradable waste, but using an anaerobic digestion system, the process is complete within a period of weeks (McLanaghan, 2002). The solid residue arising from anaerobic digestion can also be cured and used as a fertilizer. The main aim of the process is to produce a product gas, rich in methane, which can be used to provide a fuel or act as a chemical feedstock. Anaerobic digestion has been used to treat sewage sludge and agricultural wastes for many years and has also been developed for municipal solid wastes and industrial wastes (Verstraete and Vandeviere 1999). Figure below shows the main steps in the anaerobic digestion of biodegradable waste (IEA Bioenergy 1996; McLanaghan 2002).

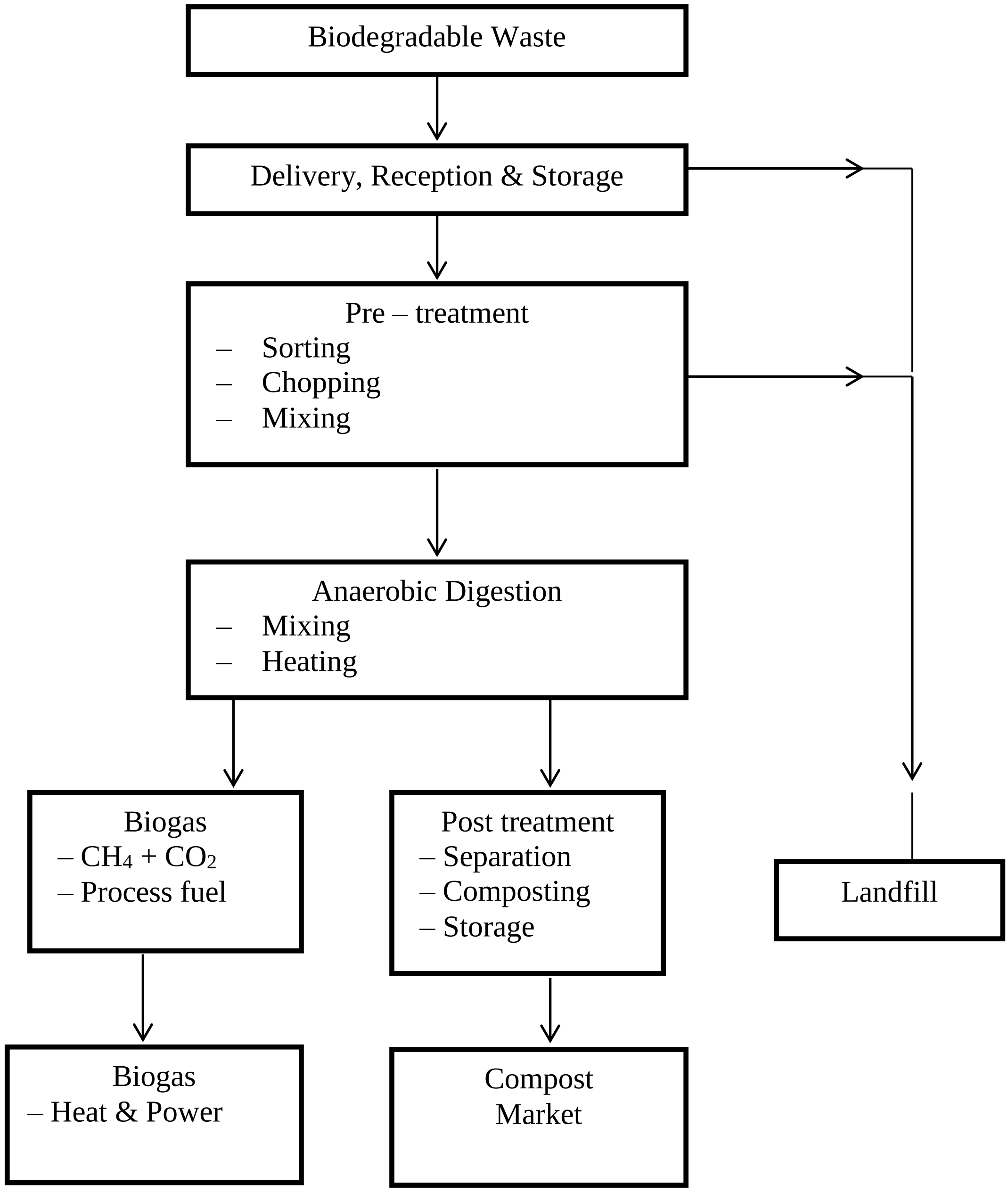

Fig 2. Schematic diagram of the anaerobic digestion process for biodegradable waste.
Sources: McLanaghan 2002; IEA Bioenergy 1996.

3.5 Integrated Waste Management

Integrated waste management has been defined as the integration of waste streams, collection and treatment methods, environmental benefit, economic optimization and societal acceptability into a practical system for any region. Integrated waste management implies the use of a range of different treatment and disposal options, including waste reduction, re-use and recycling, landfill, incineration and alternative options such as pyrolysis, gasification, composting and anaerobic digestion. However, integration also implies that no one option of treatment and disposal is better than another and each option has a role to play, but that the overall waste management system is the best environmentally and economically sustainable one for a particular region (McDougall, et al., 2001). Tchobanoglous et al., (1993) define integrated waste management in terms of the integration of six functional elements: (1). Waste generation; (2) Waste handling and separation, storage and processing at the source; (3) Collection; (4)

Separation, processing and transformation of solid waste; (5) Transfer and transport; and (6) Disposal.

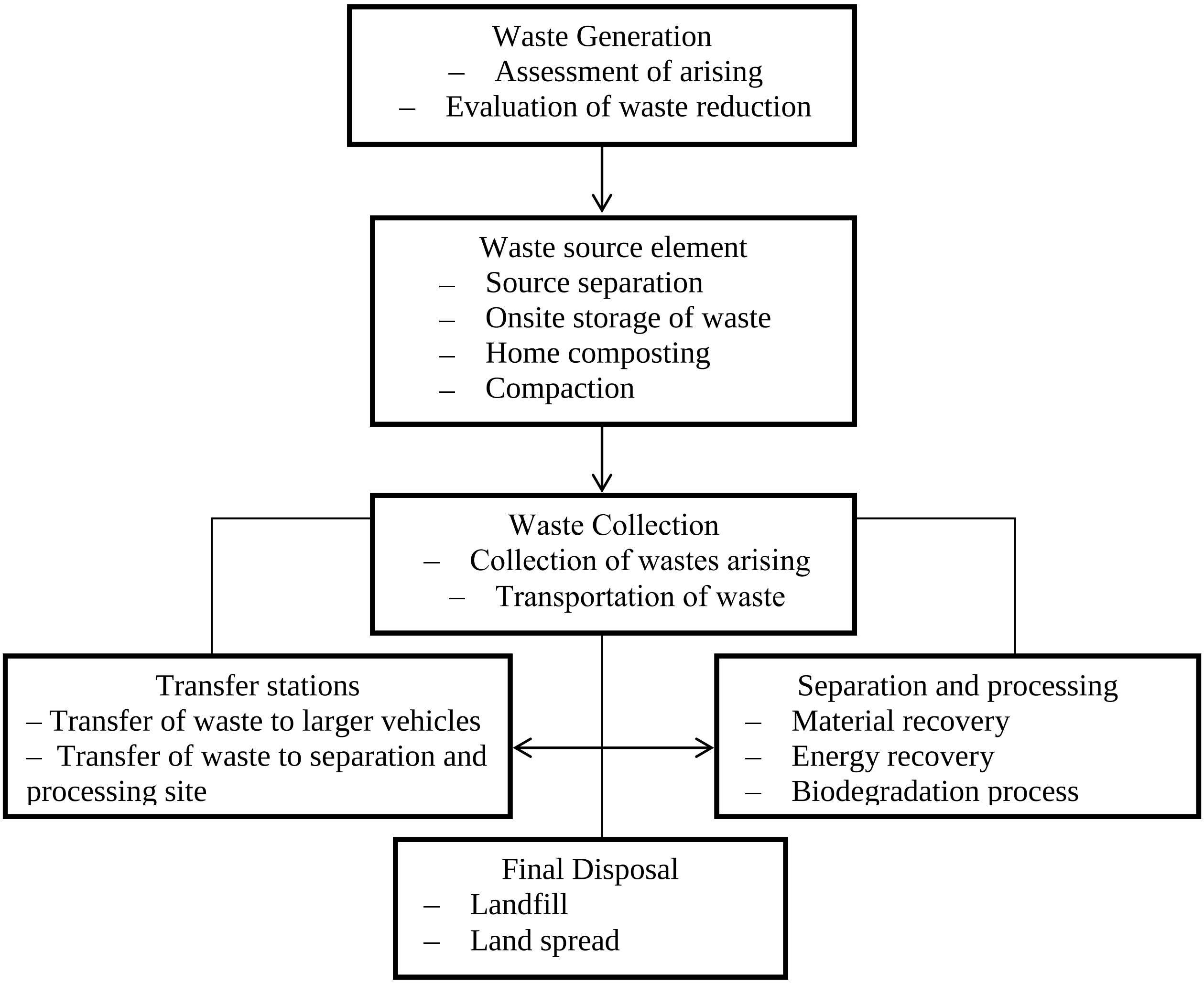

Fig. Integrated waste management

5.0 CONCLUSION

Conventional ways of treating and disposing of waste such as landfilling and incineration have impacted so much on the environment negatively that alternatives, which have a minimal environmental impact, have been developed with a an aim to recycling or energy recovery with low pollution. These alternatives have advantages over the conventional way of waste management strategies. The alternatives, depending on the technology employed, can be a multi-faceted producing various end products such as gas, oil, tar, etc. It is therefore important that these alternatives are employed in waste management and disposal strategies.

6.0 SUMMARY

- Alternative waste management and disposal developed to replace conventional ones
- The key difference between pyrolysis, Gasification and incineration is the amount of oxygen supplied to the thermal reactor.
- Pyrolysis – there is an absence of oxygen
- Gasification – there is a limited supply of oxygen
- Incineration – involves the complete oxidation of the waste in an excess supply of oxygen
- Combined Pyrolysis – gasification utilizes both pyrolysis and gasification technologies

- Aerobic digestion technology is a similitude to decomposition of waste in landfill but in an enclosed and controlled reactor.
- Integrated waste management employs the use of different treatment and disposal technology options, including waste reduction, re-use and recycling, landfill, incineration and alternative options such as pyrolysis, gasification, composting and anaerobic digestion.

6.0 TUTOR MARKED ASSESSMENT

With the aid of simple diagram, differentiate between incineration, gasification and pyrolysis

7.0 REFERENCES/ FURTHER READING

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