NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

COURSE CODE: EHS 308

COURSE TITLE: BIOTECHNOLOGY

COURSE GUIDE

EHS 308
BIOTECHNOLOGY

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INTRODUCTION

This course, *EHS 308 Biotechnology* is a two-credit unit course. The study of biotechnology is the use of living organisms (e.g. bacteria, fungi) or part of living organisms (e.g. chromosome, gene), or biological substances (e.g. enzymes) to perform specific bioprocess tasks. The biotechnologists are interested in how to use bacteria, fungi and viruses or genes from these or other living organisms to solve problems in different sectors of life such as agriculture, medicine, environmental management, etc. Specifically, biotechnologists acquire nanotechnology that enables them manipulate microorganisms and units of life such as DNA, genes and chromosomes to achieve specific goals.

Environmental biotechnology is a branch of biotechnology that is concerned with the application of these living organisms to remediate environmental pollution and contamination. Thus, environmental biotechnologists are concerned with environmental monitoring and the alternative use of living organisms to remediate contaminated sites. This is in contrast to the use of chemical and physical methods which are believed to be less environmentally friendly. The environment is often contaminated with several pollutants and contaminants, some of which are biodegradable while some are not. Environmental biotechnology has evolved several methods that utilize different species of bacteria or fungi to either degrade these pollutants and contaminants or render them less toxic and less risky to humans and the environment. The various methods of environmental biotechnology is either *in situ* (treating pollutants and contaminants at the site of contamination) or ex situ (transferring pollutants and contaminants to other sites for treatment). Environmental biotechnology also helps to develop production practices that generate less waste, less pollutants and less contaminant. This helps to reduce both the cost and time spent on treatment and to make the environment less hazardous.

This course guide tells you what to expect from reading this course material.

WHAT YOU WILL LEARN IN THIS COURSE

The study of environmental biotechnology familiarises you with the relationships between biology and engineering and how both disciplines could be fused into one discipline for the benefit of humanity. This fusion of biology and engineering to form biotechnology gave rise to genetic engineering, which is the manipulation of genes to produce desired living organisms both in form and function (performance). This course is designed to answer such questions as why some organisms are able to perform certain functions and others are not and how an

organism could be made to perform a desired function, which it could not perform originally. This course will not only break down the problems of environmental biotechnology, but it will also tell you some of the attempts made to solve the problems. It will also introduce you to the ethics and morality of biotechnology and how people of different beliefs view the advances and products of biotechnology.

COURSE AIM

The aim of this course is to provide a good understanding of the environmental biotechnology techniques for better management of the environment.

COURSE OBJECTIVES

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

- define and explain the concepts of biotechnology
- trace the historical origin of biotechnology
- identify who needs biotechnology and for what purposes
- describe the various branches of biotechnology and their functions
- describe the methods of biotechnology
- discuss the application of biotechnology to disease monitoring and control
- discuss the application of biotechnology to waste management
- discuss the application of biotechnology to pollution control and environmental sanitation
- discuss the application of biotechnology to remediation of contaminated sites, including sites contaminated with petroleum products
- discuss the merits and demerits of biotechnology
- discuss the religious, ethical and moral issues in biotechnology.

WORKING THROUGH THIS COURSE

This course has been carefully put together bearing in mind that you might be new to the course. However, efforts have been made to ensure that adequate explanation and illustrations were made to enhance better understanding of the course. You are therefore advised to spend quality time to study this course and ensure that you attend tutorial sessions where you can ask questions and compare your knowledge with that of your course mates.

COURSE MATERIALS

This course comprises of four modules broken down into 14 units. They are as listed below:

i. A course guide
ii. Study units

STUDY UNITS

This course comprises of four modules broken down into 14 units. They are as listed below:

Module 1 Introduction to Biotechnology

Unit 1 Concept and Definition of Biotechnology
Unit 2 Origin, History and Development of Biotechnology
Unit 3 Classification of Biotechnology
Unit 4 Scope of Environmental Biotechnology

Module 2 Methods in Biotechnology

Unit 1 Concept and Definition of Methods
Unit 2 Methods Used in Environmental Biotechnology
Unit 3 Traditional and Modern Methods in Environmental Health

Module 3 Application of Biotechnology to Environmental Health

Unit 1 Application of Biotechnology to Waste Management
Unit 2 Biological and Traditional Control of Pests and Diseases
Unit 3 Application of Biotechnology to Food Production and Preservation
Unit 4 Application of Biotechnology to Air and Water Pollution Control
Unit 5 Application of Biotechnology to Remediation of Contaminated Sites

Module 4 Merits and Demerits of Biotechnology Methods and Applications

Unit 1 Merits and Demerits of Biotechnology
Unit 2 The Big Debate: To be or not to be

Module 1

In Unit 1 you will be taken through the meaning and concept of biotechnology. The unit also tells you who need biotechnology and how important it is to our modern development. In Unit 2, you will be taken through the history and origin of biotechnology as well as the emerging issues in biotechnology. In Unit 3, you will be introduced to the various branches of biotechnology, its mode of classification and the functions of the various branches. In Unit 4, you will be introduced to environmental biotechnology, its classifications, scope and applications.

Module 2

In Unit 1, you will be taken through the meaning and concept of methods, and how to identify appropriate methods for a given task. In Unit 2, you will be taken through the various methods in environmental biotechnology including their timeline development. In Unit 3, you learn about the various methods used in environmental health including the comparative assessment of traditional and modern methods of biotechnology.

Module 3

In Unit 1, you will be taken through the various methods of biotechnology used in modern waste management. In Unit 2, you will be introduced to the biotechnology applications to pests and disease monitoring, surveillance and control. Unit 3 introduces you to the application of biotechnology methods to food production and food preservation. In Unit 4, you will learn about the application of biotechnology methods to the control of pollution in air and water, while, in Unit 5, you will learn about how to use biotechnology methods to prevent land pollution and remediate contaminated sites.

Module 4

In Unit 1, you will be taken through the merits and demerits of biotechnology beginning with learning about what constitutes merit and demerit. Finally, in Unit 2, you will be introduced to the big debate about biotechnology. You will join in the assessment of the various religious, ethical and moral concerns raised about biotechnology.

TEXT BOOKS AND REFERENCES

The following are list of textbooks, journals and website addresses that can be consulted for further reading:

Vasantha-Kandasamy, W. B. *Et al.* (2010). "Methods in Environmental Biotechnology for Environmentalists." *Infolearnquests Ann Arbor*, p. 144.

Scragg, A. (2005). *Environmental Biotechnology*. (2nd ed.). Oxford: Oxford University Press.

Cheremisinoff, N. P. (1996). *Biotechnology for Waste and Wastewater Treatment*. New Jersey, USA: Noyes Publications.

Roehr, M. (2001). The Biotechnology of Ethanol: Classical and Future Applications. Wiley-VCH. Verlag GmbH, Weinheim. 244 pp.

Murray, T. H. & Mehlman, M. L. (2000). *Encyclopedia of Ethical, Legal and Policy Issues in Biotechnology*. (Volume 1). New York: John Wiley and Sons Inc.

Barsanti, L. & Gualtieri, P. (2006). *Algae: Anatomy, Biochemistry and Biotechnology*. London: Taylor and Francis.

ASSESSMENT

There are two components of assessment for this course. They are the tutor-marked assignment and the final examination.

TUTOR-MARKED ASSIGNMENT

The Tutor-Marked Assignment **(**TMA) is the continuous assessment component of your course. It accounts for 30 per cent of the total score. The TMAs will be given to you by your facilitator and you will return it after you have done the assignment.

FINAL EXAMINATION AND GRADING

The examination concludes the assessment for the course. It constitutes 70 per cent of the whole course. You will be informed of the time for the examination.

SUMMARY

This course intends to provide you with the knowledge of biotechnology and environmental biotechnology as they affects man's productive capacity, health and ability to manage the environment for sustainable development.

We wish you success in this course and hope that you will apply the knowledge gained to conserve biological resources in your environment.

MAIN COURSE

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MODULE 1 INTRODUCTION TO BIOTECHNOLOGY

UNIT 1 CONCEPT AND DEFINITION OF BIOTECHNOLOGY

CONTENTS

1.0 INTRODUCTION

It may be right to say that biotechnology is not new to any of you. We are all aware that for a very long time, people have used yeast to make bread, beer and alcohol. We cannot eat cassava unless it is first fermented and processed and local gin makers know how well to allow palm wine to ferment prior to brewing. All these, as simple as they seem, are based on the principles of biotechnology – the use of living organisms in production and product processing. However, because several methods and techniques of biotechnology have progressively become more complex and more sophisticated than the traditional methods we are used to in our homes, many people have forgotten that biotechnology still involves the same simple methods we use on daily basis. At the end of this unit, you will probably become fully aware of what biotechnology is and how it applies to the environment and environmental health.

2.0 OBJECTIVES

At the end of this Unit, you will be able to:

- define biotechnology and environmental biotechnology
- explain the concept of biotechnology and its implications to the environment
- identify who needs biotechnology and environmental biotechnology
- explain the importance of biotechnology and environmental biotechnology
- discuss how the concept of biotechnology applies to Environmental health

3.0 MAIN CONTENT

3.1 Concept of Biotechnology

The term "biotechnology" is derived from two established disciplines – biology and Technology. Biology, as we know, is the study of living organisms while technology is the application of scientific knowledge for practical purposes such as making, modification, usage and knowledge of tools, machines and techniques to solve a problem, improve a preexisting solution to a problem or perform a specific function.

Thus, biotechnology is the use of living organisms (biology) in whole (e.g. bacteria, fungus) or in part (genetic materials e.g. chromosome, gene), or biological substances (e.g. enzymes) to perform specific bioprocess tasks (technology). The tasks may involve industrial processes (such as manufacturing), bioconversion of wastes (e.g. biofuel production, i.e. conversion of organic waste to gas for use as fuel) or genetic engineering to alter existing forms and function of a living organism in whole or in part. This also conforms to the definition of the United Nations Convention on Biological Diversity that biotechnology as 'any technological application that uses biological systems, living organisms or derivatives thereof to make or modify products or processes for specific use'.

In line with this, the International Society for Environmental Biotechnology defined environmental biotechnology as "the development, use and regulation of biological systems for remediation of contaminated environments (land, air and water) and for environmental-friendly processes (green manufacturing technologies and sustainable development)." This simply means that environmental

biotechnology is the optimal use of nature in a cyclic manner that sustains the environment for future generations.

In order to understand the concept of biotechnology, it is necessary to know what is meant by 'concept'. The word "concept" is a philosophical term. In its simplest form, it describes the 'general idea' or connotes the common characteristics that remain among a set of issues, objects or functions after the uncommon characteristics have been removed. This can be explained by considering the concept of being an animal. Look around your environment and see a number of objects and individuals positioned at different distances. You can see desks, other human beings, probably goats, fowls, birds and trees. After eliminating uncommon characteristics, it could be seen that individuals such as goats, birds and humans have such common characteristics as ability to move around, breathe, etc. Thus, it could be said that the concept of being an animal involves locomotion, breathing, etc. In addition, the concept of 'green' is said to be that colour common to all plants. Deriving from these, the concept of biotechnology connotes the characteristic(s) that is common to all biotechnological processes. These are the ability to use living organisms or other biological substances to produce, modify or create new substances or modify existing ones. Thus, any such process, no matter where it is found, how long it has been around and how crude, simple or sophisticated it might be is described as biotechnology. When biotechnology is directed at making the environment sustainable, it is environmental biotechnology.

3.2 *Importance of Biotechnology*

As could be seen from our discussions so far, everyone needs biotechnology. We can all agree that any effort that gives rise to more food, cleaner environment, less disease infections and better way of doing things is good for everyone. It is reputed that biotechnology could be used to develop plant cultivars that are more productive and more resistant to pests. This will lead to significant improvement on the advances of the green revolution of the 60s and 70s on improved agricultural production. However, while green revolution was driven by high-yielding plant varieties, agro-chemicals and new irrigation techniques that are harmful to the environment, biotechnology drives the new development through improved varieties of plant cultivars that are high-yielding but above all resistant to pests. As a result, it requires little or no application of pesticides and herbicides. This results in higher yields and cleaner environment. For instance, biotechnology is one singular factor that has explained the increasing trend of rice production in the last three decades (see Figure 1.1).

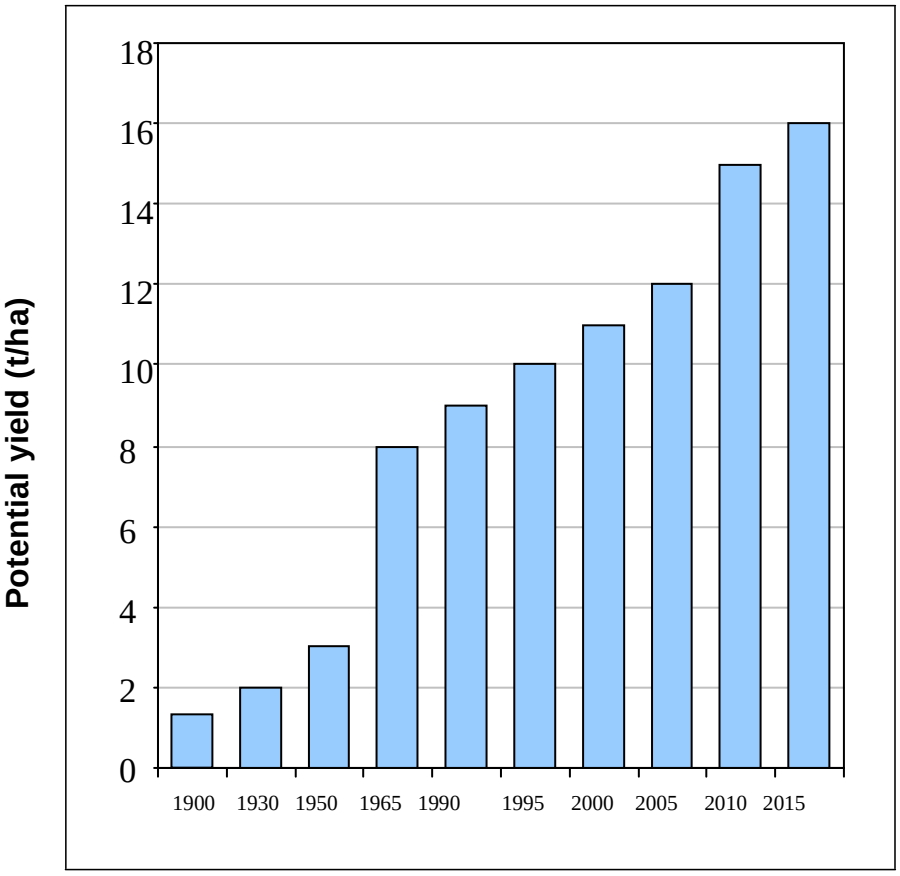

Fig. 1: Progress in the Yield Potential of Rice (Source: Datta, 2004)

Figure 1.1 shows clearly that although improved agricultural production came with the Green Revolution in the 60s, biotechnology is taking it to greater heights. This level of improved agricultural production is good for food security around the world, good for the farmers and good for the poor in the developing countries. The less pesticide application required by biotechnology driven cultivars suggest more environmental friendly agriculture, less contamination, less pollution and overall healthier populations. The improved environmental cleanliness and less disease potential are good for everyone especially children and pregnant women in the developing countries who are the most susceptible to pollution effects.

However, it must also be emphasised that biotechnology is not completely about food production. It is also used to produce biological weapons especially weapons of mass destruction. The most common of these weapons is the anthrax. This is a disease of the lungs and intestines caused by exposure to the spores of *Bacillus anthracis. Biotechnology has been used to mass-produce this bacterium for sinister purposes. When and if this technology falls into wrong hands, it constitutes a risk and danger to government and the public.*

Biotechnology can also be used in terrorism. In addition to the bombings and shootings, it can be used to send bacteria spores to unsuspecting citizens. Biotechnology is also used in drug production and in the development of some body parts for transplant purposes; as a result, pharmacists, physicians and patients need it. Transplant patients are particular in dire need of biotechnology, as it is the only option to an endless queue for donor parts.

Recall that biotechnology is an applied biology that involves the use of living organisms in the fields of engineering, technology, medicine, agriculture, pharmacy, environmental management and many other useful areas of human development. The importance of biotechnology therefore draws on the vital roles it plays to advance knowledge and practice in these areas. In medicine and pharmacy, for instance, biotechnology is contributing immensely to the production of new and more effective drugs. It is also contributing to an entirely new ways of disease diagnosis and treatment.

One of the most important of this development is the use of DNA for plant breeding, genetic engineering and fingerprint to diagnose inherited disorders in both prenatal and newborn babies in medicine. These disorders may include cystic fibrosis, hemophilia, Huntington's disease, familial Alzheimer's, sickle cell anemia, thalassemia, and many others. Early detection of such disorders enables the medical staff to prepare themselves and the parents for proper treatment of the child.

In some cases, genetic counselors use DNA fingerprint information to help prospective parents understand the risk of having an affected child. DNA fingerprint information can also help in developing cures for inherited disorders. It is also useful in crime control. It helps to link suspects to biological evidence – blood or semen stains, hair or items of clothing – found at the scene of a crime. Another important use of DNA fingerprints in the court system is to establish paternity in custody and child support litigation. The US armed services have just begun a program to collect DNA fingerprints from all personnel for use later, in case they are needed to identify casualties or persons missing in action or for suspect verification. This is another form of biological banking, the best known of which is blood bank.

In agriculture, biotechnology has been used to increase crop production without significantly harming the environment. This is because biotechnology has been used to develop high yielding cultivars that depend less on fertilisers, pesticides and other agrochemicals. Biotechnology is being applied to modify proteins in foods to increase their nutritional values and qualities. This will lead to less malnutrition and improved human well-being. It is also used to slow down the

process of spoilage in fruits and crops. This involves processes that delay ripening and slowing down of bacterial activities that lead to crops decay. This will give rise to fruits and crops with long shelf life allowing transportation to distant consumers without fear of decay. In addition, it is used to improve taste, texture and appearance of fruits and crops. Biotechnology is also being increasingly used in the manufacture of several organic products such as beer and milk products.

Bacteria species are also used in the mining industry for bioleaching. This is the extraction of metals from their ores using bacteria. This process is more efficient and much cleaner than the traditional heap leaching that uses cyanide. Because of its increasing relevance, bioleaching is now recognised as one of most important components of biohydrometallurgy. Today, it is applied as one of the most environmentally friendly methods used to recover copper, zinc, lead, arsenic, antimony, nickel, molybdenum, gold, silver, and cobalt. Biotechnology is also used to recycle and treat waste; cleanup sites contaminated by industrial activities, e.g. oil spill and point effluent discharge (constant discharge of industrial wastewater at particular point via pipes, channels or canals). It is therefore a vital component of bio-remediation.

On the negative side, biotechnology is used to produce very effective and deadly biological weapons such as anthrax. In fact, recent advances in bio-energy, bio-remediation, synthetic biology, DNA computers, virtual cell, genomics, proteomics, bioinformatics and bio-nanotechnology have made biotechnology even more powerful.

3.3 Relevance of Biotechnology to Environmental Health

To understand how biotechnology applies to environmental health, it is important to first recall the roles of environmental health in sanitation, waste management and disease control. Handling of human excreta has for centuries been at the forefront of environmental challenges and biotechnology has been the method of choice for dealing with this challenge at a large scale.

Most sewage treatment methods are based on the principle of biotechnology. We are all aware of the different types of toilet facilities in our homes; ranging from the bucket, pit and pour flush latrines to the water cistern. We are also all aware that the excreta we discharge is either taken to on-site treatment facilities, namely the pit, soak away and septic tanks or carried to distant treatment facilities via the sewer system. What we probably do not appreciate is that no matter where our excreta end up, they are degraded by micro-organisms. Traditionally, these processes take place naturally without interference.

The degradation process usually takes place in stages. Some bacteria have the capability to degrade raw and complex excreta materials into smaller molecules that other microbes can convert into nutrients. The nutrients are further converted either by nitrifying bacteria to nitrates that are either used by plant or further reduced to elemental nitrogen N_2 by the denitrifiers. Likewise, organic acids are converted into methane gas by other microbes. Degradation of other complex organic wastes such as industrial effluents (liquid waste discharged by industries) follows a similar process. The problem, however, that this process left to nature is very slow and depending on the rate at which either domestic or industrial wastes is discharged may lead to serious contamination of sites. The slow rate in nature could be attributed to four major factors, viz. low concentration, slow rate of degradation, short lifespan and adaptive ecology of the microbes.

The adaptive ecology may be due to inability of microbes concerned to tolerate changing levels of some factors in the contaminated sites, e.g. oxygen or other toxicants. Biotechnology now has answers that can be employed to tackle these challenges. Techniques now exist to increase the rate of microbe multiplication, hasten their rate of degradation and increase their lifespan. Many of these technologies involve either genetic mutation or cloning. The former is processes of reinforcing the genes that enable a potential microbe degrade organic compounds. Once such microbes are identified, genetic engineers are capable of identifying the genes that confer such attributes on them and study ways to boost their activities. In addition, it is also possible to transfer such genes to other microbe species to enable them do the same job.

Finally, biotechnology is also used to clone (artificial multiplication) completely new and more active microbe strains using cells from existing microbe species. Biotechnology is also being used to sort through what the genetic influences are and how the genes influence how we respond to environmental exposures. This will help to identify genes that respond to particular environmental stresses and how they respond to make us feel the way we do when we are ill. When this information becomes fully available, treatment of diseases will be a lot simpler because we will know what gene(s) are involved and what has happened to them to enable us become susceptible to certain environmental stimuli.

4.0 CONCLUSION

In this unit, it has been explained that biotechnology is the application of biological and engineering methods to production processes. These methods are not completely new because they have been used for a very long time. We have used living organisms of different kinds to solve

problems without really calling it biotechnology. For instance, we ferment cassava and bake bread and other products at domestic and semi-industrial levels without really appreciating that we are practicing biotechnology.

In modern biotechnology, however, deliberate efforts are made to select living organisms of choice, alter their form and composition and decide how best to use them to achieve optimal set goals. Biotechnology, however, may also be used for negative purposes as in the making of biological weapons of mass destruction. In spite of these negative implications, there is no doubt; biotechnology is an important development that will help many sectors of world economy move forward. If properly applied, biotechnology also has the potential to make the world a better and healthier place to live.

5.0 SUMMARY

In this unit we have learnt that:

- biotechnology is the use of living organisms or other biological systems and technological methods to make or modify products or processes for a specific purpose
- environmental biotechnology is the application of biotechnological methods to remediate (improve) contaminated environments (land, air and water)
- everyone needs biotechnology because it is used at all levels, from households fermentation and processing of food materials e.g. cassava, manage human excreta and other wastewaters to large industries and hospitals wastewater management and disease diagnosis and treatment respectively
- biotechnology has a wide range of application in agriculture, medicine, pharmacy and environmental management
- biotechnology methods offer great potential for cost-effective, quick, sustainable and environmentally friendly remediation of contaminated sites.

6.0 TUTOR-MARKED ASSIGNMENT

1. Give a concise definition of biotechnology and environmental biotechnology
2. Distinguish between traditional biotechnology and modern biotechnology
3. Explain the concept of biotechnology
4. Discuss the importance of biotechnology to environmental health
5. List some of the contributions of biotechnology to human development

6. Explain three areas where DNA can be applied in biotechnology.

7.0 REFERENCES/FURTHER READING

Datta, S. K. (2004). "Rice Biotechnology: A Need for Developing Countries." AgbioForum, 7 (1&2): 31-35.

Stock, W. G. (2010). "Concepts and Semantic Relations." In: "Information Science." *Journal of the American Society for Information Science and Technology,* 61(10): 1951-1969.

United Nations (1992). "Article 2: Use of Terms." In: "Convention on Biological Diversity." Retrieved from www.cbd.int/doc on 04/06/2012.

Zylstraa, G. J. & Kukor, J. J. (2005). "What is Environmental Biotechnology?" Current Opinion in Biotechnology, 16(3):243-245.

UNIT 2 ORIGIN, HISTORY AND DEVELOPMENT OF BIOTECHNOLOGY

CONTENTS

1.0 INTRODUCTION

In the last unit, we defined and explained what constitutes biotechnology. In this unit, we shall examine the history of biotechnology and how it has progressed from a simple local method of production to the very complex technologies it has become today. As we shall see, biotechnology has a long history that predated modern civilisation. Humans for a very long time have put plants and animals to several uses without actually calling it biotechnology. Fermentation and brewing have been carried out long before the turn of the first millennium and microbes were used to cure diseases.

In this unit, you will learn all about when humans started using plants and animals to solve these specific problems and the problems that have been solved using the different plants and animals. You will also learn about when the application of living organisms to solve human problems came to be called biotechnology and how the process of biotechnology progressed from simple traditional use of whole organisms to very complex techniques involving isolation and use of parts of organisms, including the smallest component of an organism known as the genes.

2.0 OBJECTIVES

At the end of this Unit, you will be able to:

- outline the history of biotechnology and environmental biotechnology
- describe emerging issues in the development of biotechnology and environmental biotechnology
- discuss the level of public awareness of biotechnology in Nigeria.

3.0 MAIN CONTENT

3.1 Origin and History of Biotechnology and Environmental Biotechnology

The word "biotechnology" was first coined by a Hungarian known as Karl Ereky in 1919 to describe a technology based on the use of living organisms either in whole or in part to convert raw materials into more useful product(s). In real sense, however, the history of biotechnology and environmental biotechnology can be divided into three major developmental periods, namely: ancient, classical and modern history. The ancient history dated hundreds of centuries ago suggesting that humans have used organisms for development almost throughout human history. During that period, techniques that today formed the background of biotechnology were developed although the word "biotechnology" was not used to describe any of the techniques. Such technologies included fermentation, which was developed in the ancient Egypt more than 6000 years ago.

Fermentation is the use of microorganisms usually bacteria or yeast to breakdown organic compounds, e.g. sugars into simpler substances e.g. carbon dioxide and alcohol. The new fermentation technology was first used to make wine and later dough rise about 4000 years ago giving birth to the world's first bread. It also gave rise to the making of many other food products such as cheese and dairy products. This period ended about 500 – 100 BC when the Chinese developed what were to become the world's first antibiotics and insecticide using moldy curds (solid part of sour milk) and powdered chrysanthemum (a perennial garden plant), respectively. During this period, only whole-organisms were used.

The classical history occurred between the 16th and 19th century AD involving the invention, discovery and development of technologies, materials and methods, that will later give rise to the use of animal parts and substances in biotechnology. The first of such materials was the

microscope invented by Zaccharias Jenssen in 1590. This led to the discovery of the cell in 1665 by an Englishman, Robert Hooke and one-celled microorganisms, bacteria and protozoa between 1675 and 1683 by Antone Van Leeuwenhoek, a tradesman of Delft, Holland. Cell theory was however not developed until 1839 when Theodor Schwann, Matthias Jakob and Rudoff Virchow propounded that the cell is the building block of all living things. In 1796, Edward Jenner, an English physician and scientist from Berkeley, Gloucestershire, developed the first successful vaccine against smallpox. This was the beginning of biotechnology application to medicine. In 1802, the term "biology" in its modern sense was propounded independently by a German naturalist, Gottfried Reinhold Treviranus (Biologie oder Philosophie der lebenden Natur) and a French soldier and naturalist, Jean-Baptiste de Lamarck (Hydrogéologie) although the word was coined in 1800 by another German physiologist, Karl Friedrich Burdach.

The development of biology as a science of study led to series of quick discoveries that culminated in the coining of the word biotechnology in 1919. First was the discovery of proteins (the building block of living organisms) in 1838 by Gerhard Johan Mulder, a Dutch chemist although the word was first used by a Swedish scientist Jöns Jacob Berzelius in 1816. This was followed by the discovery of cell nucleus in 1933 by a Scottish Botanist Robert Brown, although the nucleus had earlier been observed by Thonius Philips van Leeuwenhoek. The two important isolations of Escherichia coli and yeast in 1855 by Theodor Escherich (a German) and Louis Pasteur (a French), respectively confirmed that individual microorganisms were involved with food poisoning and food decay. Gregor Johann *Mendel, an Austrian scientist discovered the gene in 1862 and laid the foundation of not only genetics but also genetic engineering, which as we will see in later chapters play great roles in modern biotechnology. The later independent discoveries of the chromatin (1879) and chromosome (1888) by two German scientists Walther Flemming and* Heinrich Wilhelm Gottfried von Waldeyer-Hartz, respectively ended the middle age period in the history of biotechnology.

The modern biotechnology started with the coining of the word "biotechnology" in 1919 by Karl Ereky of Hungary in his book Biotechnologie der Fleisch-, Fett- und Milcherzeugung im land-wirtschaftlichen Grossbetriebe (Biotechnology of Meat, Fat and Milk Production in an Agricultural Large-Scale Farm), published in Berlin. The new technology spread within a short time to various parts of the world including Great Britain and the United States of America. It encouraged further research on the discovery of microorganisms and their application to new areas in biologically-based industries to create new fermentation products. The research intensification led to the

discovery in 1927 by Muller that x-rays cause mutation (a random change in a gene or chromosome resulting in a new trait or characteristic that can be inherited; which could be a source of beneficial, neutral or harmful genetic effect) in organisms. This was a landmark discovery, showing for the first time that changes in the internal (genetic) composition of an organism gives rise to new phenotype (visible characteristics).

Further research along this line led to the discovery of penicillin, in 1928 by the Scottish scientist Alexander Fleming and coining of the term "molecular biology" in 1938 by Warren Weaver, an American mathematician. The knowledge of molecular biology (the study of the molecular basis of biology), enhanced the understanding of the interaction between the various systems of a cell, including the interactions between deoxyribonucleic acid (DNA), ribonucleic acid (RNA) and protein biosynthesis quickly gave rise to genetic engineering in 1941. A process of altering the genetic material (DNA and RNA) and other components of the living cells to make them capable of producing new substances and/or performing new functions, genetic engineering involves the understanding of the composition, sequence and functions of genes and their constituents in an organism and the consequence of alteration of all or any of these. The applications of this technology (i.e. alteration of the composition and sequence) of genes to achieve specific functions have giving rise to several emerging issues in modern biotechnology.

3.2 Emerging Issues in Biotechnology

Recall that biotechnology involves the use of living organisms in bioprocess production. Until recently, development in biotechnology involved the identification and use of such identified organisms. The evolution of genetic engineering opened a completely new opportunities. First, it showed that in addition to using existing whole organisms, components of organisms can be isolated and used, or composition of the whole organism or its component can be altered before use. The emerging technologies for isolating a component or altering a component or a whole organism to achieve an optimal goal has opened a completely new and diverse opportunities in biotechnology research and development. It led to a more understanding of the various living components that could potentially be altered to achieve designed goals. For instance, the structure of the DNA was deciphered in 1953 by Watson and messenger RNA discovered in 1960. By the end of 1961, the genetic code was unravelled and in 1977, genetically-engineered bacteria was for the first time used to make human growth proteins.

In 1978, Hutchinson and Edgell proved that mutation can be induced at specific sites in a DNA while in 1979 the first monoclonal antibodies were synthesized.

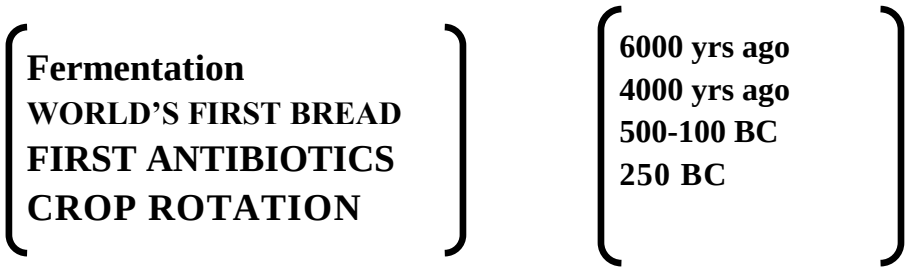

Fig. 2.1: First Monoclonal Antibodies

These developments began a new era in biotechnology. Induced mutation brought an opportunity to modify existing organisms to suit specific purposes while the synthesis of monoclonal antibodies help to develop compounds that could selectively be used against disease-causing organisms and other undesirable organisms in the environment. These developments led to several developments, creation and unravelling of genetically-related information that is relevant to medicine, agriculture and environmental management. These include creation of the first genetically engineered plants, cloning of mice and production of insulin and several other drugs from genetically engineered bacteria by the end of 1982. By the end of 1984 artificial chromosomes been made and genetic markers for specific diseases developed. Other findings included animal cloning and tissue regeneration from embryonic stem cells and genetic coding and sequencing of animal genome including those of humans in the first decade of the this Century.

3.3 Biotechnology Awareness in Nigeria

Biotechnology offers tremendous opportunities for improving the well-being of current and future generations and the environment. However, it also embodies risks as we will see in later chapters and may be misunderstood unless adequate effort is made to inform the populace of the benefits, demerits and processes of innovations attached to the new technology. This effort requires knowledge of public awareness of the technology, the sources of information to the public and how reliable such sources are. Most of what is known about public awareness of biotechnology in Nigeria is derived from a study carried out by Anyawale and his colleagues covering all parts of the country. The study reported that about two-thirds (63.2%) of Nigerians have heard of the term "biotechnology" (Figure 2.2).

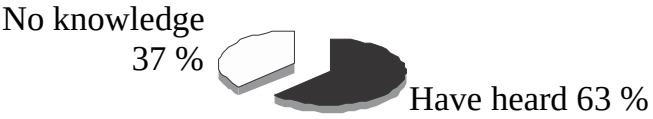

Fig. 2.2: Awareness of Biotechnology

Amongst the many that have heard of biotechnology, few have detailed knowledge of the processes of the new technology, clearly demonstrating that awareness does not necessarily equate to knowledge. In fact, only few Nigerians have an understanding of the basic procedures involved in biotechnology. A further breakdown of their findings revealed that awareness was more in the southern parts (southwest and southeast) of the country than in the northern parts. Furthermore, it is higher in the southwest than either in the southeast or south south geopolitical zones of the south. The study suggested that location of institutions such as International Institute for Tropical Agriculture (IITA), Ibadan, National Center of Genetic Resources and Biotechnology (NACGRAB), University of Ibadan, and Obafemi Awolowo University that deal with biotechnology in one form or the other in the southwest may have contributed to the higher level of awareness in the zone.

3.3.1 Perceived Advantages of Biotechnology

The investigation reported that most people that are aware of biotechnology had clear-cut perception of what they believe are its advantages and disadvantages. Majority (36%) perceived that biotechnology is beneficial and a means of achieving food security and self-sufficiency in Nigeria. Many others (>22%) believed that the new technology will contribute positively to healthcare delivery in Nigeria. This belief trend suggests that most Nigerians who are aware of biotechnology have a positive attitude towards it and will be willing to see it developed to fullness in the country.

Furthermore, most Nigerians believe that the possibility of using biotechnology to combat food insecurity, poverty and improve health is more relevant to Nigerians at this point in our national life. However, many also believed that the new technology may also have negative implications to human health. They particularly pointed at the likelihood of long term effect of consuming bioengineered products over a long period of time. Many, however, said while they have not seen or used such products, these fears come from what they heard or read in the mass media about concerns expressed by people in the United States and Europe where biotechnology products exist widely.

3.3.2 Policy and Institutional Arrangements for Biotechnology Development in Nigeria

Nigeria has a clear policy on biotechnology development in the country. The Federal Government of Nigeria recognized that biotechnology could play important roles in enhancing the quality of life through production of higher yielding crops and livestock with added value to the products. Hence, the government has established some institutions and agencies to promote the use of this technology and also to regulate the products obtained from it. Such institutions include research institutes, as represented by the International Institute of Tropical Agriculture (IITA), Ibadan, the National Biotechnology Development Agency (NABDA), Abuja, Sheda Science and Technology Complex (SHESTCO), Abuja, which houses the country's advanced biotechnology and some University departments and units involved with the teaching and research in biotechnology.

4.0 CONCLUSION

The history of biotechnology could be divided into three major period of ancient, classical and modern history. Ancient history started more than 6000 BC when man first used fermentation to process some of its food materials. During this period, no one knew that technology involved the use of other living organisms in processing foods. This knowledge came in the Middle Ages during the classical history, which started in the 14th century AD.

During this period, equipment such as microscopes was discovered and with it came the existence of living organisms that cannot be seen with the unaided eyes. The discovery of these microorganisms, the roles they play in food processing especially fermentation and techniques for manipulating them (ability to alter their populations and transfer them from one medium to another) led to several experiments on how to make them work better and faster to produce food in higher quality and quantity. This gave rise to biotechnology; a term coined in 1919 by a Hungarian agriculturist known as Karl Ereky. The emergence of the term biotechnology did not only herald a new discipline but also a new era in biotechnology. The era of modern biotechnology was born. This saw the development of very complex materials, equipment and methods of manipulating microorganisms, cells and parts of cells in bioprocess production. It also saw a significant diversification of biotechnology methods into many other fields other than food production.

5.0 SUMMARY

In this unit, you have learnt that the history of biotechnology. You also learnt that the history of biotechnology could be divided into three major periods, namely ancient, classical and modern eras. In the next unit, you will be taught the various areas of biotechnology applications.

6.0 TUTOR-MARKED ASSIGNMENT

1. Give a concise account of the origin and history of biotechnology
2. Describe the level of biotechnology awareness in Nigeria
3. What do you think are the advantages of biotechnology in Nigeria
4. Explain in details the emerging issues in biotechnology

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UNIT 3 CLASSIFICATION OF BIOTECHNOLOGY

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt that biotechnology has a long history of over 8000 years. You also learnt that the technique has developed from its initial simple and traditional application of food and wine processing to complex use in many other areas of human endeavour. This has given rise to diverse areas of biotechnology. In this unit, you will learn about these various areas of biotechnology, their mode of classification and issues common to techniques under similar classes.

2.0 OBJECTIVES

At the end of this Unit, you will be able to:

- explain the bases of biotechnology classification
- outline the various branches of biotechnology
- explain the time-based classification of biotechnology
- explain the application-based classification of biotechnology.

3.0 MAIN CONTENT

3.1 Time-based Classification of Biotechnology

As we have already known, biotechnology has gone though a long process of development spanning over 8000 years. As a result of this, timeline has become one of the bases for classifying biotechnology. Under this scheme, biotechnology is classified as ancient, classical or modern.

3.1.1 Ancient Biotechnology

This refers to most developments and discoveries before the year 1800. Most of these discoveries and developments were based on common observations about nature, which could be applied for the betterment of human life at that point in time. The developments and discoveries were directed principally to food production. Food, clothing and shelter have remained the most important basic needs of human beings irrespective of whether they lived in the ancient period or the modern period. The only factor that has changed is their types and origins. The ancient ate raw meat, whenever they found a dead animal. However, neither meat nor other foods were available all seasons and in all places at the same time. In those days, food was particularly scarce during harsh weather in some places.

Over time, this led to the domestication of food products, which gave rise to 'agriculture'. In ancient times, humans explored the possibilities of making food available by growing it near their shelters, so that the basic need for food could be met easily. They brought seeds of plants (mostly grains) and planted them near their shelters. They understood the importance of water, light, and other requirements for the optimal growth of food plants. Similar principles and needs also led them to start domestication of different wild animals, which helped them to improve their living conditions and satisfy their hunger. The need to hunt for animal was done away with it, as animals were now available to them at closer proximity, and they did not have to deal with the dangerous conditions of hunting. Domestication of wild animals was the beginning of observation, implications, and applications of animal breeding. Certainly, we can say that this was the initial period of evolution of farming, which led to another needs like the development of methods for food preservation and storage. They used cold caves to preserve food for long-term storage. It also made the way for the evolution of pots to store food products, in the form of leather bags, clay jars, etc.

After domestication of food crops and wild animals, man moved on to experiment on producing food materials from raw food products. Cheese was considered the first direct product made by humans. It was made by an accidental mixture of the stomach of a calf to sour milk. This gave birth to fermentation and it is now known that the product came from the action of rennet (an enzyme found in the calf stomach) on milk. Subsequent discovery of yeast led to further improvements in fermentation technology and gave rise to the making of bread, vinegar production and other fermentation products such as alcoholic beverages like whiskey, wine, beer, etc. Fermentation became a powerful tool to improve their living conditions, even though the ancient people were ignorant about the principle behind it.

Crossbreeding was also experimented in ancient times and the best outcome was the mule. Mule is an offspring of a male donkey and a female horse. Mules were used for transportation, carrying loads and farming. Mule was found to be comparatively easier to obtain than hinny (offspring of a male horse and a female donkey). Later experiments showed that both mule and hinny have a chromosome number 63, compared to horse (64) and donkey (62). Thus, biotechnology was in action long before its principles were understood.

3.1.2 Classical Biotechnology

The second phase of evolution and development of biotechnology can be called classical biotechnology. This phase existed from 1800 to almost the middle of the 20th century. Prior to this period, scientific inventions such as the microscope had made humans aware of the existence of microorganisms and cells setting the stage for the real understanding of the principles of several human activities such as fermentation. Important among discoveries that advanced biotechnology during the classical era was the fact that genetic information can be transferred from one individual/generation to another. This discovery was done by Gregor John Mendel (1822-1884), an Austrian Augustinian monk, based on his study of *Pisum sativum*, commonly known as pea plant. Based on his findings, Mendel proposed the "laws of inheritance," which suggested that invisible internal units of information account for observable traits, and that these 'factors' - later known as genes are passed from one generation to the next. Almost at the same time Robert Brown had discovered nucleus in cells, while in 1868, Fredrich Miescher, a Swiss biologist reported nuclein, a compound that consisted of nucleic acid that he extracted from pus cells i.e., white blood cells (WBC). These two discoveries became the basis of modern molecular biology, for the discovery of DNA as a genetic material, and the role of DNA in transfer of genetic information. 1n 1881, Robert Koch, a German physician described the bacterial colonies

growing on potato slices (first ever solid medium). Walter Hesse, one of the co-workers in Koch's laboratory, discovered agar when he asked his wife what kept the jelly solid even at high temperature of summer. She told him it was agar, since then nutrient agar became the most acceptable and useful medium to obtain pure microbial cultures as well as for their identification. In 1888, Heinrich Wilhelm Gottfried Von Waldeyer-Hartz, a German scientist coined the term 'chromosome', which is considered as an organised structure of DNA and protein present in cells or a single piece of coiled DNA containing many genes, regulatory elements, and other nucleotide sequences. Other important developments and discoveries that paved the way for modern biotechnology during this period were (1) coining of the term "biotechnology" in 1919 by Karl Ereky. (2) The development of vaccines against small pox and rabies by Edward Jenner, a British Physician and Louis Pasteur a French Biologist. (3) Formulation of the theory of the gene in 1926 by Dr. T. H. Morgan, which explained the role of chromosomes in inheritance.

Almost about the same time, in Britain, Alexander Fleming a physician discovered antibiotics, when he observed that one microorganism can be used to kill another microorganism. Fleming noted that all bacteria (Staphylococci) died when a mold was growing in a Petri-dish. Later, he discovered penicillin, the antibacterial toxin from the mold *Penicillium notatum*, which could be used against many infectious diseases. Fleming wrote, "*When I woke up just after dawn on September 28, 1928, I certainly didn't plan to revolutionise all medicine by discovering the world's first antibiotic, or bacteria killer*." Actually, vaccines and antibiotics turned out to be the best saviours of humanity. The two most important discoveries during the classical era that paved the way for modern biotechnology were the existence of genes and chromosomes as well as the ability to use one microorganism against the other.

3.1.3 Modern Biotechnology

The discovery that genes are made up of DNA and can be isolated, copied and manipulated has led to a new era of modern biotechnology. This technological development started after the World War II. In 1953, J.D. Watson and F.H.C. Crick cleared for the first time the mysteries around the DNA as a genetic material. They developed a structural model of DNA, popularly known as Double Helix Model of DNA that explained various phenomena related to DNA replication, and its role in inheritance. This was later followed by the findings of Jacob and Monad who developed the concept of Operon in 1961 and in 1975, Kohler and Milestein completed the knowledge base with the concept of

cytoplasmic hybridisation. This led to the production of world's first ever-monoclonal antibodies, which has revolutionised the diagnostics.

By this time, most of the basic concepts and materials had become available to the world's scientific community. Nearly all that is required to be known about the cell, chromosomes and genes were known and basic tools for manipulating them at molecular levels were evolving on daily basis. The era of gene technology had arrived. Dr. Hargobind Khorana was able to synthesise the DNA in test tube and Karl Mullis amplified DNA thousand times more than the original amount in a test tube. Using this technological advancement, other scientists were able to insert a foreign DNA into another host and were even able to monitor the transfer of a foreign DNA into the next generation. Ian Wilmut, an Irish scientist successfully cloned an adult animal, using sheep as model, and named the cloned sheep 'Dolly'. Cloning can be used in preserving endangered species and reviving extinct species from frozen tissues. Craig Venter, in 2000, was able to sequence the human genome. These discoveries have unlimited implications and applications. Bacteria agents can for example used to remediate oil contaminated sites and knowledge of the human genome may help trace the genetic sources roots of chronic and debilitating diseases. The trend from traditional to modern biotechnology is clearly depicted in Figure 3.1.

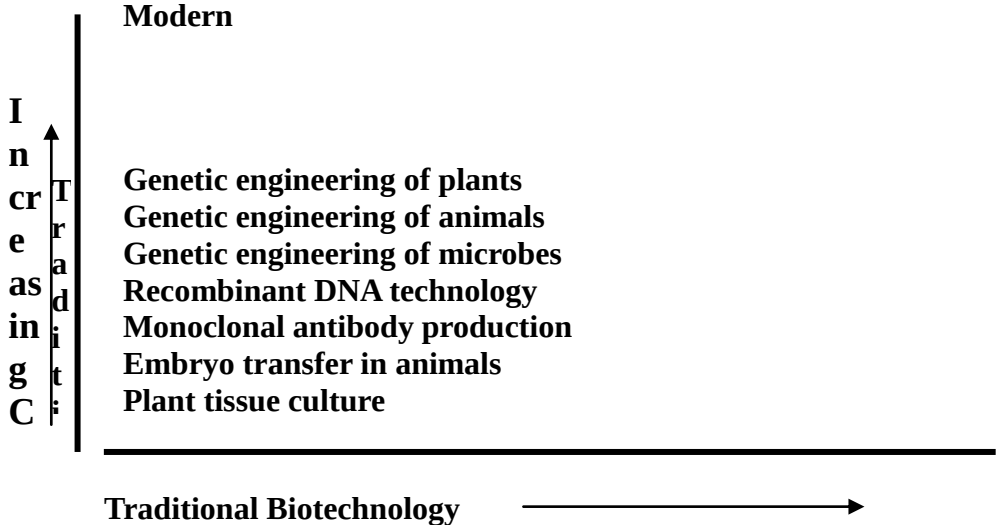

Fig. 3.1: The Trend of Progress from Traditional to Modern Biotechnology (Source: Tajudeen, 2011)

3.2 Application-based Classification

Increasing scientific and industrial activities have given rise to more specialized and diverse uses of biotechnology as a tool of development.

This diversity has in turn brought about the need for a system to classify biotechnology uses based on common features or final purpose. As a result, nowadays there exist five main groups in biotechnological applications, which have been identified by a color system.

3.2.1 Red Biotechnology

Also known as Medical biotechnology, this is a collection of techniques used in the health sector including medicine and pharmacy. Red biotechnology comprises techniques used to produce vaccines and antibiotics, develop new drugs, undertake molecular diagnosis and perform regenerative therapies. The major technique used in this branch is genetic engineering, cloning, genomics and pharmacogenics. Specifically, these techniques make it possible to understand how human body responds to drugs and how to make effective drugs. This is achieved by the application of genetically modified yeasts and bacteria for the production of drugs that would otherwise be impossible to manufacture and manipulation of a patient's genome to cure protracted and difficult diseases. Some other relevant uses of red biotechnology are cell therapy and regenerative medicine, gene therapy, forensics through DNA profiling and production of medicines based on biological molecules such as therapeutic antibodies.

3.2.2 White Biotechnology

Also known as industrial biotechnology, this comprises all the biotechnology uses related to industrial processes. It is the application of biotechnology for industrial purposes, including manufacturing, alternative energy (or "bio-energy") and biomaterials. It includes the practice of using cells from yeast, moulds, bacteria and plants or components of cells like enzymes to generate industrially useful products. Thus, its primary objective is to reduce waste and industrial dependence on fossil fuels. As a result, it pays a special attention to designing low resource-consuming processes and products, making them more energy efficient and less polluting than traditional technologies. There can be found many examples of white biotechnology, such as the use of microorganisms in chemicals production, the design and production of new materials for daily use (plastics, textiles ...) and the development of new sustainable energy sources such as biofuel.

3.2.3 Grey Biotechnology

Grey biotechnology, which is also known as Environmental Biotechnology includes all those applications of biotechnology directly related to the environment. These applications can be split up into two main branches: biotechnology for biodiversity maintenance and

biotechnology for contaminants removal. The first involves application of molecular biology to genetic analysis of populations and species in an environment, their comparison and classification and also cloning techniques aimed at species and genome storage technologies. As for pollutants removal or bio-remediation, grey biotechnology uses microorganisms and plants to isolate and dispose of different substances such as heavy metals and hydrocarbons, with the added possibility of subsequently making use of these substances or by-products from this activity.

3.2.4 Green biotechnology

Also known as Agricultural Biotechnology, this is focused on agriculture as working field. Green biotechnological approaches and applications include creating new plant varieties of agricultural interest, producing biofertilizers and biopesticides, using in vitro cultivation and cloning plants. The first approach is the one to undergo further development and attract the most interest and social controversy. Producing modified plant varieties is based almost exclusively on transgenes is, or introducing genes of interest from another variety or organism into the plant. Three main objectives are pursued by using this technology. First, it is expected to get varieties resistant to pests and diseases -for example, currently used and marketed maize varieties resistant to pests such as corn stalk borer. Secondly, use of transgenic plants is aimed at developing varieties with improved nutritional properties (e.g. higher content of vitamins). Finally, transgenesis in plants is also studied as a means to develop plant varieties able to act as bio-factories and produce substances of medical, biomedical or industrial interest in quantities easy to be isolated and purified.

3.2.5 Blue Biotechnology

This is based on the exploitation of sea resources to create products and applications of industrial interest. Taking into account that the sea presents the greatest biodiversity, there is potentially a huge range of sectors to benefit from the use of this kind of biotechnology. Many products and applications from blue biotechnology are still object of study and research, although some of them are actually used on a daily basis. No doubt using raw materials from the sea represents the most widespread blue biotechnology in many different sectors. These materials, mostly hydrocolloids and gellings are already being widely used in food, health, treatment, etc. Medicine and research are other major beneficiaries of development in blue biotechnology. Some marker molecules from marine organisms are now commonly used in research. Enzymatically active molecules useful in diagnostics and research have also been isolated from marine organisms. Some biomaterials and

pharmacological or regeneratively active agents are being produced or investigated for their use in these sectors. Finally, sectors such as agriculture and cosmetics analyze the potential of blue biotechnology for its future development.

3.2.6 Bioinformatics

This is a union of computer and biotechnology. It assists in rapid organization and analysis of biological and genetic data. It is applied in various areas, like functional genomics, structural genomics, and proteomics for various purposes like drug and molecular medicine development, gene therapy, creation of bio-weapons, improvement in crop plants for nutritional quality, resistance to disease, pest, drought etc.

4.0 CONCLUSION

It has been shown that biotechnology can be classified either in terms of historical developments or areas of application. In terms of historical development, biotechnology is classified into three main classes of ancient, classical and modern biotechnology. Ancient biotechnology include techniques developed and used from prehistoric days up to about 1800 AD, classical biotechnology include those emerging from 1800 AD to the end of the World War II, while modern biotechnology are those methods developed since the World War II. In terms of application, it has been shown that biotechnology can be classified into six classes identified by different colours. These include red (medical and pharmaceutical) biotechnology, white (industrial) biotechnology, grey (environmental) biotechnology, green (agricultural) biotechnology, blue (marine) biotechnology and bioinformation (computer-based) biotechnology.

5.0 SUMMARY

In this unit, you have been acquainted with the various branches of biotechnology. You have learnt that biotechnology is classified according to the historical developments or areas of application. There are three major historical classes of ancient (prehistoric era to 1800), classical (1800 to end of World War II) and modern (end of World War II to date). In the next unit, you will learn about the scope of environmental biotechnology.

6.0 TUTOR-MARKED ASSIGNMENT

1. Outline and briefly explain the branches of biotechnology in relation to their application in modern times.

2. Discuss the major discoveries in the ancient, classical and modern era that have led to the development of biotechnology.
3. Briefly describe five discoveries associated with the classical age of biotechnology.
4. Discuss the importance of gene discovery to modern biotechnology.

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UNIT 4 SCOPE OF ENVIRONMENTAL BIOTECHNOLOGY

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt that there are six branches of biotechnology and that environmental biotechnology also known as grey biotechnology is just one of the branches. In this unit, we will learn about the scope of environmental biotechnology, i.e. the various activities that affect the environment where biotechnology has a potential role-play for the achievement of sustainable optimal utilisation.

2.0 OBJECTIVES

At the end of this Unit, you will be able to:

- explain what is environmental monitoring
- describe the various aspects of waste management
- describe the principles of bio-remediation
- explain the term bio-energy.

3.0 MAIN CONTENT

3.1 Environmental Monitoring

3.1.1 Definition of Environmental Monitoring

Environmental monitoring is the procedure used to ascertain the level of toxins, chemical pollutants, microbial contaminants including parasites, or other harmful substances in the environment or workplace by measuring the amounts of these toxicants, pollutants and pathogens in our surroundings including the bodies of people and animals, water bodies, air, soil and other objects in that environment. It also includes the measurement of environmental exposure and degree of susceptibility of animal and plant species. All monitoring strategies and programmes aim at establishing the status of an environment or establish trends in environmental parameters. The design of a monitoring programme must therefore have regard to the final use of the data before monitoring starts. Levels in humans and animals are used as indicators of toxicity of undesirable pollutants and pathogens.

3.1.2 Environmental Monitoring System

This is the system designed for environmental monitoring. The particular system chosen for any environmental monitoring depends on the defined objectives of monitoring, the media of interest and suspected pollutants/contaminants in the environment. The overall objectives of any environmental monitoring are to describe the state of the environment and identify new issues with a view to forecasting probable future trends. The specific objectives will be to determine the current state of the environment, assess seasonal threats to the environment and to human health, provide probable inputs for remedial actions and/or monitor progress on actions decided.

The success and effectiveness of an environmental monitoring activity depends on the choice of environmental indicators. Where appropriate indicators were used, the outcome is reliable and the entire exercise is said to be successful. Where inappropriate indicators were used, however, the outcome is unreliable and the exercise is a failure. The choice of environmental monitoring indicators depends largely on the medium to monitor and the objectives of the exercise. For instance, one may want to determine the ‘state of the environment’ in a given water body or air quality in a defined location. The former will require the use of water quality parameters while the latter will demand air quality parameters. Irrespective of which medium or objective is involved,

traditional environmental indicators are physical, chemical, biological and/or socio-economic in nature as shown in Table 1.

Table 1b: Outline of Environmental Indicators Appropriate for different Objectives in different Environmental Domains

Environmental Domain	Monitoring Specific Objective	Environmental Indicators
Air	Air quality assessment	Particulate matter ($PM_{2.5}$, PM_{10} micrometers), nitrogen dioxide, carbon monoxide, sulphur dioxide, benzene, total suspended particulate, lead, pathogenic air borne microorganisms
Atmosphere	Greenhouse gas assessment	Carbon dioxide, methane, nitrous oxide, sulhur hexafluoride, hydrofluorocarbons, perfluorocarbons
	Ozone layer depletion	Stratospheric ozone
Fresh water	River water quality assessment (RWQA)	Nutrients (nitrates, phosphates, sulphates etc.), metals, acidifying compounds, heavy metals, dissolved oxygen, biological oxygen demand, chemical oxygen demand, organic matter, pathogenic microorganisms especially faecal bacteria, macroinvertebrates especially parasites
	Lake water quality assessment	Same as RWQA with emphasis on total nitrogen, total phosphorus, transparency, algal biomass
	Groundwater quality assessment	Same as RWQA with emphasis on nitrate, bacteria
Sea water/Ocean	Quality assessment	Same as RWQA with emphasis on bacteria concentration
	Inland water intrusion	Salinity parameters
	Natural resource base	Fishing and fish stocks
Land	Biodiversity	Forest cover, deforestation and desertification rates. Number

		per area of indicator species including indicators of extinction.
	Land use	Status of indicators of land use (arable cropping, mixed cropping, drystock pasture, dairy pasture, tussock grasslands, exotic forestry, native forestry etc.) and land use cover classes e.g. animal husbandry, grazing patterns, urban space, primary and secondary forest covers, vegetation cover etc.
	Soil health	Status of physical, chemical and biological soil properties e.g. total carbon content, total nitrogen content, pH, phosphate etc
	Erosion risks	Land gradient/slope to enable classification of erosion risk into severe, very severe and extremely severe.

3.2 Waste Management

According to the Basel Convention, waste is defined as substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of the law. Waste is therefore known by several terms such as rubbish, trash, refuse, garbage, junk or litter that clearly suggest they are unwanted and useless. In reality, however, the term 'waste' is a subjective term true only to a specific individual, time and place. This is because what is waste to a person, at a given time or place could be a valuable resource to another person at another time or place. There are many methods for waste management, some existing over a long period of time, others emerging. The choice of a technique at any given time depends on several factors including type of waste involved, cost of management options and available technology, personnel and infrastructure required by each technique. The available methods can broadly be divided into two categories, namely traditional and emerging methods. The traditional methods include indiscriminate disposal, open burning, composting, sanitary landfill and incineration while the emerging methods include those methods that lead to waste recycling, source reduction and bio-remediation of contaminated sites.

3.2.1 Types and Classification of Wastes

Waste is classified using several criteria. On the basis of state, waste could appear in the form of gas, liquid or solid while on the basis of fate, it could be bio-degradable or non bio-degradable. Biodegradable waste is further divided into compostable (materials that are easily broken down to smaller substances by the action of microorganisms such as bacteria e.g. food substances) and combustable (materials though could be broken down, the process of bacterial activity is very slow for which reason it is often preferable to burn them e.g. wood). Non bio-degradable materials on the other hand are substances that cannot easily be broken down by bacterial activities. These are divided into recyclable (materials that can be reprocessed using existing technologies at an economic cost, e.g. metals, plastics) and non recyclable (materials that cannot be reprocessed at any economic cost by available technologies, e.g. concrete). Waste is also classified on the basis of risk they pose to health into hazardous and non hazardous waste. Hazardous wastes are potentially dangerous and pose great threats to public health or the environment. Waste is classified hazardous on the basis of its ignitability (i.e. flammable with a flash point less than 60° C), reactivity (unstable, generates toxic or explosive gases and / or liquids when in other substances), corrosivity (pH <2 or >12.5) and / or toxicity (contain contaminants that are harmful to human health and the environment). Examples include inflammable petroleum products, infectious waste, pathological waste, sharp objects, pharmaceutical waste, genotoxic waste, chemical waste, heavy metals, pressurized, containers, radioactive waste and thousands of specific substances listed by the US Environmental Protection Agency as hazardous substances under different codes. Non hazardous waste includes all other wastes not classified as hazardous irrespective of source. Examples include most degradable municipal waste.

3.2.2 Sources of Waste

There are several sources of waste. Prominent among these sources are homes, markets, farms, industrial production, oil prospecting etc. On the basis of source; waste is classified into municipal, industrial or agricultural, hospital etc. The major sources of municipal waste are residential, commercial, institutional, construction and municipal services. Residential waste, also known as household waste, is generated in homes by various processes. Examples include human waste (faeces and urine, etc.), food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, electrical and electronics, batteries, oil, hazardous chemicals, combustion waste,

waste water, sewage etc. Commercial waste originates from stores, hotels and restaurants, pharmacy shops, markets and office buildings in commercial centres. Examples include human waste, paper, plastics, wood, food wastes, glass, metals, e-waste, etc. some of which are hazardous.

Institutional wastes come from schools, hospitals, prisons and other government and corporate establishment premises. Examples are similar to commercial waste. Construction wastes are generated by construction, road repair, renovation, demolition activities. Examples are wood, steel, cement, concrete, dirt etc. Municipal services wastes are generated in parks, beaches, street cleaning, landscaping, public latrines, and transportation, water and wastewater treatment plants. Examples include human waste; paper, vegetables, glass, plastics, electrical and electronic rejects, sludge, CO, gaseous pollutants, & used motor oil etc. Industrial waste are waste from various industrial activities such as light and heavy manufacturing, fabrication, construction, power and chemical plants, petroleum and petrochemicals production and refining. Examples are human waste, housekeeping wastes, packaging (paper, plastics, glass etc.), food wastes, construction and demolition materials, wastewaters, excess heat, hazardous and non hazardous chemicals, solvents and other materials, ashes, gaseous waste and noise. Agricultural wastes are by-products of agricultural processes including farming, fishing, feedlot and animal husbandry, dairy etc. Examples include spoilt food items, agricultural process wastes, hazardous wastes (e.g. pesticides, fertilizers), animal dung, run-off from feedlot operations, crop residues & animal carcasses. An emerging type of solid waste that is fast assuming disturbing proportions is the electronic waste commonly known as e-waste. Major sources of e-waste are; equipment such as sodium lamps, fluorescent tubes, VCR/DVD/CD players, drills, lawn mowers, electric saws, coin slot machines, computers, television, radio etc. These e-products are manufactured with heavy metals and toxic chemicals that pose great threats to the environment and human health.

3.2.3 Health and Environmental Impact of Waste

The health and environmental impacts of waste can be derived from knowledge gained from the preceding discussion on wastes and waste management. Generally, the health and environmental impacts of waste depends on the characteristics and management of the waste. The characteristics of waste determine whether it should be corrosive, toxic, radioactive, smelly, reactive or ignitable while management method determines human and animal exposure patterns (i.e. degree of contact with human beings and animals). Corrosive, toxic, radioactive, reactive or ignitable wastes are hazardous and the higher the degree of exposure,

the more the likelihood of adverse effect on human health. Humans are exposed to wastes of different forms; gas, liquid and solid. While he solid waste and liquid waste are visible, most gaseous waste are not, but in many cases more dangerous. Furthermore, solid waste treatment in the form of open burning, incineration and to some extent composting and land-filling, only change the state of waste from solid to gas or liquid. In the gaseous state, it is emitted into the air polluting the atmosphere while in liquid form; it leaches the ground polluting ground water. Either way, it becomes more widespread, less concentrated and more exposed to humans. In particular, waste burning gives rise to particulate of different sizes, most common of which are $PM_{2.5}$ and PM_{10}. The exact composition of emissions or leachate will vary with what waste is being burnt at any given time, the efficiency of the installation and the pollution control measures in place. A municipal waste incinerator sometimes contains a great variety of waste contaminated by heavy metals and man-made organic chemicals. During incineration these waste may transform into more toxic forms, thus, posing a greater danger. . The three most important constituents of emissions, in terms of health effects, are particulates, heavy metals and combustion products of man-made chemicals. The most important of these chemical products of combustion include sulphur dioxide, oxides of nitrogen, over a hundred volatile organic compounds (VOCs), dioxins, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and furans.

Health impacts of waste are exposure- related and usually associated with occupational accidents. Persons involved with the collection, loading and transport of waste are often most vulnerable. Transport of waste (often done using highly polluting trucks) is also an important (and often neglected) cause of exposure to air pollution. People living close to waste dumps are also exposed to the same level of risk as waste collectors. Impacts from landfills and incinerators are low where there is strict legislation and enforcement on emissions, but where this does not exist as in Nigeria, both landfills and mechanical-biological treatment plants give rise to a considerable impact in the form of respiratory symptoms and odour annoyance. Findings of several other studies present conflicting results. While some suggest significant associations between waste pollutants and lower male-to-female ratio, twinning, lung cancer, laryngeal cancer, ischemic heart disease, urinary mutagens and promutagens, or blood levels of certain organic compounds and heavy metals, others studies on the other hand, found no significant effects on respiratory symptoms, pulmonary function, twinning, cleft lip and palate, lung cancer, laryngeal cancer and oesophageal cancer. These results are clear indication that further studies are required to clearly identify the health effects of waste and waste management.

3.3 Pest and Disease Control

Pests and diseases are part of the natural environmental system. In this system there is a balance between predators and pests, there is health and illness and ultimately life and death. These are the nature's way of controlling populations. Predators prey on pests and other organisms and pests inflict sickness and adverse effects on predators and other organisms. Humans are predators that feed on pests and other organisms while pests cause diseases to man and his domestic animals and cause injuries to crops. The creatures that we call pests and the organisms that cause disease only become 'pest' and 'diseases causing agents' when their activities start to damage crops, affect yields and damage our health. If the process continues unabated, the pest will dominate, but if the predators succeed in eliminating the pests, predators will predominate the environment. The natural environmental system is said to be imbalanced because one population can become dominant over the other. The aim of natural control is, therefore, to ensure a balance between pest and predator and to keep pests and diseases down to an acceptable level, rarely to eradicate them altogether, as they also have a role to play in the natural ecosystem. The major environmental diseases which are of interest to environmental health practitioners are those diseases transmitted within the environment. They include diseases caused by chemical pollutants from wastes and other sources as well as biological diseases transmitted in various environmental media, namely air, soil and water. They include water borne, water washed, water based, water related vector-borne, soil transmitted and air borne diseases. They also include other diseases and injuries contracted directly or indirectly from the environment as a result of poor environmental conditions. The major diseases include but not limited to Acute encephalitis, Acute poliomyelitis, Anthrax, Cholera, Diphtheria, Dysentery, Food poisoning, Leptospirosis, Malaria, Measles, Meningitis, Meningococcal septicaemia (without meningitis), Mumps, Ophthalmia neonatorum, Paratyphoid fever, Plague, Rabies, Relapsing fever, Rubella, Scarlet fever, Smallpox, Tetanus, Tuberculosis, Typhoid fever, Typhus fever, Viral haemorrhagic fever, Viral hepatitis (Hepatitis A Hepatitis B and Hepatitis C), Whooping cough, Yellow fever, Chagas' disease, dengue, human African trypanosomiasis, leishmaniasis, lymphatic filariasis, malaria, onchocerciasis, schistosomiasis etc.

3.4 Bio-remediation

Bio-remediation can be defined as any process that uses microorganisms or their enzymes to amend a contaminated environment, i.e. return the

environment altered by contaminants to its original condition. The method uses microorganism metabolism to remove pollutants. Bio-remediation can be classified in various ways depending on the source of microorganisms, site of treatment or nature of the bio-remediator. On the basis of source of micro-remediators (i.e. microbes for remediation), there are 'intrinsic bio-remediation' or 'extrinsic bio-remediation'. It is intrinsic when microorganisms are derived from the site of remediation and extrinsic when they are brought from other sites. Bio-stimulation occurs when fertilizers are added to increase the bioavailability of resident microorganisms within the medium whether intrinsic or extrinsic. Recent advancements have made extrinsic bio-remediation increasingly successful by providing better matched microbe strains to the medium to enhance the resident microbe population's ability to break down contaminants. On the basis of site of treatment, bio-remediation is classified as in situ or ex situ. In situ bio-remediation involves treating contaminated material at the site of contamination, while ex situ involves the removal of contaminated material to be treated elsewhere. On the basis of nature of bio-remediators, bio-remediation is classified as phyto-remediation (treatment of environmental contamination through the use of plant species that mitigate the environmental problem without the need to excavate the contaminant material and dispose of it elsewhere), bio-venting (an in situ remediation technology that uses microorganisms to biodegrade organic constituents adsorbed in the groundwater), bioleaching (use of microorganisms to extract metals from their ores), land farming (a process that involves periodic turning over (tilting) of the top soil to aerate by mixes, bioreactors (any manufactured or engineered device, facility or system that supports a biologically active environment, e.g. a vessel (commonly cylindrical in shape, ranging in size from litres to cubic metres and often made of stainless steel) in which a chemical process involving organisms or biochemically active substances derived from such organisms takes place. This process can either be aerobic or anaerobic, compost (organic matter that has been decomposed and recycled as a fertilizer and soil amendment, a key ingredient in organic farming), bio-augmentation (an introduction of a group of natural microbial strains or a genetically engineered variant to treat contaminated soil or water). The principle is to study the indigenous varieties present in the location to determine if bio-stimulation is possible. If the indigenous variety do not have the metabolic capability to perform the remediation process, exogenous varieties with such sophisticated pathways are introduced. Bio-augmentation is commonly used in municipal wastewater treatment to restart activated sludge bioreactors. The common microbes involved in bio-augumentation include *Bacillus lichenformis, B. thurengensis, B. sterothemophilus, Penicillium spp., P. polymyxa, Aspergillus sp., Flavobacterium, Arthrobacter, Pseudomonas, Streptomyces, Saccaromyces,*

*Triphoderm*a, etc.). Activated sludge systems are generally based on the activities of microorganisms like bacteria, protozoa, nematodes, rotifers and fungi that are capable of degrading biodegradable organic matters.

3.5 Bio-energy

This is the energy stored in biomass (organic matter). Biomass has been a source of energy for several centuries. The use of firewood and charcoals for domestic energy production is not new or strange to anyone. However, the advent of biotechnology is fast devising new sources of bio-energy (especially, recycling of biomass wastes for energy production), to complement or replace fossil fuel for industrial production and other areas of energy use. It is expected that such innovation will make it possible to use bio-energy to provide heat, make fuels, and generate electricity. The various types of bio-energy are:

Bio-power is the use of one or more types of biomass energy to produce electricity.

- Bio-heat refers to the use of biomass energy to produce heat.
- Bio-fuels are fuels (often for transportation) made from biomass or its derivatives after processing. Examples of commercially available bio-fuels include ethanol, biodiesel and renewable diesel.
- Bio-products are commercial or industrial products (other than food or feed) that are composed in whole or in significant part of biomass. Examples of bio-products include soy ink, cellophane, food utensils, and paints made from biomass-based materials.

4.0 CONCLUSION

Environmental biotechnology deals with environmental monitoring, waste management, renewable energy production and remediation of contaminated sites. Environmental monitoring involves setting of appropriate objectives for effective and timely detection of different environmental pollutants in the different parts of the environment using appropriate indicators. For example, indicators for the assessment of air quality were identified as particulate matters of varying sizes, green house gases and air borne pathogens. For water quality assessment, appropriate indicators include heavy metal, nutrient concentrations and water borne pathogens. Apart from knowing the types and sources waste, it is also important to understand its pattern and means of generation and disposal. This helps to determine how best to manage waste to minimise its adverse environmental consequences.

5.0 SUMMARY

In this unit, you have learnt that scope of environmental biotechnology covers environmental monitoring, waste management, environmental management especially the use to bio-remediation to restore polluted environment. You have also learnt that waste management involves a good knowledge of what is waste and its various types and sources. We outlined the various waste management options and their relative contributions to environmental contamination.

We have particularly shown that involve the application of microorganisms are the most cost-effective and the most environmentally friendly. In the next unit, you will be acquainted with the various methods for achieving most environmentally sound cost-effective waste management. We also described the emerging technologies in bio-remediation, which is the application of living organisms or substances derived from them in restoring the original integrity of contaminated environment.

In this light, it was shown that the different types of bio-remediation depend on the sources of bio-remediators.

Finally, we showed that environmental biotechnology also deals with safe and clean energy production. This involves bio-energy production from biomass. Bio-energy was defined as the process of energy production using living organisms or their derivatives. The major bio-energy available were identified as bio-power (bio-energy for electricity production), bio-fuel (bio-energy for powering transport facilities) and bio-productions which are products other than food, made using living organisms or substances derived from them.

6.0 TUTOR-MARKED ASSIGNMENT

1 Describe the importance of environmental monitoring
2. List the objectives of environmental monitoring programme
3. Describe three major contributions of environmental biotechnology to environmental health
4. Briefly explain the terms:
   a. Bio-stimulation, b. Micro-remediator c. Intrinsic and extrinsic bio-remediation, d. Bio-venting, e. Bio-leaching, f. Bio-augmentation.

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MODULE 2 METHODS IN BIOTECHNOLOGY

UNIT 1 CONCEPT AND DEFINITION OF METHODS

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt about the scope of environmental biotechnology. Specifically, you learnt that environmental biotechnology involved the application of living organisms or substances derived from them in environmental monitoring and management. In this unit, you will know what constitutes a method, how to identify a good method for a given process and how to modify or adapt an existing method to meet new challenges.

2.0 OBJECTIVES

At the end of this Unit, you will be able to:

- explain what is a method
- describe what constitutes an appropriate method for a process
- describe how existing methods can be modified or adapted for a new process
- outline the various methods used in environmental biotechnology.

3.0 MAIN CONTENT

3.1 What is a Method

We are all aware that each time we need to do something, either bake a cake, solve a mathematical problem or prepare a pot of soup, the first question you must ask is "how do I do it"? Or, "how can I solve this problem?" The search for how to tackle a task is the search for a method of how to solve a problem. That is, ability to solve a problem depends on our knowledge of the method for solving that problem. Method has therefore been defined as a procedure for accomplishing or approaching a task, especially a systematic or established procedure, or a step by step process used to achieve a desired goal. A method can be either a physical or a mental process: physical as in reading of the concentration of dissolved metal in a sample using an atomic absorption

spectrophotometer (AAS) and mental as in making decisions, finding the answers to questions or solving problems in an established manner. The later suggests that methods could be overwhelming and involve all processes in problem solving including hypothesis formulation, data collection, analysis, interpretation and decision-making. An effective method is, therefore, made up of "critical parts," i.e. separate steps that must all be addressed and re- addressed effectively for the method to be successful. A method can also be scientific or non-scientific. A scientific method is a body of techniques for investigating phenomena, acquiring new knowledge or correcting and integrating previous knowledge. This means that it must be based on empirical and measurable evidence subject to specific principles of reasoning. Other characteristic of a scientific method that distinguishes it from other methods is that it must be objective and reproducible.

There are four established elements of a scientific method. These are characterisation (ability to identify properties of a subject matter and use them to identify and describe the subject matter); definition (most acceptable units for describing a subject matter both by nature and degree); hypothesis development (alternative options of a given condition which may determine the plausibility of a method) and experiment (tests carried out to test the plausibility of hypothesis or predictions). If the test-results contradict the predictions, the hypotheses which made them are called into question and become less tenable. If, however, the results confirm the predictions, then the hypotheses are considered more likely to be correct.

3.2 Identifying Right Methods for a Process

Identifying the right method for a task involves first identifying available methods and determining that which most effectively meets the goals of a particular study. This means that since there may be many goals of a study the choice of the right method or methods may depend on many factors. Since these factors may interact in a complex way, choosing the best method is often not as easy as it might seem. As a result the following steps may be required to be followed:

- List the research goals
- Identify potential methods that *might* effectively achieve those goals
- Test the ability of each method to achieve each goal.

Then choose the methods that did the best job of achieving the goals. The process may involve a consideration of accuracy (closeness of a test result to the true value), precision (closeness to each other of repeated measurement of the same or comparable quantity (ies) and cost.

Precision is inversely related to standard error. When the standard error is small, sample estimates are more precise; when the standard error is large, sample estimates are less precise. Cost is a very important factor in choosing a method. Available resources must be able to sustain a chosen method to the end of experimentation if not the entire process will be a failure. Availability of expertise and relevant materials and equipment must also be taken into consideration in choosing a method. There is no gain choosing a method for which the materials, equipment and expertise are not readily available. This also includes spare parts for repairs and maintenance. Where any or all of these are not readily available the entire process is bound to failure, and it may have been better to choose a less than best methods which satisfied most other conditions.

4.0 CONCLUSION

A method is a procedure for accomplishing or approaching a task, especially a systematic or established procedure, or a step by step process used to achieve a desired goal. Methods therefore vary according to the goal of an investigation. The goal of an investigation therefore determines the best method to be chosen from a list of several possible methods that may be available for performing a task.

5.0 SUMMARY

In this unit, you have been acquainted with what is a method and conditions for choosing a method for performing a specific task. You learnt that a method is a step by step process used to achieve a desired goal. The choice of a good method depends on the goal or objectives of a study and that because there might be several objectives in a single study; the choice of the best method is always a complex process. The process involves a listing of the goals of a study, identifying all possible methods for each goal and selecting the best method based on the ability of each method to achieve a given goal. In the next unit, we shall identify the various methods used in environmental biotechnology and the conditions for choosing each.

6.0 TUTOR-MARKED ASSIGNMENT

1. What do you understand by the term method.
2. List the processes involve in problem solving.
3. Differentiate between the scientific and non scientific method of approach.
4. Briefly describe the elements of a scientific method.
5. What are the factors to be considered in choosing a method.

6. Explain the conditions under which you may not choose the best method.

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UNIT 2 METHODS USED IN ENVIRONMENTAL BIOTECHNOLOGY

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt that a method is a procedure for accomplishing or approaching a task, i.e. a step by step process used to achieve a desired goal. In this unit, we shall identify the various methods used in biotechnology in general and environmental biotechnology in particular. Specifically, you will be acquainted with the trend of available methods and their improvement from the ancient traditional methods to the highly sophisticated methods that we have today. Efforts will be made to show the techniques of each method, as well as their advantages and disadvantages over the traditional methods, if any.

2.0 OBJECTIVES

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

- explain what constitutes traditional and modern methods
- describe the various traditional methods used in environmental biotechnology
- describe the various modern methods in environmental biotechnology.

3.0 MAIN CONTENT

3.1 Traditional Biotechnology Methods

The several methods used in biotechnology are generally divided into two major sectors, traditional and modern. The traditional methods comprise those methods that have been used since the ancient days and are generally based on the use of whole-organisms. On the other hand, modern methods include those that use either parts of organisms or substances made from organisms. Typical examples of traditional methods are fermentation, nitrogen fixation and tissue culture, while the modern methods are gene and molecular based methods.

3.1.1 Microbial Fermentation

Fermentation involves the breaking down of complex organic substances into simpler ones by the activities of microorganisms. In the process energy is released. The energy is utilized by the microorganisms in the anaerobic environment or cells in the body of organisms as their source of energy. Biochemically, fermentation is a process of oxidation of an organic compound by electron release. The electron is taken up by an electron acceptor which could also be an organic compound. A typical example is the glycolysis (splitting of a sugar molecule and removing electrons from the molecule) of glucose to produce two molecules of pyruvate (a salt or ester of pyruvic acid). The pyruvate is metabolized to various compounds, the nature of which determines the type of fermentation involved. In homolactic fermentation, lactic acid is produced from pyruvate; in alcoholic fermentation ethanol and carbon dioxide are produced and in heterolactic fermentation lactic acid as well as other acids and alcohols are produced.

Homolactic (Lactic Acid) Fermentation

During lactic acid fermentation, the electrons released during glycolysis are passed to pyruvic acid to form two molecules of lactic acid. Lactic acid fermentation is carried out by many bacteria, most notably by the lactic acid bacteria used in the production of yogurt, cheese, sauerkraut, and pickles. Some animal cells such as muscle cells can also use fermentation for a quick burst of energy.

Alcohol Fermentation

Alcohol fermentation also begins with glycolysis to produce two molecules of pyruvic acid, two molecules of ATP, and four electrons. Each pyruvic acid is modified to acetaldehyde and CO_2. Two molecules

of ethyl alcohol are formed when each acetaldehyde molecule accepts two electrons. Alcohol fermentation is carried out by many bacteria and yeasts.

Fermentation does not necessarily have to be carried out in an anaerobic environment. For example, even in the presence of abundant oxygen, yeast cells greatly prefer fermentation to oxidative phosporylation, as long as sugars are readily available for consumption (a phenomenon known as the Crabtree effect). Microbes for fermentation have from the ancient days been naturally occurring microbes. In the beginning, the microbes were resident in the media of interest only activated by the presence of sugars and other organic compounds. In recent times, technologies have evolved to culture the microbes and transfer them to substrates of interest at a concentration commensurate with the expected rate of fermentation. This is the basis of industrial fermentation. Industrial fermentation is therefore defined as the intentional use of microorganisms such as bacteria and fungi to make products useful to humans and clean the environment. Industrial fermentation now uses both naturally occurring microbes that produce desired chemicals and engineered microbes to enhance production of these chemicals (see Tables 6.1 and 6.2).

Table 6.1: Fermentations by Naturally-Occurring Organisms

PRODUCT	**APPLICATION**	**ORGANISM**
Bacitracin	Antiobiotic	*Bacillus subtilis* (bacterium)
Chloramphenicol	Antiobiotic	*Streptomyces venezuelae* (bacterium)
Citric acid	Food flavoring	*Aspergillus niger* (fungus)
Erythromycin	Antibiotic	*Streptomyces erythaeus* (bacterium)
Invertase	Candy	*Saccharomyces cerevisiae* (fungi)
Lactase	Digestive aid	*Escherichia coli* (bacterium)
Neomycin	Antibiotic	*Streptomyces fradiae* (bacterium)
Pectinase	Fruit juice	*Aspergillus niger* (fungus)
Penicillin	Antibiotic	*Penicillium notatum* (fungus)
Riboflavin	Vitamin	*Ashbya gossypii* (fungus)
Streptomycin	Antibiotic	*Streptomyces griseus* (bacterium)
Subtilisins	Laundry detergent	*Bacillus subtilis* (bacterium)
Tetracycline	Antibiotic	*Streptomyces aureofaciens* (bacterium)

Table 6.2: Fermentations by Genetically- Engineered Organisms

Product	Application	Organism
B. growth hormone	Milk production(cows)	*Escherichia coli (E. coli)*
Cellulase	Cellulose	*E. coli*
H. growth hormone	Growth deficiencies	*E.coli*
Human insulin	Diabetics	*E. coli*
Monoclonal antibodies	Therapeutics	Mammalian cell culture
Ice-minus	Prevents ice on plants	*Pseudomonas syringae*
Sno-max	Makes snow	*Pseudomonas syringae*
t-PA	Blood clots	Mammalian cell culture
Tumor necrosis factor	Dissolves tumor cells	*E.coli*

B.=bovine
H.=human
t-PA=Tissue plasminogen activator
(From Case, < http://www.accessexcellence.org/LC/SS/ferm_background.php>)
21/8/12

3.1.2 Biological Nitrogen Fixation

Nitrogen is a critical limiting element for plant growth and production. It is a major component of chlorophyll, the most important pigment needed for photosynthesis, as well as amino acids, the key building blocks of proteins. It is also found in other important biomolecules, such as ATP and nucleic acids. Even though it is one of the most abundant elements (predominately in the form of nitrogen gas (N_2) in the Earth's atmosphere), plants can only utilise reduced forms of this element. Plants acquire these forms of "combined" nitrogen by: 1) the addition of ammonia and/or nitrate fertilizer (from the Haber-Bosch process) or manure to soil, 2) the release of these compounds during organic matter decomposition, 3) the conversion of atmospheric nitrogen into the compounds by natural processes, such as lightning, and 4) biological nitrogen fixation. We will concentrate on biological nitrogen fixation.

Biological nitrogen fixation (BNF), discovered by Beijerinck in 1901 is carried out by a specialized group of prokaryotes. These organisms utilize the enzyme nitrogenase to catalyze the conversion of atmospheric nitrogen (N_2) to ammonia (NH_3). These prokaryotes include aquatic organisms, such as cyanobacteria, free-living soil bacteria, such as *Azotobacter*, bacteria that form associative relationships with plants, such as *Azospirillum*, and most importantly, bacteria, such as *Rhizobium*

and *Bradyrhizobium*, that form symbioses with legumes and other plants (see Figure 6.1).

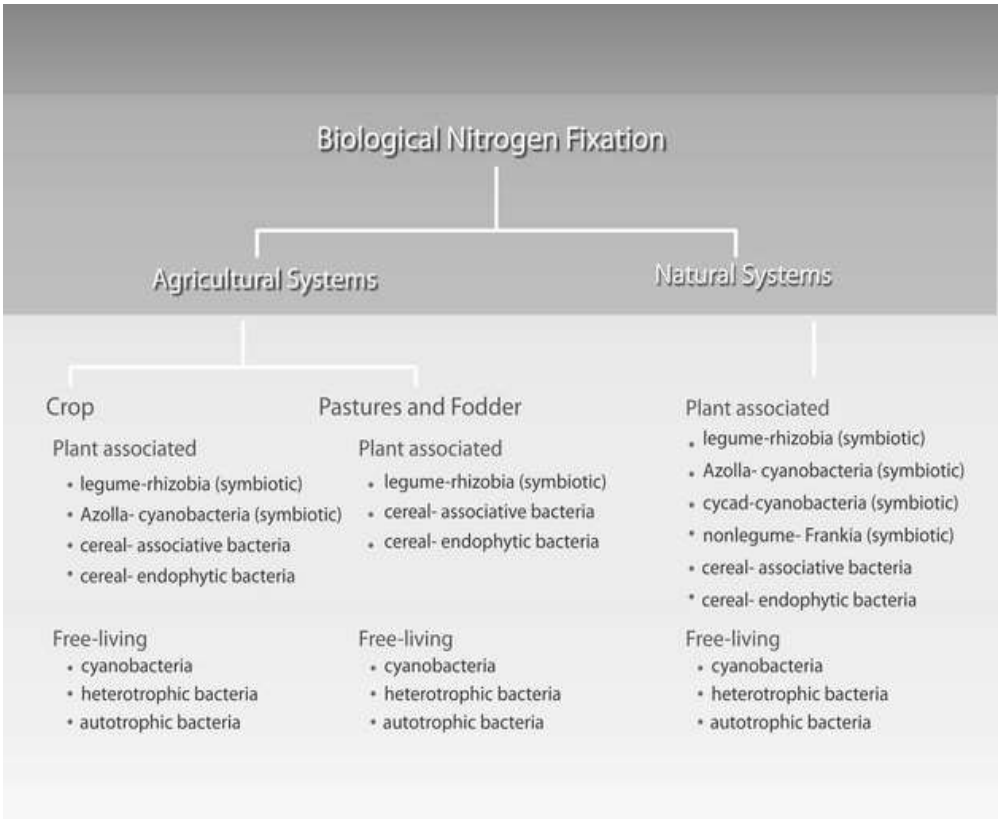


Fig: 6.1: Nitrogen-fixing Organisms Found in Agriculture and Natural Systems (source: http://staging-www.nature.com/scitable/content/nitrogen-fixing-organisms-found-in-agricultural-and-23811335)

The process involves a reduction of atmospheric nitrogen in the presence of nitrogenase which catalyses the breaking of covalent bonds and the addition of three hydrogen atoms to each nitrogen atom. This process requires a large input of energy obtained by the oxidation of organic molecules. Non-photosynthetic free-living microorganisms obtain these molecules from other organisms, while photosynthetic microorganisms, such as cyanobacteria, use sugars produced by photosynthesis. Associative and symbiotic nitrogen-fixing microorganisms obtain these compounds from their host plants' rhizospheres. Nitrogen-fixing bacteria such as *Azotobacter*, *Bacillus*, *Clostridium*, and *Klebsiella* obtain their own source of energy, typically by oxidising organic molecules released by other organisms or from decomposition. There are some free-living organisms that have chemolithotrophic capabilities and can thereby use inorganic compounds as a source of energy (Table 2.2).

The principle of nitrogen fixation has been applied in the manufacture of synthetic fertilizer, which is used worldwide. Artificial fertilizer production is now the largest source of human-produced fixed nitrogen in the environment. Ammonia is a required precursor to fertilizers, explosives and other products. The most common method is the Haber process. The Haber process requires high pressures (around 200 atm) and high temperatures (at least 400 °C), routine conditions for industrial catalysis. This highly efficient process uses natural gas as a hydrogen source and air as a nitrogen source. However, the amount of energy involved is a concern and efforts are ongoing to reduce it to acceptable level or even replace the direct use of heat with a catalyst. The rate of biological nitrogen fixation is complicated by edaphic, climatic and management factors. A legume-*Rhizobium* symbiosis might perform well in a loamy soil but not in a sandy soil, in the sub humid region but not in the Sahel, or under tillage but not in no-till plots. These factors affect the microsymbiont, the host-plant, or both.

Table 1: Well-studied Free-living Nitrogen-fixing Bacteria

Species	**Super family**	**Aerobic-Anaerobic Ae-Ana**	**Characteristics**
Clostridium pasteurianum	Firmibacteria(Low GC GRAM positive)	Ana	Isolated first (1893) • Acell free-extract. nitrogenase was first made (1962)
Klebsiella pneumoniae	Proteobacteria-gamma	Ana	Close to E.coli. Genetics was first studied
Klebsiella oxytoca	Proteobacteria-gamma	Ana	Isolated from rice root in Japan
Bacillus polymyxa	Firmibacteria (Low GC GRAM positive)	Ae	GRAM-positive bacteria
Azotobacter chroococcum	Proteobacteria-gamma	Ae	Azotobacter was isolated next.(1901). Widely used for research
Az. vinelandii	Proteobacteria-gamma	Ae	
Azospirilium brazilense	Proteobacteria- alfa	Ae	Isolated from rhizosphere of C4-plant. Widely studied as

			rhizosphere bacteria
Azospirillum lipoferum	Proteobacteria- alfa	Ae	Widely studied as rhizosphere bacteria
Rhodopspirillum rubrum	Proteobacteria- alfa	Ana	Non-S-photosynthetic bacteria. Active in H_2 production
Rhodobacter capsulatus	Proteobacteria- alfa	Ana	Non-S-photosynthetic bacteria. Active in H_2 production
Azoarcus sp.	Proteobacteria- beta	Ae	Isolated from salt-tolerant plant. Enter into root tissue
Acetobacter diazotrophicus	Proteobacteria- alfa	Ae	Isolated from sugarcane stalks. Tolerant to 30% sucrose
Herbaspirillum seropedicae	Proteobacteria- beta	Ae	Isolated inside plant tissue(endophyte)
Methanosarcina barkeri	Archea	Ana	Methane forming Archea. Discovered in 1984
Anabaena sp. 7120	Cyanobacteria	Ae	Heterocyst-forming. Most well studied among cyanobacteria
Gloethece sp.	Cyanobacteria	Ae	Uni-cellular cyanobacteria. Fix N_2 at night.

3.1.3 Plant Tissue Culture

Plant tissue culture is a method or technique to isolate parts of plants (protoplasm, cells, tissues, and organs) and grow them on artificial media in aseptic conditions in a controlled space so that parts of these plants can grow and develop into complete plants. It is based on the theory of "totipotensi" ("total genetic potential") propounded by Schleiden and Schwann in 1838. The theory states that ‘the plant cell as the smallest unit of a living organism can grow and thrive if kept in

appropriate conditions'. The various tissue culture techniques now used widely in agriculture, disease control and bioremediation include but not limited to:

- *Mikropropagasi (micro propagation of plants)*

This techniques is used to produce crops in large scale through mikropropagasi (micro propagation) or klonal (clone) propagation of various plants. Plant tissue in very small amounts can produce hundreds or thousands of plants continuously. This technique has been used in industrial scale in various countries to commercially produce various types of plants such as ornamental plants (orchids, cut flowers, etc.). Fruit crops (bananas), crops and forestry industries (coffee, tea, etc.). By using tissue culture methods, millions of plants with the same genetic characteristics can be obtained only from one eye buds. Therefore, this method becomes an alternative in the vegetative propagation of plants.

- *Improved crop*

In crop improvement efforts through the glorification of the conventional methods, to obtain pure strains can take six to seven generations of self-pollination or crosses. Through tissue culture techniques, homozygous plants can be obtained in a short time by producing haploid plants through pollen culture, anther or ovaries followed by chromosome doubling. Homozygous plants can be used as plant breeding material in order to improve the nature of the plant.

- *Production of disease-free plants (virus)*

Tissue culture technology has contributed to making plant free from viruses. In plants that have been infected with the virus, the cells in the bud tip (meristem) is believed to be in an area that is not infected with the virus. In this way the meristem can be used to obtain virus-free plants.

- *Genetic transformation*

Tissue culture techniques have become an important part in helping the success of plant genetic engineering (gene transfer). For example, bacterial gene transfer (such as cry genes from *Bacillus thuringiensis*) into the plant cells will be expressed after transgenic cell achieved plant regeneration.

- *The production of secondary metabolites, compounds*

Plant cell culture can also be used to produce biochemical compounds (secondary metabolites) such as alkaloids, terpenoids, phenyl etc. propanoid. This technology is now available in industrial scale. A typical example is the commercial production of "shikonin" a major component of zicao (purple gromwell, the dried root of *Lithospermum erythrorhizon*), a Chinese herbal medicine.

3.2 Modern Biotechnology Methods

Modern biotechnology is a term adopted by international convention to refer to biotechnological techniques for the manipulation of genetic material and the fusion of cells beyond normal breeding barriers (Fig. 6.2). The most obvious example is genetic engineering to create genetically modified/engineered organisms (GMOs/GEOs) through "transgenic technology" involving the insertion or deletion of genes. In recent times, however, modern biotechnology is understood to also include manipulation of whole organisms or other parts of organisms, such as molecules, cells, tissues and organs. Recent developments in biotechnology include genetically modified plants and animals, cell therapies and nanotechnology. Some of these techniques are not yet in everyday use but holds great promise for the future.

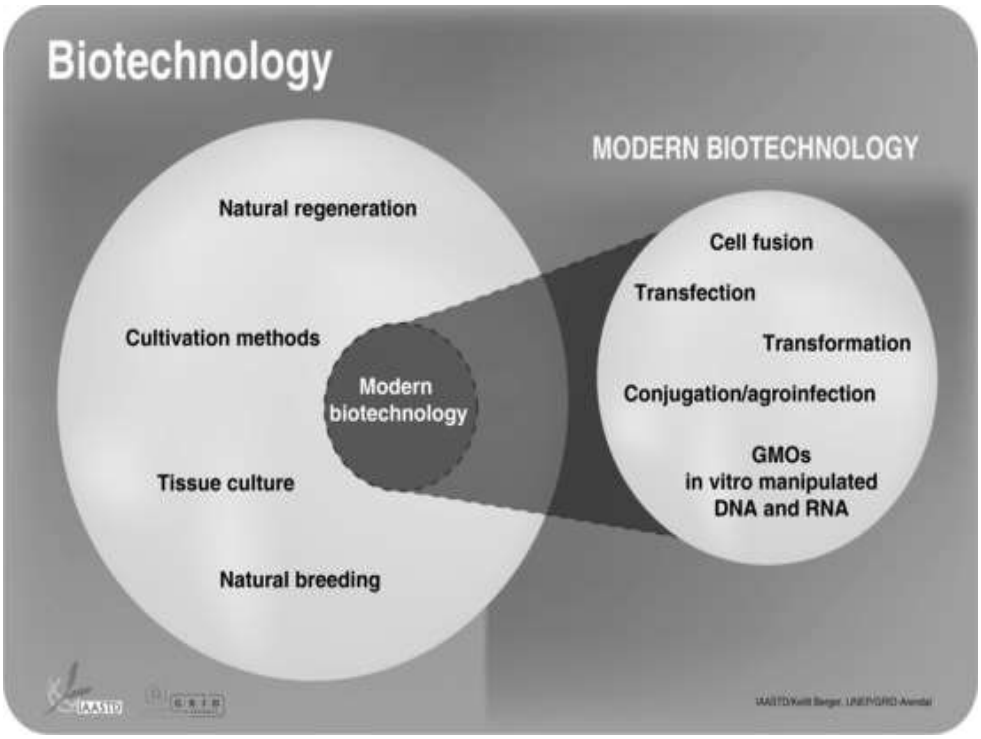


Fig. 6.2: Modern Biotechnology beyond Normal Breeding Barriers (Source: IAASTD/Ketill Berger; UNEP/GRID-Arendal, 2008)

3.2.1 Genetic Engineering

Genetic engineering is the deliberate alteration of the characteristics of an organism by manipulating its genetic material using the DNA (deoxyribonucleic acid) technology. This involves the introduction of foreign DNA or synthetic genes into the organism of interest (microbe, plant or animal). The introduction of new DNA does not require the use of classical genetic methods (gene segregation and linkage), however, traditional breeding (reproductive) methods are typically used for the propagation of recombinant organisms. Genetic engineering is used to increase plant and animal food production; to diagnose disease, improve medical treatment, and produce vaccines and other useful drugs; and to help dispose of industrial wastes. There are several methods for carrying out genetic engineering but these can be divided into three major categories, namely Plasmid Method, Vector Method and Biolistic Method.

The Plasmid Method

The plasmid method of genetic engineering is the most common and earliest technique. It is generally used for altering microorganisms such as bacteria. In the plasmid method, a small ring of DNA called a **plasmid** (a small circle of DNA that replicates itself independently of chromosomal DNA, especially in the cells of bacteria) is placed in a container with special **restriction enzymes** that cut the DNA at a certain recognizable sequence. The same enzyme is then used to treat the DNA sequence to be engineered into the bacteria; this procedure creates "sticky ends" that will fuse together if given the opportunity. Next, the two separate cut-up DNA sequences are introduced into the same container, where the sticky ends allow them to fuse, thus forming a ring of DNA with additional content. New enzymes are added to help cement the new linkages, and the culture is then separated by molecular weight. Those molecules that weigh the most have successfully incorporated the new DNA, and they are to be preserved. The next step involves adding the newly formed plasmids to a culture of live bacteria with known genomes, some of which will take up the free-floating plasmids and begin to express them. In general, the DNA introduced into the plasmid will include not only instructions for making a protein, but also antibiotic-resistance genes. These resistance genes can then be used to separate the bacteria which have taken up the plasmid from those that have not. The scientist simply adds the appropriate antibiotic, and the survivors are virtually guaranteed (barring spontaneous mutations) to possess the new genes. Next, the scientist allows the successfully altered bacteria to grow and reproduce. They can now be used in experiments or put to work in industry. Furthermore, the bacteria can be allowed to evolve on their own, with a "selection

pressure" provided by the scientist for producing more protein. Because of the power of natural selection, the bacteria produced after many generations will outperform the best of the early generations.

The Vector Method

The second method of genetic engineering is called the vector method. It is similar to the plasmid method, but its products are inserted directly into the genome via a viral vector. The preliminary steps are almost exactly the same: cut the viral DNA and the DNA to be inserted with the same enzyme, combine the two DNA sequences, and separate those that fuse successfully. The only major difference is that portions of the viral DNA, such as those that cause its virulence, must first be removed or the organism to be re-engineered would become ill. This does yield an advantage - removal of large portions of the viral genome allows additional "space" in which to insert new genes. Once the new viral genomes have been created, they are allowed to synthesize protein coats and then reproduce. Then the viruses are released into the target organism or a specific cellular subset (for example, they may be released into a bacterium via a bacteriophage, or into human lung cells as is hoped can be done for cystic fibrosis patients). The virus infects the target cells, inserting its genome - with the newly engineered portion - into the genome of the target cell, which then begins to express the new sequence. With vectors as well, marker genes such as genes for antibiotic resistance are often used, giving scientists the ability to test for successful uptake and expression of the new genes. Once again, the engineered organisms can then be used in experiments or in industry.

The Biolistic Method

The biolistic method, also known as the gene-gun method, is a technique that is most commonly used in engineering plants - for example, when trying to add pesticide resistance to a crop. In this technique, pellets of metal (usually tungsten) coated with the desirable DNA are fired at plant cells. Those cells that take up the DNA (again, this is confirmed with a marker gene) are then allowed to grow into new plants, and may also be cloned to produce more genetically identical crop. Though this technique has less finesse than the others, it has proven quite effective in plant engineering.

Examples of Genetically- engineered organisms

Animals

Transgenic animals are used as experimental models to perform phenotypic and for testing in biomedical research. Genetically- modified

(genetically-engineered) animals are becoming more vital to the discovery and development of cures and treatments for many serious diseases. By altering the DNA or transferring DNA to an animal, we can develop certain proteins that may be used in medical treatment. Stable expressions of human proteins have been developed in many animals, including sheep, pigs, and rats. Some examples are: Human-alpha-1-antitrypsin, which has been developed in sheep and is used in treating humans with this deficiency and transgenic pigs with human-histo-compatibility have been studied in the hopes that the organs will be suitable for transplant with less chances of rejection. Transgenic livestock have been used as bioreactors since the 1990s. Many medicines, including insulin and many immunizations are developed in transgenic animals. In March 2011, the bioactive recombinant Human Lysozyme was expressed in the milk of cloned transgenic cattle. This field is growing rapidly and new pharming (production of human protein in animal milk) uses are being discovered and developed. The extent that trangenic animals will be useful in the medical field as well as other fields is very promising based on results thus far. Examples include:

Enviro-Pig

Enviro-Pig is genetically engineered to be able to break down phosphorus. It contains edited DNA from a pig and genetic material from mice. Normally, pigs are unable to metabolise phosphorus for which reason they excrete phosphorus in their feces. This faeces then acts as fertilizer for crops but when they eventually run-off into streams and rivers, they lead to increase algal blooms and destroys habitats for fish. The genetically-engineered Enviro-Pig is made to rectify this environmental problem.

Cows (with human genes)

More recently in 2011 Chinese scientist have been breeding cows genetically engineered with genes from human beings to produce milk that would be the same as human breast milk.

Goats (that produce silk in their milk?)

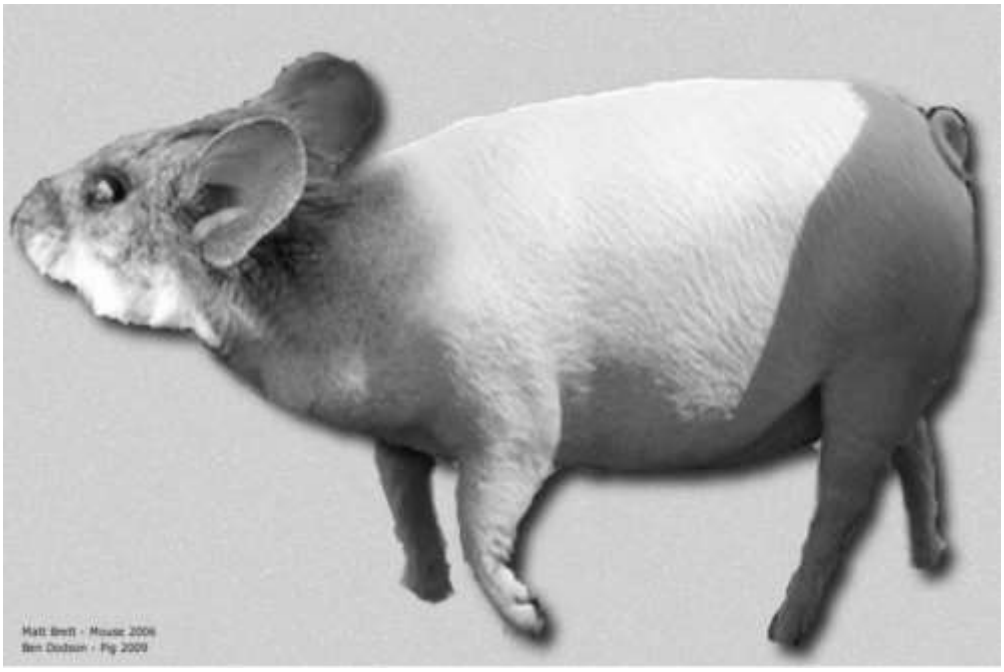
A company called Biosteel has genetically engineered goats to produce milk with strong spider web like silk proteins in their milk. These particles are used by the company to make bulletproof vests and anti-ballistic missile systems for military contracts.

Pigs (that glow in the dark!)

In 2006 in Taiwan scientists used genetic material from a jelly fish and implanted it into pig embyros. The result? Pigs that glow bright green in the dark! During the daylight hours these pigs have a tinge of green on their skin, snout and teeth but as soon as night comes they are light very fat fireflies trotting around their pigpen. The pig's whole body including its internal organs and heart glow green.

Apes (with human genes)

Japanese scientists have implanted human genes into marmosets and are currently using the monkeys to work on a cure for Huntington's disease and strokes in humans. Again is it good to be putting human genetics into animals? I'm not sure, as said earlier there has to be a line somewhere, but where? It should also be noted that for a very long time scientists have been replacing the genes in mice (known as knockout mice) to perform these types of tests for cancer, Parkinson's and other such diseases.



Enviro-Pig (Source: Anonymous, 2012b)

Glowing Pig (Source: Anonymous, 2012b)

Plants

Transgenic plants have genes inserted into them that are derived from another species. The inserted genes can come from species within the same kingdom (plant to plant) or between kingdoms (bacteria to plant). In many cases the inserted DNA has to be modified slightly in order to correctly and efficiently express in the host organism. Transgenic plants are used to express proteins like the cry toxins from *Bacillus thuringiensis*, herbicides resistant genes and antigens for vaccination. Transgenic carrots have been used to produce the drug Taliglucerase which is used to treat Gaucher's disease. In the laboratory, transgenic plants have been modified to increase their photosynthesis (currently about 2% at most plants to the theoretic potential of 9-10%. This is possible by changing the rubisco enzyme (i.e. changing C3 plants into C4 plants), by placing the rubisco in a carboxysome, by adding CO_2 pumps in the cell wall, by changing the leaf form/size. Still other transgenic plants have been modified to fixate ambient nitrogen in the plant. Other genetically engineered plants are listed below:

- Transgenic maize containing a gene from the bacteria *Bacillus thuringiensis* canola
- corn, including popcorn and sweet corn but not blue corn
- cotton
- flax
- papaya

- potatoes (Atlantic, Russett Burbank, Russet Norkatah, and Shepody)
- red-hearted chicory (radicchio)
- soybeans
- squash (yellow crookneck)
- sugar beet
- tomatoes, including cherry tomatoes

3.2.2 Cell Therapy

Cell therapy (also known as cellular therapy, cellular suspensions, glandular therapy, fresh cell therapy, siccacell therapy, embryonic cell therapy, stem cell therapy and organotherapy) describes the process of introducing new cells into a tissue in order to treat a disease. Cell therapies often focus on the treatment of hereditary diseases, with or without the addition of gene therapy. Cell therapy is a sub-type of regenerative therapy. There are two major types of cell therapy the autologous cell therapy and the allogeneic cell therapy. In autologous cell therapy, cells are harvested from a patient, treated or expanded and re-introduced back into the same patient. This is patient-specific and the fear of immunological incompatibility is low, compared with the allogeneic method. The allogeneic method involves the harvesting of cells from one, or a few, universal donors followed by large scale expansion and banking of multiple doses before introduction to the recipient patient. To reduce the rate of immune response incompatibility, the allogeneic approach utilises cell types that do not elicit immune responses, for which reason it has the potential to treat hundreds of patients from a single manufactured lot of cells. The allogeneic methodology is used in the pharmaceutical industry for drug manufacturing because the product can be readily available for "off the shelf" distribution. The mesenchymal stem cells are the main cells used for this procedure due to their plasticity, established isolation procedures, and capacity for *ex vivo* expansion.

3.2.3 Nanotechnology

Nanotechnology involves creating and manipulating organic and inorganic matter at the nanoscale. The techniques for nanotechnology involve atom-by-atom construction of objects that have potential applications in medicine, electronics, information technology, environmental monitoring and remediation, military equipment and weapons, and so forth. It assumes that since the atom (cell) is the building block of all materials and molecules, the world's needs could be met by utilising a limitless supply of atoms or cells to manufacture valuable materials/molecules. Though not principally a branch of biotechnology, they share principles and involve technology at the

lowest level of matter. It is generally believed therefore that experiences gained in one area will help in the other.

3.2.4 Bio-remediation

Bio-remediation is a biological method for restoring contaminated and polluted lands to their original state. The various types of bioremediation are either *in situ* or *ex situ*. The *in situ* techniques include bio-sparging, bio-venting bio-augmentation and phyto-remediation, while the ex situ methods are the various types of composting, i.e. windrow, land farming and bio piling.

Bio-sparging is an *in situ* treatment technique using natural microorganisms, like yeast or fungi, to decompose hazardous soil substances. Some microorganisms can ingest dangerous chemicals without harm. In turn, those pollutants are transformed into less toxic or nontoxic substances, usually in the form of carbon dioxide and water. To be successful, bio-sparging requires active and healthy microorganisms. This is encouraged via increased bacterial growth in the soil, which creates optimal living conditions. After the contaminants are regulated, the microorganisms reduce in number because their food source is gone. Bio-sparging can occur under aerobic and anaerobic conditions.

Bio-venting is another *in situ* remediation technology that uses microorganisms to biodegrade organic constituents in the soil. Bio-venting enhances the activity of indigenous bacteria and simulates the natural *in situ* biodegradation of hydrocarbons by inducing air or oxygen flow and if necessary, by adding nutrients. During bio-venting, oxygen may be supplied through direct air injection into residual contamination in soil. Bio-venting primarily assists in the degradation of adsorbed fuel residuals, but also assists in the degradation of volatile organic compounds (VOCs) as vapors move slowly through biologically active soil.

Bio-augumentation is the introduction of a group of exotic natural microbial strains or a genetically engineered variant to complement or bio-stimulate indigenous microorganisms in contaminated soil or water. Bio-augumentation is necessary only when it is certified that indigenous microbes are incapable of degrading the contaminants at desired rate but susceptible to bio-stimulation. This process increases the reactive enzyme concentration within the bioremediation system and subsequently may increase contaminant degradation rates over the non-augmented rates, at least initially after inoculation. Bio-augmentation is typically only applicable to bioremediation of chlorinated ethenes, although there are emerging cultures with the potential to biodegrade

other compounds. It is remediation tool of choice for sites where soil and groundwater are contaminated with chlorinated ethenes, such as tetracholroethylene and trichloroethylene. These compounds are completely degraded to ethylene and chlorine which are non-toxic.

Phyto-remediation, also called green remediation, botano-remediation, agro-remediation, or vegetative remediation, can be defined as an *in situ* remediation strategy that uses vegetation and associated microbiota, soil amendments, and agronomic techniques to remove, contain, or render environmental contaminants harmless. Most of the plants used in phyto-remediation are metal accumulators. The idea of applying phyto-remediation to decontaminate contaminated lands was first introduced in 1983 although the concept had been used for over 300 years on wastewater management.

Composting, a major *ex situ* method, is a process during which biodegradable organic materials are degraded (or eaten) by microorganisms, resulting in the production of simpler organic and/or inorganic by-products (compost) and energy in the form of heat. Composting is classified further on the basis of the arrangement of the composting materials. In **windrow composting** the organic matter or biodegradable waste, such as animal manure and crop residues is piled in long rows (windrows). This method is used to produce large volumes of compost. These rows are generally turned to improve porosity and oxygen content, mix in or remove moisture, and redistribute cooler and hotter portions of the pile. The rate of composting in windrows depends on the initial ratios of carbon and nitrogen, the amount of bulking agent added to assure air porosity, the pile size, moisture content, and turning frequency.

Land farming is a bioremediation technique that is performed in the upper soil zone or in excavated stockpiled cells. Contaminated soils, sediments and sludges can be spread on the ground and periodically tilled to aerate and encourage bacterial growth. Nutrients, minerals, and/or moisture may be added to speed degradation. Sometimes bacteria which have been selected for their success in breaking down hydrocarbons are added. Contaminants are degraded, transformed, and immobilized by microbiological processes and by oxidation. Contaminated material is usually treated in lifts that are up to 50 cm thick. When the desired level of treatment is achieved, the lift is removed and a new lift is constructed. It may be desirable to only remove the top of the remediated lift, and then construct the new lift by adding more contaminated media to the remaining material and mixing. This serves to inoculate the freshly added material with an actively degrading microbial culture, and can reduce treatment times.

In the bio-pile composting, also known as bio-cells, bio-heaps, bio-mounds, and compost piles organic is an important method for treating petroleum constituents in excavated soils. This technology involves heaping contaminated soils into piles (or "cells") and stimulating aerobic microbial activity within the soils through the aeration and/or addition of minerals, nutrients, and moisture. The enhanced microbial activity results in degradation of adsorbed petroleum-product constituents through microbial respiration. Bio-piles are similar to land farms in that they are both above-ground, engineered systems that use oxygen, generally from air, to stimulate the growth and reproduction of aerobic bacteria which, in turn, degrade the petroleum constituents adsorbed to soil. However, while land farms are aerated by tilling or plowing, bio-piles are aerated most often by forcing air to move by injection or extraction through slotted or perforated piping placed throughout the pile. Bio-piles, like land farms, have been proven effective in reducing concentrations of nearly all the constituents of petroleum products typically found at underground storage tank (UST) sites. Lighter (more volatile) petroleum products (e.g., gasoline) tend to be removed by evaporation during aeration processes (i.e., air injection, air extraction, or pile turning) and, to a lesser extent, degraded by microbial respiration. The mid-range hydrocarbon products (e.g. diesel fuel, kerosene) contain lower percentages of lighter (more volatile) constituents than gasoline. Biodegradation of these petroleum products is more significant than evaporation. Heavier (non-volatile) petroleum products (e.g., heating oil, lubricating oils) do not evaporate during bio-pile aeration; the dominant mechanism that breaks down these petroleum products is biodegradation. However, higher molecular weight petroleum constituents such as those found in heating and lubricating oils, and, to a lesser extent, in diesel fuel and kerosene, require a longer period of time to degrade than do the constituents in gasoline. Efficiency of these techniques depends largely on soil characteristics, constituent characteristics and climate conditions.

4.0 CONCLUSION

Various methods used in biotechnology and in particular environmental biotechnology can be divided into two broad categories, traditional and modern. The traditional methods comprise those methods that have been used since the ancient days and are generally based on the use of whole-organisms. On the other hand, modern methods include those that use either parts of organisms or substances made from organisms. Typical examples of traditional methods are fermentation, nitrogen fixation and tissue culture, while the modern methods are gene and molecular based methods, including genetic engineering, cell therapy and nanotechnology. Genetic engineering, which involves the transfer of genes or DNA, involves the use of three well-established methods

based on the vehicle used for the transfer. The methods are plasmid that uses the plasmid (a DNA ring that replicates independent of chromosomal DNA) as vehicle; the vector method that uses another microorganism and the bio-listic method that uses metals and other markers as vehicle.

5.0 SUMMARY

In this unit, you have been acquainted with the various methods used in biotechnology in general and of environmental biotechnology in particular. You have learnt that the various methods used in biotechnology and in particular environmental biotechnology can be divided into two broad categories, traditional and modern. The traditional methods include fermentation, biological nitrogen fixation and plant culture while modern methods involved the methods used to manipulate the genetic composition of organisms for the achievement of specific goals. The most important of these methods is the genetic engineering, which uses specialised techniques to alter the genetic composition of an organism. The techniques involve principally gene transfer from one organism known as the donor to another known as the target. In the plasmid method, the transfer is made via a special DNA ring known as the plasmid while in the vector method, another organism, often a microbe is used to make the transfer. In a third method known as bio-listic, a metal usually tungsten or other suitable markers is used to make the transfer. You also learnt that biotechnology methods are specialised methods that have been used to change the outlook, composition and function of microbes, plants and animals for the achievement of specific goals.

In the next unit, you will learn how these methods are applied to the various areas of environmental health.

6.0 TUTOR-MARKED ASSIGNMENT

1. With the aid of examples, briefly explain the process of fermentation.
2. what is the basis for industrial fermentation?
3. List the sources of nitrogen to plants.
4. With examples, explain the three methods of genetic engineering.

7.0 REFERENCES/FURTHER READING

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UNIT 3 TRADITIONAL AND MODERN METHODS IN ENVIRONMENTAL HEALTH

CONTENTS

1.0 INTRODUCTION

In the last unit, we discussed major types of methods used in biotechnology and environmental biotechnology. We learnt that there two major types of methods, the traditional and modern methods. In this unit, we will learn about the use of these methods in the area of environmental health. You will be acquainted with the choice of methods given specific conditions of environmental health challenges. Specifically, you will be able to know what method is most appropriate for a given situation and why.

2.0 OBJECTIVES

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

- explain the traditional methods of waste management
- discuss the modern methods of waste management
- describe the preventive methods of pest and disease control
- discuss the chemical and non chemical based methods of vector control.

3.0 MAIN CONTENT

3.1 Sanitation and Waste Management

Sanitation is the set of actions and activities carried out to improve the quality and reduce nuisance value and potential for disease transmission. Quality of the environment implies removing or reducing nuisance, odour and disease causing agents from human and animal reach. The common nuisances in the environment include wastes of various types – gaseous, liquid or solid, dirty and defaced premises, stray dogs and other pests. Others include statutory nuisance insects and lower vertebrates and unwarranted noise from individuals, group of individuals, electronic devices, vehicles, machinery or equipment and weapons of individual squabble, community strife and civil/international wars. Many of these factors enhance and sustain the transmission of different types of diseases. Environmental health, which has the responsibility to address all the physical, chemical and biological factors external to a person, and all the related factors affecting human behaviour and human must device, means to reduce the contact rate between these agents of nuisance and disease control.

The Basel Convention defined waste as substances or objects, which are disposed of or are intended for disposal or are intended to be disposed of by the provisions of the law. Waste is therefore known by several terms such as rubbish, trash, refuse, garbage, junk or litter that clearly suggest they are unwanted, useless and only meant for disposal. While this is not completely true for all situations, in most cases, waste has a high nuisance value and could enhance disease transmission if not properly managed. However, if properly managed, waste can also be a source of wealth and raw material. There are many methods for waste management; some existing over a long period, others emerging. The choice of a technique at any given time depends on several factors including type of waste involved, cost of management options and available technology, personnel and infrastructure required by each technique.

The available methods can broadly be divided into two categories, namely, traditional and emerging methods. The traditional methods include indiscriminate disposal, open burning, composting, sanitary landfill and incineration while the emerging methods include those methods that lead to waste recycling, source reduction and bioremediation of contaminated sites.

3.1.1 Traditional Waste Management Methods

Indiscriminate disposal and open burning

This is the cheapest and easiest method of waste disposal and requires no special explanation because it is the system practiced in most homes in Nigeria and most of the developing countries. Here people collect waste in any manner they deem fit using whatever material available and dispose in the nearest bush, garden or piece of land. The waste accumulates into a dump and is either burnt openly or left to decay causing public nuisance and health risks

Composting

This is a natural process that turns organic material into a dark rich substance known as compost or humus under the action of microorganisms. However, only biodegradable waste can be turned into compost but the good news is that biodegradable waste constitute over 90% of municipal waste in most communities. However, care must be taken to avoid wastes that attract pests and domestic animals such as rodents, dogs, cats, flies etc. Examples of wastes to avoid include fatty food items like meat, fish, oils etc.

Sanitary landfill

The sanitary landfill is the main system of municipal waste disposal today. In a modern sanitary landfill, each day's waste is covered over and sealed off. When the landfill is full it is covered, graded for drainage, and **leachate** (polluted water seeping from the landfill) drained without contaminating ground water. For effective results sanitary landfills should be located on sites that can geographically & geologically support them – sites with natural clay soils. If clay soil cannot be found, a clay lining must be constructed to prevent leachates reaching groundwater. Sanitary landfills are not to be located over sand or gravel deposits that would allow leachates flow to groundwater. In spite of precautions the production of leachates & contamination of groundwater can still occur if the clay breaks or if the landfill is located improperly, or if explosions & fires caused by the accumulation of dangerous amounts of methane gas created by anaerobic decomposition of refuse occur.

Incineration

This is a coordinated burning of waste using well designed incinerators. Incineration has both negative and positive implications. On the negative consideration, it is very expensive in terms of economic and

environmental costs and although it could reduce waste volume substantially, sometimes by as much as 80-90 %, the 10-20 % residue/ash may be toxic and difficult to handle. On the positive side, the heat produced can be used for electric generation. Incineration requires large amounts of waste and is therefore most appropriate in crowded urban cities. It should be emphasized that sustainable incineration requires controlled burning using appropriate facilities. It should never involve open burning.

3.1.2 Modern Waste Management

These methods do not only aim at efficient and environmentally friendly waste disposal and treatment, it also aims at regulating the way waste is produced and used. Some of the methods, e.g. waste recycling, assumes that most waste generated by one sector of the economy is not really not useless as it can be reused by the same or another sector of the economy. In waste reduction method, technologies are constantly being developed to minimize the quantity of waste produced to the barest minimum.

Waste recycling methods

This is the re-use of used materials (waste). Such material may be re-used as it is or cleaned up to appeal to new users or processed into new products. The current globalization is making recycling of several products e.g. electronics, clothes, transport vehicles, plastics etc. very attractive. Overall, recycling reduces the amount of waste that reaches the dumpsites or treatment sites. Recycling requires that waste sorting is carried out mostly cost-effectively at source.

Waste conversion/reduction

Waste reduction means decreasing the amount of waste generated by any activity. It is achieved in two ways, source reduction and recycling. Source reduction attempts to eliminate waste or reduce the amount of waste generated through improved technology. Recycling as already explained, reduced waste volume through re-use of existing waste.

3.2 Pest and Disease Control Methods

Diseases are spread through several means including infected body fluids such as blood, faeces, vomit, saliva and nasal secretions. Pathogenic objects include microorganisms, poisons, pollutants etc. transmission (i.e. invasion of fluid) may be direct or through several vehicles such as air, insects (vectors) or intermediate hosts (mollusks and lower vertebrates). To control disease, it is important to identify the

pathogen involved, the vehicle used and the fluid affected. Reduction in disease level may be achieved through preventive (preventing disease transmission) or morbidity control (reducing the effect of established disease on individuals and communities). Preventive measures are aimed at preventing pathogens from gaining access to the body fluids while control methods involved reducing or eliminating pathogens in the body fluids. The specific methods used to achieve these are outlined below.

3.2.1 Preventive Methods

The preventive methods involve taking precautionary measures to prevent pathogens and pollutants reaching the body fluids. It also includes activities carried out to reduce vector and intermediate host population. Methods to prevent infection and injuries can be directed either to host or environment and include:

Standard Precautions

- Hand Hygiene - The most important hand hygiene method is to wash hands for at least 20 seconds, using soap and warm running water before handling food or eating, after using the bathroom and toilet, diapering, handling raw meat, cleaning activities, making contact with pets, patients and after any activity that contaminates the hands. Children and infants need help to wash their hands properly.
- Use of personal protective equipment (PPE): gloves, aprons, eye protection, face masks etc.
- Handle and dispose of sharps objects safely
- Dispose of contaminated waste safely
- Managing blood and body fluids: spillages and transport of specimens
- Decontaminating equipment: cleaning, disinfection and sterilization
- Maintain a clean clinical environment
- Prevent occupational exposure to infection
- Manage sharp injuries & blood splash incidentsManage linen safely
- Place patients with infections in appropriate accommodation
- Correct disposal of excretions & soiled material
- Soiled clothing & bed linen - place in a hot wash (>60)
- Disinfection is especially important in nurseries, schools & residential institutions
- Health education should emphasize personal hygiene & hygienic preparation and serving of food

3.2.2 Parasite Targeted Control

Three major methods are used to reduce parasite load in infectious diseases, either in animals or plants. The first is to destroy any animal infected by the parasite organisms, whether it be the host animal or an intermediate host, such as an insect or mollusks that transmit the infective organism. This method, however, cannot be used in the human population even when it works very effectively in other animal populations. Typical examples are the eradication in the United States of hog cholera in swine and yellow fever in humans through the elimination of hog and mosquitoes respectively.

The second method is therapeutic using synthetic and herbal drugs including antimicrobial drugs. The development of resistant strains of many micro-organisms to a number of antimicrobial drugs and high rate of re-infection has limited the efficacy of these methods and caused concern although the method is still widely used.

A third method of control is to immunise with a form of the organism that will induce an immune response. This requires the use of vaccines containing an immunogen that induces persisting protection against the invading organism. This method offers the greatest promise. It is simple, inexpensive, requires few administrations, and, most importantly, prevents infection and, therefore, minimises damage that often accompanies infection. Greater safety and effectiveness in newer biological products will enhance their use. Immunisation exposes individuals to infectious agents artificially so that they will develop antibodies and be protected against the common disease-causing organisms. The vaccines in common use are made from either attenuated living organisms or inactivated organisms.

The attenuated living organisms have reduced virulence, are required only in small amounts, and, in general, induce long-lasting immunity. They elicit a controlled subclinical infection and, in general, are very effective. Occasionally, however, they produce side effects that may be as severe as the natural infection. Inactivated vaccines are safe in that they do not contain any infectious material, but they are weak in terms of stimulating an immune response. They usually require multiple injections over several weeks to induce an immune response comparable to that induced by living organisms. They also may cause undesirable side effects evident both at the site of inoculation and sometimes as a general side reaction as the individual responds adversely to the many antigenic components in the vaccine.

In other words, the use of whole organisms in either the living or inactivated form may cause adverse reactions. These reactions are due to certain components of the whole organism, that is, proteins, lipids or carbohydrates that may not be necessary for immunisation. Biotechnology is improving this lapse as we will see later.

3.2.3 Vector Control Methods

Integrated vector control method is a holistic approach to managing vector populations and is based on the understanding of the interrelationship between the vector, the environment and humans. Such understanding leads to the selection and deployment of the most cost-effective and sustainable intervention(s), either individually or combined— the objective being to achieve the maximum possible reduction or local elimination of the disease transmitting vectors and intermediate hosts. The table below summarises the common interventions currently used for the vectors of major human diseases.

Table of chemical-based and non-chemical vector control methods (Source: IVM, 2012)

Control Method	Brief Description	Disease Targets	Major Vectors Targeted
Chemically- based vector control method			
Adulticides			
• Indoor residual spraying	Timely application of long-lasting chemical insecticides on the walls and ceilings of houses in order to kill the adult vectors that land on these surfaces.	Malaria, lymphatic filariasis, visceral leishmaniasis (kala-azar), chagas disease	Indoor biting/resting female *Anopheles* mosquitoes; phelbotomine sandflies; reduviid bugs
• Long-lasting insecticidal nets	Sleeping under insecticide-impregnated polyethylene, polyester or cotton net to prevent bites	Malaria, lymphatic filariasis, visceral leishmaniasis (kala-azar),	Indoor biting/resting female *Anopheles* mosquitoes; phelbotomine sandflies

	from disease-baring insects.		
• Other insecticide-impregnated materials	Use of insecticide-impregnated clothing, coverings (blankets), door and window blinds, etc to prevent human-vector contact and bites	Malaria, lymphatic filariasis, cutaneous leishmaniasis, African trypanosomiasis (sleeping sickness), onchocerciasis	*Anopheles, Aedes, Culex* mosquitoes; phelbotomine sandflies; tsetse flies; *Simulium damnosum* black flies
• Molluscicides	The use of molluscicides and insecticides to kill disease vectors in the adult stages.	Schistosomiasis, lymphatic filariasis, dengue	Fresh-water snails (*Biomphilaria, Bulinus, Onchomelania*); *Anopheles, Aedes, Culex* mosquitoes
• Insect Traps	Insecticide-impregnated traps targeting flying vectors; may also have an attractant (color or light)	Malaria, African trypanosomiasis (sleeping sickness)	*Anopheles, Aedes, Culex* mosquitoes; tsetse flies
Chemical larvicides	The release of chemicals on water bodies and surfaces to kill larvae and pupae of insect vectors.	Malaria, dengue, lymphatic filariasis, onchocerciasis	*Anopheles, Aedes, Culex* mosquitoes; *Simulium damnosum* black flies
Non-Chemical Vector Control Methods **Non- Chemically- based control methods** **Environmental methods**			
• Modification	Permanent environmental changes aimed at the	Malaria, dengue, lymphatic filariasis,	*Anopheles, Aedes, Culex* mosquitoes; Fresh-water snails (*Biomphilaria,*

	elimination of local vector breeding areas	schistosomiasis	*Bulinus, Onchomelania)*
• Manipulation	Temporary environmental changes to disrupt the reproductive cycle of a vector	Malaria, dengue, lymphatic filariasis, schistosomiasis	*Anopheles, Aedes, Culex* mosquitoes; Fresh-water snails (*Biomphilaria,Bulinus, Onchomelania)*
House Modification	An improvement in the housing structure to restrict entry of disease vectors	Malaria, lymphatic filariasis, Chagas diseases	Indoor biting/resting female *Anopheles* mosquitoes; reduviid bugs
Larviciding			
• Larvivorous fish	Use of natural predators (tilapia and other fish) that feed on the larvae and pupae of mosquito vectors	Lymphatic filariasis	*Anopheles, Aedes, Culex* mosquitoes;
• Biological larviciding	The use of bacteria against mosquito larvae or pupae (e.g. *Baccillus thuringiensis*)	Malaria, dengue, lymphatic filariasis, onchocerciasis	*Anopheles, Aedes, Culex* mosquitoes; *Simulium damnosum* black flies
Non-larvivorous natural predators	The use of natural predators against disease vectors (e.g. molluscivorous fish, crawfish and crabs)	Schistosomiasi	Fresh-water snails (*Biomphilaria, Bulinus, Onchomelania*);
Polystyrene beads	Formation of a layer on top of the	Malaria, dengue, lymphatic	Mosquitoes

	breeding water body to prevent the larvae and pupae from breathing	filariasis	
Others			
Topical Repellants	Use of topical insecticides to repel biting insect vectors as a personal protection measure.	Malaria, dengue, lymphatic filariasis, African trypanosomiasis (sleeping sickness)	Mosquitoes; tsetse flies

4.0 CONCLUSION

In this unit, we have outlined the various methods of waste management. It was shown that waste management methods are both traditional and modern. The traditional methods include those methods that are used by households, municipal agencies and institutions, offices, etc. on daily bases including indiscriminate dumping and open burning, composting, sanitary landfill and incineration. The modern methods target waste management form source, recycling those that are still useful in other sectors of the economy and developing technologies to minimise the quantity of waste produced by each activity. Several methods used in pest and disease control were also described. These included appropriate personal hygiene, chemical and non chemical methods of vector control.

5.0 SUMMARY

In this unit, you have learnt about the methods of waste management. You have been taught that waste management methods can be divided into two major categories. The traditional methods involve collection and disposal without prior consideration of the environmental consequences. These methods include indiscriminate dumping and open burning, composting, sanitary landfills and incineration. On the other hand, the modern methods such as recycling and source reduction technologies make environmental consequences a critical outcome of management, for which reason they are source based, considering not just collection and disposal, but also how the wastes are generated. You have also been acquainted with the methods used to prevent and control pests and diseases. In the next unit, you will be acquainted with the various modifications which biotechnology have made to make waste management not only more environmentally friendly, but also more beneficial.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the terms sanitation and waste.
2. Compare and contrast the traditional and modern methods of waste management.
3. Outline the factors to be considered in controlling diseases in an area.
4. Discuss ten standard methods of disease precaution and control.

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MODULE 3 APPLICATION OF BIOTECHNOLOGY TO ENVIRONMENTAL HEALTH

UNIT 1 APPLICATION OF BIOTECHNOLOGY TO WASTE MANAGEMENT

CONTENTS

1.0 INTRODUCTION

In the last Unit, you have been taught about the traditional and modern methods of waste management and the environmental implications of each method. In this Unit, you will learn about the emerging biotechnology methods and how these are applied to waste management vis-à-vis the traditional and modern methods.

2.0 OBJECTIVES

At the end of this Unit, you will be able to:

- describe the emerging biotechnology methods of waste management
- describe the process of waste minimisation technology
- describe the waste recycling and conversion technologies with respect to organic fertilizer and bio-fuel production.

3.0 MAIN CONTENT

3.1 Waste Minimisation Technology

Waste minimisation is any action that reduces the amount and/or toxicity of waste produced by a process. The most desirable method of waste minimisation is source reduction (minimising quantity of waste produced at source), which reduces the impact of chemical wastes on the environment to the greatest extent. This activity reduces or eliminates the generation of waste at the source.

The next most desirable approach is waste minimisation through recycling. When a waste material is used for another purpose, treated and reused in the same process, or reclaimed for another process, this is called recycling. The last minimisation method is treatment. The most common treatment that can be performed is elementary neutralisation (minimising or eliminating the corrosive or toxic chemical in waste). Other kinds of treatment may involve chemical, physical or biological methods. Other methods include waste substitution, which involves replacing one material with another in a process of production. Example includes substituting hazardous material with non-hazardous ones to minimise the toxic effect of waste produced. For example, Alconox may be used in the cleaning of glassware instead of chromic acid based cleaners. Modification of procedures, processes or equipment can also lead to waste minimisation. In laboratories or factories where high volumes of spent solvents are generated, distillation would provide a cost-effective means of re-using these solvents. Good production practices such as computer modelling and small-scale experiments can minimise waste. Generally waste minimisation reduces the quantity and/or hazardousness of waste generated by a process at source or at any other point of generation, recycling at source (at the factory or at any other point) of waste generated and undertaking appropriate treatment of waste to reduce its harzardousness (see Figure 1.1). As shown by the figure, waste reduction is achieved through product modification or process modification while waste treatment reduces the hazardousness of waste. The examples below clearly illustrate these. Study the examples properly and determine, which is a product of modification and a process modification. Outline the specific modification involved and level of waste minimisation achieved in each example.

3.2 Waste Recycling and Conversion Technology

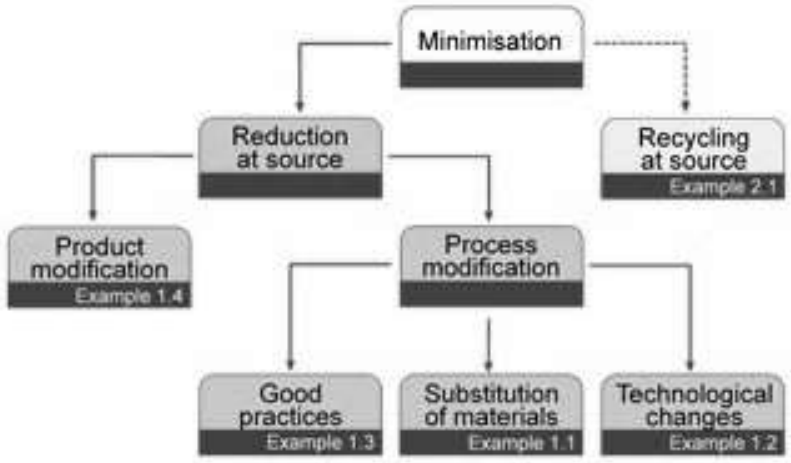

Fig. 1.1: A Typical Waste Minimisation Model
(source: Agencia de Residus de Calalunya, 2012)

Example 1: Substituting raw materials with less pollutant ones

A company that manufactures metal parts by means of precision cutting techniques decided to replace the chlorinated solvent used in the degreasing process with a water-based alkaline detergent. This measure required the installation of two cleaning machines incorporating an oil and dust separation system in order to prolong the useful life of the bath. This measure enabled the elimination of the consumption and subsequent management of the chlorinated solvent (from 9.6 tons/year to 0 tons/year).

Example 2: Introducing new, more efficient technologies into the production process

A company that repairs and cleans merchant ships uses spray guns and solvent-based paint in the hull painting process. Electrostatic paint guns, which increase the application capacity of the paint, were installed and a reduction in the consumption of paint (38%), solvent (2.6%) and packaging waste (7.6%) was achieved. The payback period, taking into account the investment (€41,000) and the annual savings on raw materials and waste management (€1,105,032.12), was 1 month.

Example 3: Applying good environmental practices

A metal processing company systematically cleaned the die by hand before verifying its state and preparing it for new operations. The cleaning process was carried out by submerging the die in a bath of 30% sodium hydroxide, which subsequently had to be managed as liquid

waste. The good practice that was applied consisted in introducing a new procedure to control the state of the die, preventing unnecessary cleaning. This good practice reduced the generation of liquid waste by 40% (41 tons/year), and it also had an effect on the availability of personnel, as time could be spent on other activities.

Example 4: Developing new products and applying improvements to already existing ones, integrating environmental criteria (ecodesign)

A company that manufactures plastic components for the automobile industry has developed a new method of joining or welding parts. The new system involves the use of a system of joining by vibration or ultrasound. Using this ecodesign method, the company has minimised manufacturing waste and made a significant reduction in the energy consumption associated with this process.

Example 5: Once the waste has been generated, trying to recycle it at the source

A company that manufactures interior modules for vehicles uses hydraulic oil to operate its plastic injection machines. It installed filters in the oil circuits in order to prolong their useful life by eliminating impurities that would accumulate, thus minimising waste. Thanks to this measure, oil changes are now carried out every 7 years instead of every year, representing a reduction of 16.72 tons/year. This also led to a reduction of 21.3 tons/year of oil waste, representing a reduction of 60%.

3.2.1 Organic fertilizer and bio-fuel production

As already described in Unit 4, composting is a natural process that turns organic material into a dark rich substance known as compost or humus under the action of microorganisms. Improved composting through biotechnology is now being used to produce organic fertilizer which is being marketed around the country under different brand names. Factories for organic fertilizer production now exist in Ibadan, Minna, Akure, Lagos etc. Modern biotechnology methods of organic fertilizer production include:

- Engineered landfill
- Biodigester/bioreactor

The engineered landfill involves anaerobic digestion of municipal wastes in containment facilities. The main constituents of bio-digesters are pre fabricated facilities mounted above the ground shelter. The bio-

digester tank is a cylindrical structure with the provision of inlet for waste supply and out let for biogas. Temperature in the bio – digester is maintained between 5-30 ˚C. A consortium of anaerobic bacteria converts the organic waste into methane, carbon dioxide and black soil. They also eliminate the smell of night soil, the disease causing organisms in the night soil and the solid matter totally. On dry weight basis, 90 per cent of the solid waste is reduced. The gaseous effluent (biogas) is continuously let off to the atmosphere. The biogas can be collected and used for various energy incentive activities like cooking, water and room heating. Liquid effluent can be drained to any surface or soak pit without any environmental hazards. Bioreactors facilities mounted underground is known as bioreactor. Both are very efficient, easy to maintain and environmentally friendly. Samples of organic fertiliser production facilities and bagged organic fertilisers in Ibadan are shown in Figures1.2-1.6.

Fig. 1.2: Underground Chinese Batch Type / Indian Dome: Feed Chamber (Source: Tajudeen, 2011)

Fig. 1.3: Sub-Surface Concrete Bio-digester (Source: Tajudeen, 2011)

Fig. 1.4: Evacuation Chamber (Source: Tajudeen, 2011)

Fig. 1.5: Sample of Organic Fertilizer (Unbagged)(Source: Tajudeen, 2011)

Fig. 1.6: Sample of Organic Fertilizer (Bagged)(Source: Tajudeen, 2011)

Biotechnology is fast optimising performance and efficiency of bio-digesters and bioreactors by developing more efficient microbes and enzymes not only to make bio-digesters work better but faster too. The most typical example is the development of Hydro-Bio-digesters (HBD-O), a combination of all natural bacteria, lab-grade purified enzymes with micro and macronutrients. HBD-O bacteria and enzymes target biodegradable materials in bio-digester facilities and by out competing the natural occurring bacteria for resources available, odor causing bacteria die off and thus the objectionable smell is eliminated. HBD-O are so prolific they multiply by double every 15-20 minutes. If you start out with one cell in fifteen minutes you have two and so on. In 8 hours you will have 17-million and in twenty-four hours you have a 1 with one hundred and twenty six zeros behind it. They simply outnumber the bacteria present in the system. HBD-O was developed by Hydro Engineers of United States of America. There are over 3,000 known bacterial strains in HBD-O. The bacteria and enzymes are selected for their ability to aggressively breakdown the targeted substrate. Process of selection involves first selecting only facultative strains that can operate in aerobic (with oxygen) or anaerobic (oxygen depleted) situations. They are, however, most effective in an aerobic state working 5-7 times faster than in anaerobic condition. They are also resistance to high and low pH, chemical shock and temperature. HBD-O can tolerate a ph of 4.5 to 9.5 without dying off, but, the closer to neutral pH of 7 the better. They are resistant to disinfectants like chlorine up to 150 ppm and remain active in temperature ranges of 10-60˚C. HBD-O are not genetically-engineered but are all naturally occurring strains. They are marketed in two forms, liquid and dry formulars each at a concentration of 1.22 trillion cells Kg of active cell count for two years. Once stabilized in a liquid that does not break the micro encapsulation process HBD-O remains 100% viable with a cell

count of 119 billion per litre for one full year. **Dosing rate of** HBD dry formula is used for seed dosing (initial propagation) at a rate of 1 Kg pound per 14000 litres of wastewater. The product is simply mixed in warm (not hot) water and evenly introduce into all water holding tanks within the system. HBD Liquid can be automatically dosed into the water. Application rates are 85 g per 4000 litres of water per day. HBD-O enzymes and microorganisms work in concert to digest long chain hydrocarbons, light fuels, sludge, fats, and grease. HBD-O'S targeted enzymes breakdown the substrate for digestion by the bacteria. In high hydrocarbon applications nutrients supplement the bacteria's diet. The result is a significant reduction of BOD/COD and TSS. The byproducts produced from this biological transformation are absolutely harmless and "stink" free – only carbon dioxide and water remain. They propagate the bottom solids reducing them and liberating oils and grease into the water column for digestion. Floating fatty crust is broken down and eliminated. The bacteria take up residence in the entire system constantly eating it clean, coalescing plates are kept clean, pipes and valves don't plug up. Many other genetically-engineered bacteria working in similar way are available in the market.

4.0 CONCLUSION

In this unit, we have described the application of biotechnology methods to waste management. Two important emerging methods were described. These included waste minimisation and waste to wealth technologies. Waste minimisation is achieved through the use to technologies that lead to waste recycling and waste reduction while waste to wealth technologies involves the production of organic fertilizers and bio-fuel which is mainly methane. Both waste recycling and waste reduction involve either process or product modification or both. Modification may involve change in the raw materials used or change in the process of production to minimise the quantity waste produced and to reduce the hazardousness of the waste. Production of organic fertilizer and bio-fuel employ the principle of composting using either genetically-engineered microbes or genetically-modified enzymes in well designed facilities known as bio-digester (mounted above the surface) or bioreactor (mounted underground). Examples were given of companies that now manufacture and market either genetically-engineered or biotechnologically optimised bacteria for this process.

5.0 SUMMARY

In this unit, you have learnt the various ways biotechnology can be applied to waste management methods. You have learnt that the emerging waste management methods are directed towards waste minimisation involving waste recycling, re-use and reduction at source.

Waste minimisation is based on process and product modification as well as waste treatment to reduce the hazardousness of waste. These may involve change in the raw materials used or development of technologies that reduces amount of waste generated.

You have also learnt about waste conversion processes for the production of bio-fuels and organic fertilizer. This process uses the principle of composting involving well designed facilities. The two common of such facilities are the bio-digesters and bioreactors. Bio-digester facility is usually mounted above the ground while bioreactor facilities are mounted underground. Each facility, which is usually cylindrical in shape, is designed such that waste materials are loaded from one end and gas released at the other. The methane gas released may be collected and used for heating, lighting or electric generation. Black soil left in the facilities after decomposition by microorganisms is used as organic fertilizer. The role of either genetically-engineered microbes or biotechnologically optimised bacteria and enzymes in bio-digester/bioreactor technologies was also described. In the next unit, you will learn how similar biotechnological methods are applied to pest and disease control.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is waste minimisation.
2. What are the methods of waste minimisation.
3. Define the tem recycling.
4. Describe the mechanisms of a bio-digester and a bio-reactor.

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UNIT 2 TRADITIONAL AND BIOTECHNOLOGICAL METHODS OF PEST AND DISEASE CONTROL

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt about the application of biotechnology to environmental health. You learnt that biotechnology can be applied to recycle and reduce the amount of waste generated by any process and that biotechnology is now driving the waste-to-wealth creation in the areas of organic fertilizer and bio-fuel production. In this unit, we shall discuss the application of biotechnology to environmental health by showing the role it plays in pest and disease control.

2.0 OBJECTIVES

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

- describe the role of gene therapy in disease prevention and control
- describe the production and effects of biosynthetic vaccines in disease prevention
- explain the chemical synthesis of drugs and its effects on disease control
- describe the role of insect sterilisation in the control of disease vectors

- describe the role of genetically- engineered bacteria and viruses in disease control.

3.0 MAIN CONTENT

3.1 Preventive Methods

Disease prevention implies activities designed to protect patients or other members of the public from actual or potential health threats and their harmful consequences. It is a branch of healthcare which focuses on the prevention of disease, both in individuals and communities, rather than cure. It involves a number of branches of science and medicine that are intertwined in their contributions to disease transmission. Several methods are used to prevent diseases but we will concentrate on modern methods using emerging biotechnology methods.

3.1.1 Biosynthetic vaccine

As already described, the objective of vaccine development over the years has been to identify the important antigens responsible for protection and to produce them in the purest form. Until recently, vaccines have been made from attenuated living organisms or inactivated organisms. Recently, however, advantages of biotechnology have made recombinant DNA technology (rDNA, genetic engineering) available to help produce defined antigens, or antigenic determinants, on a large scale and in a cost-effective manner. The isolation of these antigenic determinants from the surface of infectious agents represents the first step in trying to produce a more specific antigen. Since these determinants occur in repeated subunits and their production is controlled by specific genes in the nucleus of the organism, these genes may be used to produce antigenic determinants.

By isolating the specific gene (DNA) that encodes for the surface antigenic determinant, and by using a plasmid method (Unit 4) to insert this gene as a bacteria, yeast, or mammalian cell, the gene recombines with the cell's own genes to produce the antigenic determinant along with other cellular products. The antigenic determinant may be isolated and used as an immunogen. This immunogen will be recognised by the immune system as being foreign and will stimulate the production of antibodies or a cellular response that will protect the animal or prepare the animal's immune system for future infection with the infectious agent.

Antigenic determinants can be produced by growing the cells on a large scale and collecting arid purifying the antigen as it is expressed. The

antigen may have improved characteristics compared to the antigen derived from the whole organism. These characteristics are purity, safety, and stability. Also, the risk of having the vaccine contaminated with infectious material used in production of the whole organism is reduced. All of these characteristics help in developing improved vaccines.

3.1.2 Chemical Synthesis of Vaccines

Another method of producing antigenic determinants is chemical synthesis. Most antigenic determinants are proteins composed of chains of amino acids. Individual amino acids may be linked together in a linear form to mimic antigenic determinants. So, if the amino acid sequence of the native antigenic determinant is known, it can be made synthetically.

Biotechnology has evolved methods to determine the amino acid sequence of antigenic sites by isolating the gene that encodes for it. The gene is composed of DNA that contains the genetic code in its nucleotide sequence. This nucleotide sequence can be determined and translated into an amino acid sequence (the bases, adenine, thymine, guanine and cytosine code in triplet- combination for each amino acid). Thus, an amino acid sequence for a surface protein may be derived from the nucleotide sequence of its gene. Only a small part of this surface protein may be required to produce an immunogen.

The peptide can be made by sequentially adding amino acids. Forty or 50 amino acids may be joined together in a linear sequence forming a peptide by using an amino acid synthesizer controlled by a computer program. The peptide is removed from the resin and may be coupled to a carrier protein or polymerized to increase its size. These forms of the antigenic determinant have been found to be active in inducing humoral and cellular immune responses.

The advantage of chemically synthesized peptides over biosynthesized peptides is that the chemical process is more precise and reduces the variability found in a biological process. This precision leads to further improvement in purity. There also is no chance that an infectious agent or foreign nucleic acid will find its way into a chemically synthesized product.

3.2 Parasite-based Control

3.2.1 Gene Therapy

Gene therapy is a procedure that is used to treat genetic and other related diseases. The technique is based on the introduction of copies of a "healthy" gene from one cell or organism into the body cell of the same or another organism. The disease is controlled if the introduced gene(s) work normally. This is called somatic gene therapy because it introduces the gene into a somatic or body cell. Any cells that could divide to form sperms or eggs will not have genes introduced into them through somatic gene therapy. Somatic gene therapy is intended solely to eliminate the clinical consequences of the disease in an individual and is therefore not inherited. Future generations are, therefore, not affected by the therapy because the inserted gene is not passed down the hereditary line. This contrasts with the Germ line gene therapy, involving the insertions of a healthy gene into the fertilized egg of an animal that has a specific genetic defect. This has been performed successfully in several animal studies. The new gene is obtained in every cell in the body including reproductive cells. There are three overwhelming technical problems that are preventing consideration of this technique for the use in human beings. "The first is that scientists have no way of diagnosing genetic disorders in the fertilized egg. Secondly, the procedure is most often used to insert genes into fertilized eggs - injection with a microscopically guided glass needle - has a high failure rate and thirdly, the problem is lack of control over where the gene is inserted into the embryo's genetic machinery.

Procedure for gene therapy is to first identify cells affected by faulty genes through a painstaking diagnosis using symptoms and signs as a first line lead. The affected cell is called the target cell. When faulty genes are suspected, the first step is to compare their functions with those of the ‘healthy genes’. Once fault is confirmed detailed investigation of how it affects the chemical reactions within a cell is undertaken. Estimates are made to determine if the reactions could be reversed by drug therapy or not. Where a reaction is reversible by drug therapy, and an effective drug is known, this option is taken because it is cheaper and simpler.. In some cases, it could lead to the development of new drugs or new line of treatment. Where it is obvious that drug therapy is not an option or where it has failed, gene therapy is considered and carried out where this technology is available. Human sufferings, due to inherited diseases, have been reduced more by the use of genetic diagnosis than any other medical technology. It is important to identity the gene responsible for a genetic disease before beginning to consider gene therapy.

3.2.2 Genetic Engineering Drugs

The war against infectious agents has produced a powerful arsenal of therapeutics, but treatment with drugs can sometimes exacerbate the problem. By killing all but the drug-resistant strains, infectious agents that are least susceptible to drugs survive to infect again. They become the dominant variety in the microbe population, a present-day example of natural selection in action. This leads to an ever-present concern that drugs can be rendered useless when the microbial world employs the survival-of-the-fittest strategy of evolution. And frequently used drugs contribute to their own demise by strengthening the resistance of many enemies. Drug-resistant pathogens — whether parasites, bacteria, or viruses — can no longer be effectively treated with common anti-infective drugs. A healthy future for the world's population will depend on engineering new strategies to overcome multiple drug resistances. Over the past two decades, many genetically-engineered drugs have been developed and approved for the treatment of patients. Typically, these drugs are characterized by a high and specific activity in the presence of optimal safety. They include hormones, enzymes, growth and coagulation factors, antibodies as well as vaccines. All these proteins are generated using recombinant DNA technology. An expression vector with the gene encoding for the protein of interest is introduced into an appropriate microorganism or cell line. The biochemical machinery of the host cell then translates the genetic information into the corresponding protein. Large scale production of the recombinant drugs uses biotechnological processes. The genetically-modified organisms are grown in bioreactors from which the desired protein is finally isolated and purified.

One major challenge in this endeavor will be to understand more fully how drug resistance comes about, how it evolves, and how it spreads. Furthermore, the system for finding and developing new drugs must itself evolve and entirely new approaches to fighting pathogens may be needed also.

Genetic engineering drugs have also provided the opportunity for the development of personalised medicine. This is the process of combining genetic information with clinical data to optimally tailor drugs and doses to meet the unique needs of an individual patient. Doctors have long known that people differ in susceptibility to disease and response to medicines. But, with little guidance for understanding and adjusting to individual differences, treatments developed have generally been standardized for the many, rather than the few or the individual. It is also known that though individuals contain about 20, 000 genes encoding three billion letters of information, the specific information that gives an individual his/her distinct characteristics is

encoded in less than 1% of the genes. Emerging genetic engineering techniques can now be used to identify these special genes in each individual and tailor treatments for that individual along these lines. Ultimately, the personalization of medicine should have enormous benefits. It will make disease (and even the risk of disease) evident much earlier, when it can be treated more successfully or prevented altogether. It could reduce medical costs by identifying cases where expensive treatments are unnecessary or futile. It will reduce trial-and-error treatments and ensure that optimum doses of medicine are applied sooner. Most optimistically, personalized medicine could provide the path for curing cancer, by showing why some people contract cancer and others do not, or how some cancer patients survive when others do not.

3.3 Vector-based Control

3.3.1 Sterile Insect Technique (SIT)

Sterile insect technique (SIT) is a biological control method that uses sterile male insects to reduce the reproductive rate of a species of target insect. The technology involves a deliberate genetic manipulation of male insects of a target insect, e.g. mosquito to make their males sterile. It is effective in many insect species because the female only mates once during her lifetime. She carries her mate's genetic material with her for the rest of her life and may lay several batches of eggs, but in many cases, she only receives genetic material from a male a single time during her life. If the genetic material she receives from the male fails to produce offspring, then the female will be unable to lay eggs that hatch into young insects. This technique works well with Screw flies (*Cochliomyia hominivorax*), an ecto-parasite of mammals, for an example. The Screw fly lays its eggs into the open wound of a large animal like a cow, goat, or sometimes even a human. When the eggs hatch the larvae feed on the flesh of the host animal inflicting pain and injury that sometimes could be fatal. Tsetse fly that causes sleeping sickness in parts of Africa, and the Mediterranean fruit fly, a pest of citrus crops has also been controlled through the sterilisation technique. The most widely used method of SIT is ionising radiation using gamma isotopic sources (such as cobalt-60 or caesium-137), high-energy electrons or X-rays. Other methods of sterilisation include elevated temperature, chemical liquids or gases although these are still not well established. Sterilisation by ionising radiation might weaken the newly sterilised insects, if doses are not correctly applied, making them less able to compete with wild males. However, Insect irradiation is safe and reliable when established safety and quality-assurance guidelines are followed. The key processing parameter is absorbed dose, which must be tightly controlled to ensure that treated insects are sufficiently

sterile in their reproductive cells and yet able to compete for mates with wild insects. To that end, accurate dosimetry (measurement of absorbed dose) is critical. Irradiation data generated since the 1950s, covering over 300 arthropod species, indicate that the dose needed for sterilisation of arthropods varies from less than 5 Gy for blaberid cockroaches to 300 Gy or more for some arctiid and pyralid moths. Factors such as oxygen level, and insect age and stage during irradiation, and many others, influence both the absorbed dose required for sterilisation and the viability of irradiated insects. Consideration of these factors in the design of irradiation protocols can help to find a balance between the sterility and competitiveness of insects produced for programmes that release sterile insects. Many programmes apply "precautionary" radiation doses to increase the security margin of sterilisation, but this overdosing often lowers competitiveness to the point where the overall induced sterility in the wild population is reduced significantly.

Recent development in science has made it possible to apply SIT to the control of mosquitoes, the vector of malaria and many other infectious diseases. It was initially thought that this method cannot be used on mosquitoes because when they lay eggs the eggs harden too quickly making it difficult to apply traditional sterilisation treatment. Recently, genetic engineering method was used to delay the hardening of the eggs by altering the genetic material of the mosquitoes. This variation of sterile insect technology does not use radiation to sterilize insects, but genetic modification or genetic radiation. This is also known as recombinant DNA technology. It works by adding a Dominant Lethal gene to the mosquitoes. The DNA in such genes can be suppressed while the mosquitoes are being bred in the lab, but once released in the wild, become active. The gene either causes any mosquito that carries it to die before they are able to reproduce, or make them unable to function as a host to the malaria parasite. This is an exciting new technology that might be used to drastically reduce the number of yearly malaria infections.

Insect sterilisation technology does have its drawbacks. Repeated treatments are often required for the method to be effective. It is more expensive than ordinary pesticides and many insects must be bred in factories and released into the wild. It can sometimes be difficult to separate the insect sexes for sterilisation. Also, the technology is species specific, so while there are twenty two species of Tsetse fly living in Africa, sterile males would have to be produced for each different species. Furthermore, when radiation is used it can affect the health of the male insect, causing it to be less likely to mate. This reduces the effectiveness of the effort.

Despite the drawbacks, sterile insect technology is a promising tool to fight insect infestations and insects spreading diseases around the world. It has the benefit of not using chemicals that affect the environment or any species other than the target species. Besides, recent results have greatly improved the fitness of genetically-modified insects compared to wild populations with new approaches such as the post-integration elimination of transposon sequences, stabilising any insertion in genetically-modified insects. Encouraging results, suggest that SIT alters some metabolism processes that also affect the viability of offsprings from released parent insect in the wild. Recent studies on vector symbionts would also bring a new angle in vector control capabilities, while complete DNA sequencing of some arthropods could point out ways to block the deadly impact on animal and human populations. These new potential approaches will improve the levels of control or even in some cases would eradicate vector species and consequently the vector-borne diseases they transmit.

3.3.2 Microbe- based Control

The role of microbial populations in the control of insects of medical and veterinary importance has expanded considerably with the discovery and development of new microbial control agents and genetic improvement in bacterial and viral pathogens, and improvements in formulation, application options and compatibility with other interventions. Several species of bacteria, viruses, fungi, protozoans and nematodes are now used as agents of control either naturally or genetically-modified. The most widely used of all microbial control agents is *Bacillus thuringiensis* (see subspecies in Table 9.1). The isolation within the past two decades of new strains that are larvicidal for certain Diptera and Coleoptera has increased the utility of the bacterium considerably. Further improvements in efficacy and broadening of its host range are in progress with the isolation of strains with new toxins and the manipulation of *B. thuringiensis* genes that encode toxin production using both recombinant and nonrecombinant methods. Genetic manipulation of these genes has also enabled their incorporation into crop plants. The development and commercial availability of entomopathogenic nematodes in the families Steinernematidae and Heterorhabditidae expands the options for the control of insects, especially those with soil inhabiting stages. The results of natural epizootics of fungi and viruses often make the need for additional interventions unnecessary. Recent understanding of the genetics of *Baculovirus* and subsequent gene manipulation has increased their virulence and utility. It is now possible to produce this virus using insect cell culture technology. Hopefully, this will not only make it more affordable but also easily available. Fungi continue to offer the only control options using entomopathogens against plant

sucking insects. Although fungi have great potential for development as microbial control agents, only a few have been used on an operational scale. Potential for development of resistance is also high in this technology and might limit its use. Since microbes very effective as control agents and have minimal environmental impact, they are ideal components of integrated pest management. However, if they are used merely as replacements for chemical pesticides, then eventually these agents will face some of the same fate as the chemicals they replace, particularly with respect to resistance.

Another approach for reducing disease transmission by arthropods is to genetically modify symbiotic bacteria of arthropod vectors to prevent the arthropods from transmitting human pathogens. By this approach, the arthropod is not transformed rather the symbiotic bacteria that it harbors are changed genetically. Such arthropods are called para-transgenic. This approach is based on the assumption that 1) many arthropods (especially those that throughout their entire developmental cycle feed on restricted food sources such as blood, cellulose, phloem, stored grains) harbor bacterial symbionts; 2) in some cases, these symbionts can be cultured and genetically transformed to express a gene whose product kills a pathogen that the arthropod transmits; 3) normal arthropod symbionts can be replaced with genetically-modified symbionts, resulting in a population of arthropod vectors that can no longer transmit disease. While not applicable to all groups of arthropods, this approach has been successful in the control of arthropod species that transmit Chagas disease.

3.3.3 Genetically- modified Microbial Pesticides

Synthetic chemical insecticides provide many benefits to food production and human health, but they also pose some hazards. In many instances, alternative methods of insect management offer adequate levels of pest control and pose fewer hazards. One such alternative is the use of microbial insecticides, also known as genetically-modified microbial insecticides. Genetically-modified microbial pesticides are either bacteria, fungi, viruses, protozoa, algae or their products whose DNA has been modified to express pesticidal properties. The modified microorganism generally performs as a pesticide's active ingredient. Microbial insecticides are especially valuable because their toxicity to non-target animals and humans is extremely low. Compared to other commonly used insecticides, they are safe for both the pesticide user and consumers of treated crops. Microbial insecticides also are known as biological pathogens, and biological control agents (Table 9.2).

Microbial insecticides are comprised of microscopic living organisms (viruses, bacteria, fungi, protozoa, or nematodes) or the toxins produced

by these organisms. They are formulated to be applied as conventional insecticidal sprays, dusts, liquid drenches, liquid concentrates, wettable powders, or granules. Each product's specific properties determine the ways in which it can be used most effectively.

Advantages of Microbial Insecticides

Individual products differ in important ways, but the following list of beneficial characteristics applies to microbial insecticides in general:

- The organisms used in microbial insecticides are essentially nontoxic and nonpathogenic to wildlife, humans, and other organisms not closely related to the target pest. The safety offered by microbial insecticides is their greatest strength.
- The toxic action of microbial insecticides is often specific to a single group or species of insects and this specificity means that most microbial insecticides do not directly affect beneficial insects (including predators or parasites of pests) in treated areas.
- If necessary, most microbial insecticides can be used in conjunction with synthetic chemical insecticides because in most cases the microbial product is not deactivated or damaged by residues of conventional insecticides.
- Because their residues present no hazards to humans or other animals, microbial insecticides can be applied even when a crop is almost ready for harvest.
- In some cases, the pathogenic microorganisms can become established in a pest population or its habitat and provide control during subsequent pest generations or seasons.

Disadvantages of Microbial Insecticides

The limitations or disadvantages listed below do not prevent the successful use of microbial insecticides. Understanding how these limitations affect specific microorganisms will help users to choose effective products and take necessary steps to achieve successful results:

- Because a single microbial insecticide is toxic to only a specific species or group of insects, each application may control only a portion of the pests present in a field, garden, or lawn. If other types of pests are present in the treated area, they will survive and may continue to cause damage. Conventional insecticides are subject to similar limitations because they too are not equally effective against all pests. Nonetheless, the negative aspect of selectivity is often more noticeable for microbials.
- Heat, desiccation (drying out), or exposure to ultraviolet radiation reduces the effectiveness of several types of microbial

insecticides. Consequently, proper timing and application procedures are especially important for some products.

- Special formulation and storage procedures are necessary for some microbial pesticides. Although these procedures may complicate the production and distribution of certain products, storage requirements do not seriously limit the handling of microbial insecticides that are widely available. (Store all pesticides, including microbial insecticides, according to label directions).
- Because several microbial insecticides are pest-specific, the potential market for these products may be limited. Their development, registration, and production costs cannot be spread over a wide range of pest control sales. Consequently, some products are not widely available or are relatively expensive (several insect viruses, for example).

Tables 2.2: Microbial Insecticides: A Summary of Products and their Uses

Pathogen	**Product Name**	**Host Range**	**Uses and Comments**
BACTERIA			
Bacillus thuringiensis var. *kurstaki* (*Bt*)	Bactur®, Bactospeine®, Bioworm®, Caterpillar Killer®, Dipel®, Futura®, Javelin®, SOK-Bt®, Thuricide®, Topside®, Tribactur®, Worthy Attack®	caterpillars (larvae of moths and butterflies)	Effective for foliage-feeding caterpillars (and Indian meal moth in stored grain). Deactivated rapidly in sunlight; apply in the evening or on overcast days and direct some spray to lower surfaces or leaves. Does not cycle extensively in the environment. Available as liquid concentrates, wettable powders, and ready to use dusts and granules. Active only if ingested.
Bacillus thuringiensis var. israelensis (*Bt*)	Aquabee®, Bactimos®, Gnatrol®, LarvX®,	larvae of *Aedes* and *Psorophora* mosquitoes,	Effective against larvae only. Active only if ingested. *Culex* and

	Mosquito Attack®, Skeetal®, Teknar®, Vectobac®	black flies, and fungus gnats	*Anopheles* mosquitoes are not controlled at normal application rates. Activity is reduced in highly turbid or polluted water. Does not cycle extensively in the environment. Applications generally made over wide areas by mosquito and blackfly abatement districts.
Bacillus thuringiensis var. *tenebrinos*	Foil® M-One® M-Track®, Novardo® Trident®	larvae of Colorado potato beetle, elm leaf beetle adults	Effective against Colorado potato beetle larvae and the elm leaf beetle. Like other *Bt*s, it must be ingested. It is subject to breakdown in ultraviolet light and does not cycle extensively in the environment.
Bacillus thuringiensis var. *aizawai*	Certan®	wax moth caterpillars	Used only for control of was moth infestations in honeybee hives.
Bacillus popilliae and *Bacillus lentimorbus*	Doom¨, Japidemic¨,® Milky Spore Disease, Grub Attack®	larvae (grubs) of Japanese beetle	The main Illinois lawn grub (the annual white grub, *Cyclocephala* sp.) Is NOT susceptible to milky spore disease. The disease is very effective against Japanese beetle grubs (not a major pest in Illinois) and cycles effectively for years in the soil.
Bacillus sphaericus	Vectolex CG®, Vectolex WDG®	larvae of *Culex, Psorophora,*	Active only if ingested, for use against *Culex,*

		and *Culiseta* mosquitos, larvae of some *Aedes* spp.	*Psorophora*, and *Culiseta* species; also effective against *Aedes vexans*. Remains effective in stagnant or turbid water. Commercial formulations will not cycle to infect subsequent generations.
FUNGI			
Beauveria bassiana	Botanigard®, Mycotrol®, Naturalis®	aphids, fungus gnats, mealy bugs, mites, thrips, whiteflies	Effective against several pests. High moisture requirements, lack of storage longevity, and competition with other soil microorganisms are problems that remain to be solved.
Lagenidium giganteum	Laginex®	larvae of most pest mosquito species	Effective against larvae of most pest mosquito species; remains infective in the environment through dry periods. A main drawback is its inability to survive high summertime temperatures.
PROTOZOA			
Nosema locustae	NOLO Bait®, Grasshopper Attack®	European cornborer caterpillars, grasshoppers and mormon crickets	Useful for rangeland grasshopper control. Active only if ingested. Not recommended for use on a small scale, such as backyard gardens, because the disease is slow acting and grasshoppers are very mobile. Also

			effective against caterpillars.
VIRUSES			
Gypsy moth nuclear plyhedrosis (NPV)	Gypchek® virus	gypsy moth caterpillars	All of the viral insecticides used for control of forest pests are produced and used exclusively by the U.S. Forest Service.
Tussock moth NPV	TM Biocontrol-1®	tussock moth caterpillars	
Pine sawfly NPV	Neochek-S®	pine sawfly larvae	
Codling moth granulosis virus (GV)	(see comments)	codling moth caterpillars	Commercially produced and marketed briefly, but no longer registered or available. Future re-registration is possible. Active only if ingested. Subject to rapid breakdown in ultraviolet light.
ENTOMOGENOUS NEMATODES			
Steinernema feltiae (=*Neoaplectana carpocapsae*) *S. riobravis*, *S. carpocapsae* and other *Steinernema* species	Biosafe®, Ecomask®, Scanmask®, also sold generically (wholesale and retail), Vector®	larvae of a wide variety of soil-dwelling and boring insects	*Steinernema riobravis* is the main nematode species marketed retail in the U.S. Because of moisture requirements, it is effective primarily against insects in moist soils or inside plant tissues. Prolonged storage or extreme temperatures before use may kill or debilitate the nematodes. Effective in cool temperatures.

Heterorhabditis heliothidis	currently available on a wholesale basis for large scale operations	larvae of a wide variety of soil-dwelling and boring insects	Not commonly available by retail in the U.S.; this species is used more extensively in Europe. Available by wholesale or special order for research or large-scale commercial uses. Similar in use to *Steinernema* species but with some differences in host range, infectivity, and temperature requirements.

PATHOGEN			
Steinernema scapterisci	Nematac®S	late nymph and adult stages of mole crickets	*S. scapterisci* is the main nematode species marketed to target the tawny and southern mole cricket. Best applied where irrigation is available. Irrigate after application.

Source**:** Weinzierl et al., (2012)

4.0 CONCLUSION

In this unit, we have described the application of biotechnology methods to pest and disease control. We learnt that most biotechnology methods involved the direct use of microorganisms or transformation of their genetic materials to enable them performs more efficiently as a control agent. You also learnt the methods target different stages of disease transmission. While some methods such as development of biosynthetic vaccine and chemically synthetic vaccines are used for prevention, others such as gene therapy, genetic engineering drugs, sterile insect technique, and microbe- based control and genetically-modified microbial pesticides are targeting parasites or the vectors of disease transmission. Generally, these biotechnology methods have been found

useful, effective and very promising although there are still some teething challenges yet to be addressed.

5.0 SUMMARY

In this unit, you have learnt about the role of biotechnology techniques in pest and disease control. You learnt that biotechnology methods can be applied in the prevention and control of diseases. While preventive methods aim at preventing the establishment of disease, control methods target either the parasites or vectors of disease transmission. The preventive methods are based on the development of biosynthetic and chemically based vaccines. Vaccines are inoculations of dead microbes that help the body immune system develop resistance against future infection of the same disease.

We also discussed the role of genetically-modified microbial pesticides. These are pesticides that use bacteria, fungi, viruses, protozoa, algae or their products whose DNA has been modified to express pesticidal properties as active ingredients rather than the normal organic or inorganic compounds. These have been tested and found very effective. Several brands are widely marketed and represents one of the most widely used and accepted products of biotechnology. In the next unit, you will learn about how these genetic engineering methods can be applied to food safely and hygiene.

6.0 TUTOR-MARKED ASSIGNMENT

1. Differentiate between somatic and germ line gene therapy.
2. State the hindrances associated with using the germ line gene therapy in human.
3. Discuss the importance of genetic engineering drug in the treatment of resistant diseases.
4. Explain the mechanism of insect sterilisation and its application in vector control of diseases.
5. Describe the role of biotechnology in the chemical synthesis of vaccines.

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UNIT 3 APPLICATION OF BIOTECHNOLOGY TO FOOD PRODUCTION AND PRESERVATION

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt about the role of biotechnology in pest and disease control. In this unit, you will learn the principles of biotechnology application looking at food safety and hygiene.

2.0 OBJECTIVES

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

- explain what is a genetically-modified food including the role it plays in crop production and animal husbandry
- describe the quality of genetically-modified foods, including taste and texture
- explain the role of biotechnology in food preservation
- explain public concerns on genetically-modified foods.

3.0 MAIN CONTENT

3.1 Genetically-modified Food

Microorganism such as bacteria and fungi in collaboration with worms play vital roles in creating and maintaining soil fertility. When animals, plants or other organisms die, the remains are broken down by decomposers, especially fungi, bacteria and earthworms. Decomposition recycles important nutrients such as nitrogen and phosphorus into the

soil to make them available for plants. Insects play a secondary role in this process, because both their remains and their faeces are recycled in the same manner. Some fungi colonise plant roots and act as symbionts, providing nutrients such as phosphorus and nitrogen to the plant in exchange for carbon.

Nitrogen-fixing and nitrifying bacteria play a more important role by capturing atmospheric nitrogen and converting it to compounds plants can use. Earthworms also help mix the soil, carrying organic compounds from higher soil to lower layers and increasing porosity, which increases the rate of nutrient and water flow. Some species of fungi can help clump or bind soil particles, increasing the amount of water the soil can hold. Not only do bacteria, fungi and earthworms help sustain plant life, they lend soil its characteristic odor.

These activities increase soil fertility, which generally is a function of available nutrients in the soil. Plant growth in any soil therefore depends on the availability of nutrients and ability of plants to take them up. Application of biotechnology to plant growth is usually directed at either optimising the activities of soil microorganisms to enhance soil nutrients or the ability of plants to take up nutrients, or both. Specifically, it involves a genetic modification of plant seedlings for better crop yield and to make them more resistance to pests, reduce weed and pest effects. Genetically-modified foods are therefore foods produced by altering the genetic materials either in plants or animal to enable them grow better or withstand pests or pathogens of diseases in the environment.

3.1.1 Genetically-modified crops

Conventional plant breeding to improve plant characteristics involves selecting and breeding individuals with desired characteristics. Consequently, modern plants evolving in the last millennium differ substantially from their ancestors. Plant breeding is carried out by crossing breeds of two individuals of the same or of two very closely related species. Each parent contributes half of its genetic material (DNA) to its offspring (equivalent to sexual reproduction). This means a wholesome transfer of both beneficial and non-beneficial characteristics. Progressive selection may subsequently eliminate all or some of the non -beneficial characteristics, but there is never a full proof assurance that this will ever happen. This is because, this conventional method is slow to act and takes very long time, often many generations to take place.

Modern biotechnology has changed all these. By using genetic engineering methods, it is now possible to identify those genes encoding

beneficial characteristics, isolate them and incorporate them into another plant at the expense of non-beneficial threats. This gives rise to a new, better and beneficial crop. This is the genetically-modified or engineered crop (commonly known as GM crops). Several methods are used to accomplish genetic modification of crops. These include (1) cisgenesis which involves the insertion or deletion of genes. In this process, genes are artificially transferred between organisms that could be conventionally bred. (2) transgenesis in which genes from a different species are inserted into another plant (a form of horizontal gene transfer). Transgenesis may also occur in nature when exogenous DNA (foreign DNA) penetrates the cell membrane of another plant species for any reason. Artificially, gene transfer can be carried out using different methods (1) as part of an attenuated virus genome, (2) by physically inserting the extra DNA into the nucleus of the intended host using a microsyringe (requiring a highly technical skill), (3) by coating the gene on gold nanoparticles and firing from a gene gun. Naturally, transfer between plant cells is carried out by vector bacteria such as *Agrobacterium* and between animal cells by vector virus such as lentiviruses.

Introducing new genes into plants requires a promoter specific to the area where the gene is to be expressed. For instance, if we want the gene to be expressed only in rice grains and not in leaves, then an endosperm-specific promoter gene would be used. The codons (a sequence of three adjacent nucleotides constituting the genetic code that determines where specific amino acids are inserted in a polypeptide chain during protein synthesis or the signal to stop protein synthesis) of the gene being transferred must also be optimised for the organism because every gene determines what codon it uses in each organism. The transgenic gene products should also be able to be denatured by heat so that they are destroyed during cooking.

Growth of genetically- modified plants is growing by the day. It started in the industrialised countries but is now spreading in many developing countries. In 2006, 252 million acres of transgenic crops were planted in 22 countries by 10.3 million farmers. The majority of these crops were herbicide- and insect-resistant soybeans, corn, cotton, canola, and alfalfa. Other crops grown commercially or field-tested are a sweet potato resistant to a virus that could decimate most of the African harvest, rice with increased iron and vitamins that may alleviate chronic malnutrition in Asian countries, and a variety of plants able to survive weather extremes.

On the horizon are bananas that produce human vaccines against infectious diseases such as hepatitis B; fish that mature more quickly; cows that are resistant to bovine spongiform encephalopathy (mad cow

disease); fruit and nut trees that yield years earlier, and plants that produce new plastics with unique properties.

In the same year 2006, countries that grew 97 per cent of the global transgenic crops were the United States (53 per cent), Argentina (17 per cent), Brazil (11 per cent), Canada (six per cent), India (four per cent), China (three per cent), Paraguay (two per cent) and South Africa (one per cent). Although growth is expected to stabilise industrialised nations, it is increasing in developing countries. By the year 2020, it is expected that rate of genetically-modified crops will grow exponentially in the developing nations as researchers gain increasing and unprecedented access to genomic resources that are applicable to a wide range of organisms.

3.1.2 Genetically-modified Animals

A genetically- engineered or "transgenic" animal is an animal that carries a known sequence of recombinant DNA in its cells, and which passes that DNA onto its offspring. Recombinant DNA refers to DNA fragments that have been joined together in a deliberate pattern. The resultant recombinant DNA "construct" is usually designed to express the protein(s) that are encoded by the gene(s) included in the construct, when present in the genome of a transgenic animal. Because the genetic code for all organisms is made up of the same four deoxynucleotide building blocks, this means that a gene makes the same protein whether it is made in an animal, a plant, or a microbe. Transgenic animals look and behave normally, and differ from their non-modified counterparts only in the expression of an additional protein produced by the extra DNA encoded in its genome. Some examples of proteins that have been expressed in transgenic animals include therapeutic proteins for the treatment of human diseases, proteins that enable animals to better resist disease and proteins that result in the production of more healthful animal products (milk, eggs, or meat) for consumers.

A variety of techniques have been used to produce transgenic livestock with varying degrees of success. Microinjection of foreign DNA into newly fertilized eggs has been the predominant method used for the generation of transgenic livestock over the past 20 years. This technology is inefficient (3-5 per cent of animals born carry the transgene) and this results in an animal welfare concern because it requires the use of many more animals than would be needed if success rates were higher. Additionally, this technique results in random integration and variable expression levels of the target gene in the transgenic offspring. Thus, the level of expression of the introduced gene is generally very poor. This has sometimes resulted into significant growth abnormalities. Newer methods of making transgenic

animals have been developed that employ somatic cell nuclear transfer cloning. The cloning process was first made famous by Dolly the sheep. Cloning offers the opportunity to produce 100 percent transgenic offspring from cell lines that are known to contain the transgene, and further also allows gene targeting whereby researchers are able to integrate the foreign DNA at a specific location in the genome, and thereby have more control over the expression level of the transgene. There have been published reports of the following species being cloned: carp, sheep, mice, cattle, goats, pigs, cats, rabbits, mules, horses, rats, and a deer. Some closely related species have also been cloned (a banteng, a wild cow, and a mouflon, a kind of sheep). A gaur, a wild ox, was cloned but died within two days.

Attempts have also been made, without success, to clone monkeys, dogs, pandas, chickens, and at least two extinct species: the Tasmanian tiger and the woolly mammoth. The mammoth experiment used an elephant surrogate and tissue found in permafrost.

Genetic engineering is a useful technology because it enables animals to produce extra and beneficial proteins. Conventional animal breeding is constrained to selection based on naturally-occurring variations in the proteins that are present in a species, and this limits the range and extent of genetic improvement. Genetically-engineered animals are being produced for two distinct applications: human medicine and agriculture.

Most commercial transgenic animal research is in the field of human medicine. Many therapeutic proteins for the treatment of human diseases require that animal cells are specifically modified in a specific way. This can only be done using the genetic engineering techniques, in most cases using the mammalian cell-based bioreactors.

In 2006, the first human therapeutic protein, Antithrombin III (ATryn®, GTC Biotherapeutics, Framingham, Mass.), derived from the milk of genetically-engineered goats was approved by the European Commission for the treatment of patients with hereditary antithrombin deficiency. Transgenic animals are also being used to produce serum biopharmaceutical products, such as antibodies that can be used for the treatment of infections, cancer, organ transplant rejections and autoimmune diseases such as rheumatoid arthritis.

Transgenic mice have also become increasingly important for biological and biomedical research and have generated a vast amount of vital information about human diseases. Other transgenic animals, including livestock species, are being produced specifically as biomedical research models for various human afflictions including Alzheimer's disease, eye disease, and the possible xenotransplantation of cells,

tissues, and organs from genetically-engineered animals into human organ-transplantation patients. Transgenic animals are also being used to study animal diseases such as "mad cow" disease (BSE, bovine spongiform encephalopathy), and infection of the udder (mastitis).

Transgenic livestock for agricultural applications have also been produced but not at a commercial scale. These animals have enhanced production traits (e.g. egg-laying), are environmentally beneficial (produce less waste) and are disease resistant.

3.2 Quality and Safety of Genetically-modified Foods

The use of genetic engineering in agriculture and food production has impacts, not only on the environment and biodiversity, but also on human health. Therefore, thorough bio-safety assessment requires, not only evaluation of environmental impacts of genetically- engineered organisms, but also assessment of the risks that genetically- engineered foods may pose to the health of consumers.

There are three hazards that may arise from genetic engineering of foods. These are (1) allergens, (2) toxins, and (3) reduced nutritional quality. The genetic engineering of foods involves the introduction of new genetic information into a food-producing organism. Some of the health risks associated with genetically-engineered foods can therefore come from the organism being modified (unmodified organism UMO) or from the donor organism (gene source, GS) from where the genetic material being transferred was taken. For instance, if a gene derived from peanuts is introduced into a tomato, food produced from the resulting genetically-engineered tomato might cause allergic reactions in people that are allergic either to tomatoes (UMO) or to peanuts (GS). A third source of hazard is the procedure of genetic engineering itself. Current recombinant DNA methods and those likely to be developed in the future are all capable of accidentally introducing unintended changes in the function and structure of the food producing organism. As a result, the genetically-engineered food may have characteristics that were not intended by the genetic engineer, and that cannot be foreseen on the basis of the known characteristics of the unmodified organism or gene source. To assure the safety of genetically-engineered foods, it is essential to test for health hazards derivable from all three sources of risk above.

As already stated the three most important hazards of genetically-engineered foods are allergens, toxins and reduced nutritional quality. Although there are several ways by which allergens could develop in genetically-engineered foods empirical evidence of its rate is sparse probably because only few of these foods have been tested for

allergenicity. However, evidence that it exists was provided by Pioneer Hybrid (a biotech company), which developed genetically-modified soybeans that contain proteins which turn out to be allergenic to a significant proportion of the population. The company subsequently terminated plans to commercialize this product.

Most substances that will occur in foods as a result of genetic engineering will be proteins that will be present in only trace concentrations. Nevertheless, those added components, in even trace amounts, may substantially alter either the nutritional or other biological characteristics of the food. In addition to allergenicity, recombinant proteins could manifest a variety of other biological activities, and, in the case of recombinant enzymes, could catalyze the production of other compounds with biological activities not normally present in a particular food. Such substances could act as toxins, irritants, hormone mimetic (imitation), etc., and could act at the biochemical, cellular, tissue, or organ levels to disrupt a range of physiological functions.

An example of a class of genetically-engineered foods that are of particular concern are those that have been modified to produce biological control agents, such as the family of insecticidal Bt enterotoxins. Each of the Bt toxins is specific for a certain class of insects. Although the Bt toxin has been used topically in organic farming for many years without unexpected effects, concern still remain of its long term effect. The greatest concern however, is the underlying fact that it is impossible to carry out laboratory experiments that will exhaustively, thoroughly, and conclusively establish that a genetically-engineered food is free of such toxins, and therefore absolutely safe. This fact was clearly illustrated by the tragic case of L-tryptophan (an essential amino acid in the human diet). The company Showa Denko genetically-engineered a microorganism to produce L-tryptophan at high levels. The enzymes expressed in this bacterium through genetic manipulations were not present in massive amounts, but they altered the cellular metabolism substantially, leading to greatly increased production of tryptophan. This organism was immediately used in commercial production of L-tryptophan, and the product placed on the market in the USA. Within two months, 37 people died and 1500 were permanently disabled from using this product. Apparently, this may have been due to the presence of traces of powerful toxic contaminants in the product. This contaminant was extremely powerful, since the preparation was at least 98.5% tryptophan.

Nutritionally, genetically-modified foods are of high quality and taste and nutritionally rich. It improves yield and shortens production cycles. Genetic modification also endows crops with greater resistance to common diseases and harsh weather conditions. Genetic modification of

animals, likewise, improves animal health, minimizing their chances of being affected with common infections. Naturally, the improved breeds give better yields of eggs, meat and milk. Genetically-modified foods were first introduced to the market in the early 1990s. The first was the tomato called FlavrSavr (created by Calgene in 1992). It was released in the US market post FDA approval in 1994. A slightly different variant of the FlavrSavr was introduced in Europe in a paste form in 1996. Other GM food crops in the market are herbicide and insecticide-resistant soybeans, canola, corn, cotton, sweet potato (resistant to a virus that has been destroying most of the African harvest), an iron and vitamin-enriched rice variety (to combat widespread malnutrition in Asian nations). A variety of plants able to withstand extreme weather conditions are being field-tested prior to being launched in the market. Genetically-modified fruit and nut varieties that attain maturity early and bear fruits for long (or twice a year) have also been introduced. Finally, genetic modification has also been used to develop fast maturing varieties of fish and poultry and milk production.

3.3 Food Preservation

Preserving food to extend its shelf-life, whilst ensuring its safety and quality, is a central concern of households and food industries. Preservation usually involves preventing the growth of bacteria, fungi (such as yeast), and other micro-organisms (although some methods work by introducing benign bacteria or fungi to the food), as well as retarding the oxidation of fats. Food preservation can also include processes which inhibit visual deterioration, such as the enzymatic browning reaction in apples after they are cut, which can occur during food preparation.

Many processes designed to preserve food will involve a number of food preservation methods. Preserving fruit by turning it into jam, for example, involves boiling (to reduce the fruit's moisture content and to kill bacteria, yeasts, etc.), sugaring (to prevent their re-growth) and sealing within an airtight jar (to prevent recontamination). There are many traditional methods of preserving food that limit and reduce carbon footprint ("the total set of greenhouse gas (GHG) emissions caused by an organization, event, product or person.).

There are several traditional methods of food preservation and a few emerging biotechnology ones. The traditional methods include but not limited to sun drying, refrigeration, freezing, vacuum packing, salting, sugaring, smoking, artificial food additives, pickling, lye (sodium hydroxide that makes food too alkaline for bacteria to act on, canning and bottling (to prevent microbial access), jellying (cooking in a material that solidifies to gel also to prevent microbial access), jugging

(a process of stewing the meat in a covered earthenware jug or casserole). Irradiation (exposure to ionizing radiation such as high-energy electrons, X-ray from accelerators, gammar rays emmitted from radioactive sources as Cobalt-60 or Caesium-137), pulsed electric field processing (a method of processing cells using brief pulses of a strong electric field, a type of low temperature alternative pasteurization process for sterilizing food products), modified atmosphere (environmental manipulation), hih pressure (exposure to high pressure) and burial in the ground (exposure to low temperature, low oxygen etc.). The emerging biotechnology methods include controlled use of microorganisms, biopreservation and hurdle technology.

Controlled use of microorganisms is based on the principle that some foods, such as many cheese, wines and beers will keep for a long time because their production involved the use of specific micro-organisms that combat spoilage from other less benign organisms. These micro-organisms keep pathogens in check by creating an environment toxic for themselves and other micro-organisms by producing acid or alcohol. Starter micro-organisms, salt, hops, controlled (usually cool) temperatures, controlled (usually low) levels of oxygen and/or other methods are used to create the specific controlled conditions that will support the desirable organisms that produce food fit for human consumption.

Biopreservation is the use of natural or controlled microbiota or antimicrobials to preserve food and extend its shelf life. Beneficial bacteria or the fermentation products produced by these bacteria are used in biopreservation to control spoilage and render pathogens inactive in food. One of such beneficial bacteria are lactic acid bacteria (LAB). Lactic acid bacteria have antagonistic properties which make them particularly useful as biopreservatives. When LABs compete for nutrients, their metabolites often include active antimicrobials such as lactic and acetic acid, hydrogen peroxide, and peptide bacteriocins. Some LABs also produce the antimicrobial nisin which is a particularly effective preservative. LAB bacteriocins are now used as an integral part of hurdle technology for maximum effect. Using them in combination with other preservative techniques can effectively control spoilage bacteria and other pathogens, and can inhibit the activities of a wide spectrum of organisms, including inherently resistant gram negative bacteria.

Hurdle technology is combination of preservative methods with an objective of total eliminating of pathogens in food products. This method can be thought of as an assemblage of "hurdles" pathogens have to overcome if they wish to remain active in the food. The right combination of these hurdles ensures that none of the pathogens ever is

a able to overcome all and subsequently all are eliminated or rendered too weak to be harmful.

Accordingly, Leistner (2000) defined hurdle technology as 'an intelligent combination of hurdles which secures the microbial safety and stability as well as the organoleptic and nutritional quality and the economic viability of food products. The organoleptic quality of the food refers to its sensory properties, that is its look, taste, smell and texture.

Examples of hurdles in a food system are high temperature during processing, low temperature during storage, increasing the acidity, lowering the water activity or redox potential, or the presence of preservatives or biopreservatives. According to the type of pathogens and how risky they are, the intensity of the hurdles can be adjusted individually to meet consumer preferences in an economical way, without sacrificing the safety of the product. The basic well tested hurdle options available are presented in

Table 10.1: Principal Hurdles Used for Food Preservation (after Leistner, 1995)

Parameter	**Symbol**	**Application**
High temperature	F	Heating
Low temperature	T	Chilling, freezing
Reduced water activity	a_w	Drying, curing, conserving
Increased acidity	pH	Acid addition or formation
Reduced redox potential	E_h	Removal of oxygen or addition of ascorbate
Biopreservation		Competitive flora such as microbial fermentation
Other preservatives		Sorbates, sulfites, nitrites

4.0 CONCLUSION

In this unit, you have learnt the principles of biotechnology application to food safety and hygiene. We have explained the meaning, concept and scope of genetically-modified foods including how they are produced. Genetically- modified foods are crops and animals produced by a deliberate alteration of their genetic constitution to enable them grow better and withstand environmental adversities such as pest infestation and / or disease infection. Specifically, genetically-modified crop or genetically-engineered crop (abbreviated to GM or GE crop) involved a deliberate alteration of the genetic makeup of a plant species to increase productivity, withstand insect pest, weeds and improve on

the nutritional quality of its products. The alteration is carried out either through cisgenesis (insertion or deletion of genes involving artificial transfer between organisms that could be conventionally bred) or transgenesis (inserted into another plant of different species). Most genetically-engineered crops grown around the world are herbicide- and insect-resistant and included soybeans, corn, cotton, canola, alfalfa, sweet potato and rice. The United States of America is leading other 21 nations known to grow genetically-modified crops. Although several concerns were expressed about the safety of genetically-modified foods, acceptance is increasing so is the proportion of genetically-modified foods in the market.

5.0 SUMMARY

In this unit, we have described the application of biotechnology to food production and safety. You learnt that biotechnology methods can be used to improve on food production, processing and preservation. You learnt that biotechnology techniques such as genetic engineering is being used to make crops better by developing insect and disease resistant crops, herbicide resistant crops and high yielding seedling and cultivars for the production of genetically-modified foods (GM foods) also known as genetically-engineered foods (GE foods). You learnt that genetic engineering is also used to reduce the time it takes crops to begin production and to make tastier and better looking crops and fruits. In the next unit, we will continue the discussion by looking at the application of biotechnology to pollution control and abatement.

6.0 TUTOR-MARKED ASSIGNMENT

1 i Write a concise essay on the importance of genetic engineering in the production of genetically-modified crops.
   ii. List some of the modified crops produced by genetic engineering.
2 Compare and contrast the method use in producing transgenic livestock.
3 State the advantages and disadvantage of the genetic engineering technology over the conventional method of animal breeding
4 Explain the following:

   i. controlled use of micro organism
   ii. bio-preservation
   iii hurdle technology

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UNIT 4 APPLICATION OF BIOTECHNOLOGY TO AIR AND WATER POLLUTION CONTROL

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt all about the principles of biotechnology application to production and preservation for safety and hygiene. You learnt that food production using biotechnological techniques involves the alteration of genetic materials in crops and animals to make them better, safer and of higher nutritional quality. In this unit, we shall discuss application of biotechnology to pollution control and abatement.

2.0 OBJECTIVES

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

- explain the conventional methods of air pollution control
- describe the various types of bio filtration and their application to air pollution control
- explain what is aerobic biological treatment of polluted water
- explain what is anaerobic biological treatment of polluted water
- describe the application of enzymes and microbial cells to effluent treatment.

3.0 MAIN CONTENT

3.1 Air Pollution Abatement

Air pollution is the presence in larger than normal concentrations of chemicals, particulate matter and biological materials that cause harm or discomfort to humans or other living organisms, or cause damage to the natural environment, or built environment in the atmosphere. The composition of normal free air in the atmosphere is Nitrogen (N_2) 78.084%, Oxygen (O_2) 20.9476%, Argon (Ar) 0.934%, Carbon Dioxide (CO_2) 0.0314% and Neon (Ne) 0.001818%. Substantial change in this proportions or infiltration of other particles including disease causing materials constitutes pollution. There are several major types of pollutants in air causing different types of effects on the environment and human health. These include smog, acid rain, the greenhouse effect, and "holes" in the ozone layer. Each of these problems has serious implications for our health and well-being as well as for the whole environment.

One type of air pollution is the release of **particles** into the air from several human activities including burning fuel for energy. Diesel smoke is a good example of this particulate matter loading. The particles are very small pieces of matter measuring between 2.5 ($PM_{2.5}$) and 10 (PM_{10}) microns that form black carbon pollution in the air. Other sources include exhaust from burning fuels in automobiles, homes, and industries as well as the burning of biomass materials such as wood and charcoal.

Another type of pollution is the release of **noxious gases**, such as sulfur dioxide, carbon monoxide, nitrogen oxides, and chemical vapors. These can take part in further chemical reactions once they are in the atmosphere, forming smog and acid rain. Pollution is also created in our homes, offices and schools by some activities we perform, e.g. smoking and cooking. Exposure to harmful indoor pollutants can be serious and increases as the number of hours we spend inside built up environment increases. It is therefore important to consider both indoor and outdoor air pollution in any mitigation and control programmes.

3.1.1 Conventional Methods

Conventional methods of air pollution control are based mainly on things we as individuals can do to prevent air pollution and make our environment cleaner and safer. Recommended clean air practice include carpooling, walking, riding bicycles and using public transportation systems to help reduce the number of cars on the road, thus, air pollution from exhaust pipes. On a larger scale, there are many

different types of equipment available for businesses and factories to cut down or even prevent air pollution. These equipment include baghouse filters, activated carbon absorbers and gas absorption towers. Baghouse filter can be used in many areas like coal, power, steel, chemical, and even mining industries. They have the capacity to filter huge gas volumes and remove most particulate matter from air before it is released into the atmosphere. The carbon absorbers remove things like organic acids, hydrogen sulfide and aldeheydes. Chemical absorption towers are designed to remove chemicals such as hydrogen sulfide, ammonia, sulfuric acid, nitrogen oxides, sulfur dioxide and many more. Sometimes it may be necessary to customize any of these equipment to meet specific needs.

Cigarette smoke is also a major contributor to air pollution and one of the best control practice is reduction in the number of smokers and the rate at which individuals smoke. Indoor air pollution is best controlled by appropriate ventilation and reduction in rate of activities that generate smoke or polluted air indoors. Such practices include indoor smoking, cooking etc.

3.1.2 Biofiltration

Biofiltration is a pollution control technique that uses living materials to capture and biologically degrade process pollutants. Common uses include processing waste water, capturing harmful chemicals or silt from surface run-off and microbiotic oxidation of contaminants in air. Examples of biofiltration include bioswales, biostrips, biotrickling, biofilters, constructed and natural wetlands, slow sand filters, treatment ponds, green belts and the living walls. The most commonly used filters for the removal of odour and particulate matter are the biofilters and bioscrubbers in air.

A biofilter is simply a bed of organic material (medium), typically a mixture of compost and wood chips or shreds, about 25-46 cm deep. As air passes through the biofilter the microbes on the organic material convert odorous gases to carbon dioxide and water. The effectiveness of the biofilter is primarily a function of the amount of time the odorous air spends in the biofilter (contact time) and the moisture content of the filter material. Contact time is part of the biofilter design while moisture content is a function of good management. The size (footprint) of the biofilter depends primarily on the amount of air needing treatment. A typical biofilter will require 4.65 – 7.90 m^2/28.3 m^3/minute of airflow. Biofilters are also categorised by their configuration (open or closed), flow sequence (up-flow, down-flow or horizontal flow).

A bioscrubber has a circulated scrubbing liquid which contains water and microorganisms for degradation of the substances to be separated off from the dirty gas. The gas enters at an inlet, moves through a mass-transfer zone, where it undergoes a phase change from the gas phase to the liquid phase, and the clean gas exits through an outlet. The system has a device for irrigating the mass-transfer zone with the scrubbing liquid, and a tank for collecting the scrubbing liquid and for activating the microorganisms. The bioscrubber has particularly high separation rates and particularly low risk of blockage because, in at least one mass-transfer zone of the bioscrubber, there may be provided a package of adjacent vertical tubes and a cleaning device for cleaning the tubes. A mass-transfer zone can be formed by a spray tower.

3.2 Water Pollution Abatement

Water pollution is an undesirable change in the state of water, contaminated with harmful substances. It is the second most important environmental issue next to air pollution. Any change in the physical, chemical and biological properties of water that has a harmful effect on living things is water pollution. It affects all the major water bodies of the world such as lakes, rivers, oceans and groundwater. Pollution of the water bodies disturbs the ecosystem as a whole. Polluted water is not only unsafe for drinking and other consumption purposes, but it is also unsuitable for agricultural and industrial uses. The effects of water pollution are detrimental to human beings, plants, animals, fish and birds. Polluted water also contains virus, bacteria, intestinal parasites and other pathogenic microorganisms. Using it for drinking purpose is the prime cause for waterborne diseases such as diarrhoea, dysentery and typhoid. The important sources of water pollution are domestic wastes, industrial effluents and agricultural wastes. Other sources include oil spills, atmospheric deposition, marine dumping, radioactive waste, global warming and eutrophication. Among these, domestic waste (domestic sewage) and industrial waste generate most pollutants, which make their way to groundwater and surface water bodies. In order to reduce the level of pollution of water and effectively utilize water resources, it is important to control not only existing pollution in water but also the rate of pollution in the future. Although 71% of earth's surface is covered with water bodies, we don't have enough water to drink. Many researches have been done on water purification systems in order to have safe drinking water. However, there are about 1 billion people, who don't have proper access to drinking water. Therefore, water needs to be conserved and prevented from pollution in order to make it safe for drinking and other consumption purposes. The major water treatment procedures available to achieve this goal are broadly divided into chemical and biological methods. There are three major types of biological treatment methods defined on the basis of oxygen

demand. All involves the activities of microorganisms in the presence of oxygen (aerobic), absence of oxygen (anaerobic) or in oxygen deficient environment (anoxic).

3.2.1 Aerobic Biological Treatment

Aerobic biological treatment which may follow some form of pretreatment such as oil removal, involves exposing wastewater to microbes and oxygen in a reactor or pond to optimise the growth and efficiency of the biomass. The microorganisms act to catalyse the oxidation of biodegradable organics and other contaminants such as ammonia, generating harmless by- products such as carbon dioxide, water, and excess biomass (sludge). This is a bioprocess activity in which microorganisms (aerobes) utilise dissolved oxygen supplied naturally or artificially from aerators to degrade organic wastes. The microorganisms may consist of naturally occurring bacteria, fungi, protozoa, rotifers or other microbes usually present in most wastewaters or may be genetically-engineered to optimise their activities. Population dynamics of the microbes depend on environmental factors such as pH, temperature, type and concentration of the substrate, hydrogen acceptor, concentration of essential nutrients e.g. nitrogen, phosphorus, sulfur, etc. The microorganisms feed on the organic materials in the process degrading them to simpler organic or inorganic compounds. Typical organic materials that are found in residential wastewater include carbohydrates, fats, proteins, urea, soaps and detergents. These are degraded into simple organics like CO_2 or biologically transformed from organic forms to mineralised forms (i.e., NH3, NH4, NO3, SO4, and PO4). The primary mechanism of action used by both the aerobic and anaerobic microorganisms is fermentation process in two lines. The first line involves heterotrophic microorganisms that use organic carbon for the formation of new biomass. These organisms are consumers and decomposers that depend on a readily available source of organic carbon for respiration and growth. They primarily reduce soluble BOD in wastewater treatment. The second line are the autotrophic microorganisms that utilise simple forms of carbon (such as carbon dioxide) to remove nitrogen from wastewater. Design of treatment facilities such as bioreactors provide the microbes with optimal conditions for rapid degradation of wastewaters. This includes excess dissolved oxygen to enable the aerobic and facultative microbes rapidly oxidise soluble, bioavailable organic and nitrogenous compounds in wastewater. When dissolved oxygen is available, the aerobic decomposition of organic compounds consumes dissolved oxygen in the water. If the rate of re-aeration is not equal to the rate of consumption, the dissolved oxygen concentration will fall below the level needed to sustain a viable aquatic system.).
Aerobic treatment has many advantages and disadvantages. The

advantages include:

(1) Production of minimum odour effect when properly loaded and maintained
(2) Removal of large biochemical oxygen demand (BOD) providing a good quality effluent
(3) High rate treatment allowing smaller scale systems, e.g., less land required
(4) The final discharge may contain dissolved oxygen which reduces the immediate oxygen demand on a receiving water; and
(5) The aerobic environment eliminates many pathogens present in agricultural wastes.

Aerobic treatment also has main disadvantage which include:

(1) High energy cost of aeration that must be maintained to achieve adequate rate of dissolved oxygen levels needed to maintain aerobic conditions in the treated wastewater for aerobic growth
(2) Some organics cannot be efficiently decomposed aerobically because they are biologically non-reactive and may constitute about 70% of the chemical oxygen demand (COD)
(3) Rapid production of sludge may affect the storage capacity of the ponds.

3.2.2 Anaerobic Biological Treatment

Anaerobic (without oxygen) and anoxic (oxygen deficient) treatments are similar to aerobic treatment, but use microorganisms that do not require the addition of oxygen. These microorganisms use the compounds other than oxygen to catalyse the oxidation of biodegradable organics and other contaminants, resulting in harmless by-products. Since the organic pollutants are degraded by anaerobic microorganisms in the absence of oxygen the gas produced contain predominantly methane and carbon dioxide. This is known as "biogas".

3.2.3 Aeration and Loading Techniques

Regardless of the type of system selected (aerobic, anaerobic or anoxic), there are two major contact design options that could be adopted to maintain the required population of microbes in a bioreactor. These are:

- Fixed film processes — microorganisms are held on a surface, the fixed film, which may be mobile or stationary with wastewater flowing past the surface/media. These processes are designed to maintain active contact between the biofilm, wastewater and oxygen (where necessary).

- Suspended growth processes — biomass is freely suspended in the wastewater and is mixed and can be aerated by a variety of devices that transfer oxygen to the bioreactor contents

It is also possible to combine both methods in a single reactor for more effective treatment.

There are many types of fixed film process, as described below:

Biotrickling filters: Also known as biotowers, is the one of the most commonly used fixed film process. It consists of a basin or tower filled with support media such as stones, plastic shapes, or wooden slats. Wastewater is applied intermittently, or sometimes continuously, over the media. The water then trickles downward through the bed. Air circulates upward through the media as treated water is removed by an under drain system. As the wastewater trickles downward through the bed, a biological slime of microbes develops on the surface of the media. Continuous flow provides the needed contact between the microbes and the organics. Microorganisms become attached to the media and form a biological layer or fixed film. Organic matter in the wastewater diffuses into the film, where it is metabolised. Oxygen is normally supplied to the film by the natural flow of air either up or down through the media, depending on the relative temperatures of the wastewater and ambient air. Forced air can also be supplied by blowers but this is rarely necessary. The thickness of the bio-film increases as new organisms grow.

Rotating biological contactor (RBC): This consists of vertically arranged, plastic media on a horizontal, rotating shaft. The biomass coated media are alternately exposed to wastewater and atmospheric oxygen as the shaft slowly rotates at 1–1.5 rpm, with about 40% of the media submerged. High surface area allows a large, stable biomass population to develop, with excess growth continuously and automatically shed and removed in a downstream clarifier. RBC systems are particularly used in the in the petroleum industry because of their ability to quickly recover from upset conditions and because it can easily be expanded if need arises.

Submerged biological contactors (SBC): This is similar to RBC, but operates at nearly 90% (RBC is about 40%) submergence with coarse-bubble diffused aeration providing a means of both aeration and motive force for rotation. Because of greater submergence, the load on the shaft is significantly less than that of an RBC. The SBC also provides nearly three times the surface area of a conventional RBC per foot of shaft length. With its compact design, the SBC is very easy to cover for VOC and odor containment. Unlike the RBC, the SBC system is driven

completely by air, making it one of the lowest maintenance and lowest operation-intensive biological- treatment systems available. Like the RBC, the SBC is modular and can easily be expanded
Examples of the suspended-growth processes include:

Diffused aeration: Here air is added to wastewater artificially, increasing dissolved oxygen content and supplying microorganisms with oxygen necessary for aerobic biological treatment. Fine-bubble diffused-aeration systems are available in various types including ceramic and membranes, and are highly efficient. More reliable, but less efficient, coarse-bubble aeration systems are also available, and are normally manufactured of corrosion- resistant, stainless-steel components. Both systems are compatible with new installations and replacement of existing gas-aeration equipment. Fine-bubble aerators offer very low VOC stripping potential, and both fine and coarse diffusers provide good BOD and COD removal efficiency.

Jet aeration: The jet-aeration system is designed to provide required aeration as well as maintain suspension of biological solids, with the flexibility to either aerate or mix independently without the need for additional equipment. Air flow rates to the system can be varied. When aeration requirements decrease and air is completely shut off, pumps provide the required mixing action to enhance process control and save energy. The subsurface discharge leads to smooth and quiet operation, with no misting, splashing or spray from the basin. This also translates to low VOC release to the atmosphere. Since jet aeration requires no moving parts in the basin, the system offers long life with no in-basin routine maintenance required.

Surface aeration: This involves the use of surface aeration from high and low speed floating aerators pumping oxygen by breaking up the wastewater into a spray of droplets. The large surface area of the spray allows oxygen to enter the wastewater from the atmosphere. At the same time, the oxygen-enriched water is dispersed and mixed, resulting in effective oxygen delivery. High- and low-speed surface aerators offer excellent oxygen transfer and low operating costs. They are also able to handle environmental extremes such as high temperatures. Another alternative to surface aeration is the use of horizontally mounted aeration discs or rotors. These disc or rotor aerators can be used in oxidation ditches known as looped, "race track" reactor configurations. They provide stable operation with resulting high-quality effluent. The aerators are above water for easy maintenance and are energy efficient. Other multichannel processes use a concentric arrangement of looped reactors, which is particularly energy efficient and designed to achieve total nitrogen removal through simultaneous nitrification/denitrification. Disc and rotor surface aerators offer good

BOD and COD removal efficiencies, and are very easy to replace if necessary. Reactors in a vertical-loop configuration are also available for surface aeration. They are essentially oxidation ditches flipped on their sides. Upper and lower compartments separated by a horizontal baffle run the length of the tank. Surface-mounted discs or rotors provide mixing and deliver oxygen. Typically, two or more basins make up the system. The first basin operates as an aerated anoxic reactor and the second basin is operated under aerobic conditions. These types of reactors also have high BOD/COD removal efficiency.

3.2.4 Effluent Treatment Using Enzymes and Microbial Cells

A microbial fuel cell (MFC) is a device that converts chemical energy to electrical energy by the catalytic action of microorganisms. The idea that microbial cells could be used to produce electricity was first conceived at the turn of the twentieth century by M. Potter. However, empirical evidence was not provided until 1931 when Barnet Cohen created a number of microbial half fuel cells that, when connected in series, produced over 35 volts, though only with a current of 2 milliamps of electricity. Now studies on electricity generation using organic matter from the wastewater as substrate have shown unequivocally that MFCs can be used to produce electricity from water containing glucose, acetate or lactate. The principle is based on the understanding that bacteria gain energy by transferring electrons from an electron donor, such as glucose or acetate, to an electron acceptor, such as oxygen. The larger the difference in potential between donor and acceptor, the larger the energetic gain for the bacterium, and generally the higher the growth yield. In a microbial fuel cell, bacteria do not directly transfer their electrons to their characteristic terminal electron acceptor, but these electrons are diverted towards an electrode, i.e. an anode. The electrons are subsequently conducted over a resistance or power user towards a cathode and thus, bacterial energy is directly converted to electrical energy. To close the cycle, protons migrate through a proton exchange membrane (Figure 11.1). In the process of bio-products production, the MFC provides the most complete and environmentally friendly reaction as shown below:
Bio-ethanol:

$$C_6H_{12}O_6 \longrightarrow 2\,C_2H_5OH + 2\,CO_2$$

Biogas:

$$C_6H_{12}O_6 \longrightarrow 3\,CH_4 + 3\,CO_2$$

Hydrogen gas:

$$C_6H_{12}O_6 + 6\,H_2O \longrightarrow 12\,H_2 + 6\,CO_2$$

Microbial fuel cell:

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,H_2O + 6\,CO_2$$

4.0 CONCLUSION

In this unit, you have learnt the scope of environmental biotechnology application to pollution control and abatement. You learnt that all environmental media air, water and land are susceptible to pollution and contamination. However, though the specific types of pollutants and contaminants may vary from one media to the other and from one locality to another, they are all physical, chemical or biological in nature. Control of pollution in any of the media is carried out either by conventional methods or by biotechnological methods. The major biotechnological methods for air pollution control are bio-filtration in nature and include bio-swales, bio-strips, bio-trickling, bio-filters, constructed and natural wetlands, slow sand filters, treatment ponds, green belts and the living walls. These filter different types of materials to expose microorganisms to organic material (medium) for biodegradation. In water and wastewater treatment, different bioreactor facilities provide platforms for biodegradation activities of microorganisms either in the presence (aerobic) or absence (anaerobic) of oxygen.

Decontamination of degraded land is done by any of the various bio-remediation methods. These include windrows, land farming, bio piling and composting, although most are based on the principle of composting. Another method which is fast gaining ground is phyto - remediation which is the application of resistant plants in the re-mineralisation of contaminated lands.

5.0 SUMMARY

In this unit, you have learnt about the application of biotechnology methods to pollution control. You have learnt that there are several methods based on the application of living organisms that could be used in the prevention and control of pollution of the air, water and land. In the next unit, we will learn about the application of these methods to the decontamination of contaminated land sites.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the advantages and disadvantages of aerobic treatment?
2. Describe in detail the biological methods of treating polluted water.
3. Write a comprehensive essay on the sources of air and water pollution.
4. Compare and contrast the methods of air and water pollution control.

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UNIT 5 APPLICATION OF BIOTECHNOLOGY TO REMEDIATION OF CONTAMINATED LAND SITES

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt about the application of biotechnology methods for the control of pollution in air and water environment. In this unit, you will learn about the different biotechnology methods that can be applied to remediate and decontaminate land sites contaminated by different types of pollutants such as oil, heavy metals and solid wastes.

2.0 OBJECTIVES

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

- explain what a contaminated land is
- describe the various techniques for remediating heavy metal contaminated lands
- explain the various techniques for remediating lands contaminated by non degradable chemical and other preparations
- describe the various techniques for remediating oil and tar contaminated lands
- describe the various options for remediating land contaminated by industrial particles e.g. asbestos, quarrying dust, etc.

3.0 MAIN CONTENT

3.1 What is a Contaminated Land?

Land may be said to be contaminated when there are substances in, on or under it that actually, or potentially, form a hazard to health or the environment. Confirmation that a piece of land is contaminated is based on the actual or potential identification of the source(s) of pollution and a defined link between the source and the land in question. The major pollutants of land contamination are heavy metals (e.g. arsenic, cadmium and lead), oils and tars (gasoline, diesel, etc), non degradable chemical substances and preparations (e.g. solid waste. solvents, chemical effluents, etc.), toxic gases, industrial particles (asbestos, quarrying dust) and other radioactive substances. Sources of land contamination include agricultural production, mining, quarrying, sewage sludge accumulation, dredged spoils, improper disposal of household and other municipal and hospital wastes, demolition and construction waste, oil spill and industrial liquid and solid waste including radioactive waste (Table 12.1). Land may be contaminated by accidents or spills, leaking underground storage tanks, past industrial uses and waste disposal.

(Table 12.1)**: Sources and Methods of Land Pollution**

Sources	**Methods**
Agriculture	• accumulation of animal manures • excessive input of chemical fertilizers • illicit dumping of tainted crops on land
Mining and Quarrying	• using of explosives to blow up mines • using of machineries which emits toxic byproducts and leaks to the ground
Sewage sludge	• improper sanitation system causes sludge to leak at surrounding soil
Dredged spoils	• improper method of dredging at fertile land causes soil infertility, leaving the soil more prone to external pollution
Household	• improper waste disposal system causes waste accumulation • improper sanitation system
Demolition and construction	• non biodegradable rubbles or debris which are not cleared settled in the soil undergo chemical reactions and I increase soil toxicity
Petroleum prospecting and use	• Oil spill from different sources

Industrial	• poisonous/toxic emissions of gases which are not filtered or neutralised • improper discharge of toxic and polluted effluent • oil and tar contaminated land • contamination by radioactive substances

There are many methods for remediating contaminated land to restore them to their original state. Many of these methods are biotechnology based methods already discussed in Unit 6 utilise microorganisms and/or macroinvertebrates to degrade the contaminants. These include *in situ* techniques such as bio-sparging, bio-venting and bio augumentation; composting and compost- related methods such as windrows, land farming and bio-pile and phyto-mediation. Where phyto-remediation is found ineffective as a result of poor growth resulting from poor environmental conditions, soil fertility may be optimised using either microbes or different organic and / chemical fertilizers.

3.2 Remediation of Heavy Metal Contaminated Land

Heavy metal contamination is the presence in soil or water of metal especially heavy metals in concentrations higher than recommended values. A heavy metal is any metal with a specific gravity greater than about 5.0, especially one that is toxic and/or poisonous. They include lead, mercury, zinc, copper, cadmium, mercury, nickel, and iron. The sources of heavy metal contamination of land are variable but can be broadly divided into natural or anthropogenic (i.e. human activity sources). The sources include a wide variety of anthropogenic sources in the form of metal mine tailings, disposal of high metal wastes in improperly protected landfills, leaded gasoline and lead-based paints, land application of fertilizer, animal manures, bio-solids (sewage sludge), compost, pesticides, coal combustion residues, petrochemicals, and atmospheric deposition. The heavy metals essentially become contaminants in the soil environments because (i) their rates of generation via man-made cycles are more rapid relative to natural assimilation capacities (ii) they become transferred from mines to random environmental locations where higher potentials of direct exposure occur, (iii) the concentrations of the metals in discarded products are relatively high compared to those in the receiving environment, and (iv) the chemical form (species) in which a metal is found in the receiving environmental system may render it more bio-available. A simple mass balance of the heavy metals in the soil can be expressed as follows:

$$M\text{total} = (Mp + Ma + Mf + M\text{ag} + M\text{ow} + M\text{ip}) - (M\text{cr} + Ml)$$

where "M" is the heavy metal, "p" is the parent material, "a" is the atmospheric deposition, "f" is the fertilizer sources, "a g" are the agrochemical sources, "ow" are the organic waste sources, "ip"are other inorganic pollutants, "cr" is crop removal, and "l" is the losses by leaching, volatilisation, and so forth. It is projected that the anthropogenic emission into the atmosphere, for several heavy metals, is one-to-three orders of magnitude higher than natural fluxes. Heavy metals in the soil from anthropogenic sources tend to be more mobile, hence bio-available than pedogenic, or lithogenic ones. Contaminated soil or land can be remedied by several methods broadly classified as (i) source control or (ii) containment remedies. Source control involves *in situ* and *ex situ* treatment technologies for sources of contamination. In situ or in place means that the contaminated soil is treated in its original place; unmoved, unexcavated; remaining at the site or in the subsurface. In situ treatment technologies treat or remove the contaminant from soil without excavation or removal of the soil. *Ex situ* means that the contaminated soil is moved, excavated, or removed from the site or subsurface for treatment at other sites. Implementation of *ex situ* remedies requires excavation or removal of the contaminated soil. Some of these methods are biological in nature while others are non biological (Table 12.3).

Table 12.2: Technologies for Remediation of Heavy Metal-Contaminated Soils

Category	Remediation Technology
Isolation	(i) Capping (ii) subsurface barriers
Immobilization	(i) Solidification/stabilisation (ii) vitrification (iii) chemical treatment
Toxicity and/or mobility reduction	(i) Chemical treatment, (ii) permeable treatment walls iii) biological treatment (phyto-remediation), bioleaching, biochemical processes
Physical separation	Several engineering based escavations
Extraction	(i) Soil washing, pyro-metallurgical extraction, in situ soil flushing, and electro-kinetic treatment

Source: Wuana & Okieimen (2011)

The biological methods used to decontaminate heavy metal contaminated lands include the *in situ* methods of bio-sparging, bio-venting, bio-piling and phyto-remediation. The first three methods are used as described in Unit 6. Phyto-remediation is particularly useful because some plants have the ability to remove and stabilise metal

contaminants. Some species for instance have the peculiar characteristic to bio-accumulate metals up to 100-fold greater than those typically measured in shoots of the common non-accumulator plants. Thus, a hyper-accumulator plant will concentrate more than 10 mg kg−1 Hg, 100 mg kg−1 Cd, 1000 mg kg−1 Co, Cr, Cu, and Pb; 10 000 mg kg−1 Zn and Ni. Phyto-remediation is usually followed by soil amendments using different fertilizers (chemical, organic or plants with the capacity to fix nitrogen from the air). Phyto-remediation is energy efficient, aesthetically pleasing method of remediating sites with low- to-moderate levels of contamination, and it can be used in conjunction with other more traditional remedial methods as a finishing step to the remedial process.

The advantages of phyto-remediation compared with classical remediation are that (i) it is more economically viable using the same tools and supplies as agriculture, (ii) it is less disruptive to the environment and does not involve waiting for new plant communities to recolonise the site, (iii) disposal sites are not needed, (iv) it is more likely to be accepted by the public as it is more aesthetically pleasing than traditional methods, (v) it avoids excavation and transport of polluted media thus reducing the risk of spreading the contamination, and (vi) it has the potential to treat sites polluted with more than one type of pollutant. The disadvantages are: (i) it is dependent on the growing conditions required by the plant (i.e., climate, geology, altitude, and temperature), (ii) large-scale operations require access to agricultural equipment and knowledge, (iii) success is dependent on the tolerance of the plant to the pollutant, (iv) contaminants collected in senescing tissues may be released back into the environment in autumn, (v) contaminants may be collected in woody tissues used as fuel, (vi) time taken to remediate sites far exceeds that of other technologies, (vii) contaminant solubility may be increased leading to greater environmental damage and the possibility of leaching.

3.3 Remediation of Non Degradable Chemical Substances and Preparations in Contaminated Lands

Non biodegradable substances are any organic or inorganic substance that cannot be broken down to smaller substances by natural processes. They include:

A. Substances such as:

- plastics (polyethylene, nylon, rayon, polyester, lexan, PVC (polyvinyl chloride), dacron)
- metals (iron, platinum, steel, tin, aluminum, lead, silver, gold, arsenic, bismuth, zinc, chromium...)

- ceramics (carbon fiber, fiberglass, kevlar)
- foams (cups, coolers)
- glasses
- circuit boards/silicon based materials
- noble gases and more
- Diamond.

B. And chemical preparations such as:

- pesticides
- styrofoam
- chips bags
- plastic bottles
- regular shopping bags
- detergents
- motor oil
- paint
- varnish
- chemical dyes.

The method applied to decontaminate land contaminated by non degradable chemicals substances and preparations depend on the substance and preparation involved. However, compost piling and other ex situ compost methods can be used to degrade several chemicals including pesticides, dyes, varnish etc. The microorganisms usually involved are species of fungi and bacteria usually found in garden compost piles or genetically-engineered for quicker results. Compost used in bioremediation is referred to as tailored or designed compost because it is specially formulated to treat specific contaminants depending upon the site. A yard-waste compost may work well for soil contaminated with heavy metals, whereas wood chips and well-aged compost can remediate soil contaminated with the herbicides and other pesticides.

3.4 Remediation of Oil and Tar Contaminated Land

Oil and tar contamination of land involves any piece of land contaminated with fraction of petroleum listed in Table 12.3

Table 12.3: Carbon Content, Boiling Points and Uses of Petroleum Fractions

Names of Fractions	C atoms in the molecule	Boiling range in ^{o}C	Uses of the fraction - mainly depends on its physical properties
Fuel Gas, LPG, Refinery Gas	1 to 4	-160 to 20^{o}C	Methane gas fuel, C_{3-4} easily liquefied, portable energy source bottled gas for cooking (butane), higher pressure cylinders (propane)
Gasoline, Petrol	5 to 11	20 to 60^{o}C	Easily vaporised, highly flammable, easily ignited, car fuel
Naphtha	7 to 13	60 to 180^{o}C	Not good as a fuel, but valuable source of organic molecules to make other things, cracked to make more petrol and alkenes
Paraffin, Kerosene	10 to 16	120 to 240^{o}C	Less flammable than petrol, domestic heater fuel, jet fuel
Diesel oil, Gas oil	15 to 25	220 to 250^{o}C	Car and larger vehicle fuel
Fuel oil, lubricating oils and Waxes	20 to 70	250 to 350^{o}C	Not so easily evaporated, not as flammable, safe to store for central heating oil, quite viscous (sticky) and can also be used for lubricating oils, clear waxes and polishes
Bitumen (Tar)	over 70	over 350^{o}C	Forms a thick, black, tough and resistant adhesive on cooling, used as waterproofing material and to sticks rock chips on roofs or road surfaces

Source: Brown (2012)

Soil contaminated with petroleum is hazardous to human health, causes organic pollution of ground water which limits its use, causes economic loss, environmental problems and decreases the agricultural productivity of the soil. Remediation of the oil contaminated soil can be achieved in many ways including physico-chemical and biological methods. Biological methods are more economical and efficient than chemical and physical methods. Almost all the bioremediation methods such asparging, bio-venting, bio-piles and the various compost related methods can be applied to decontaminate oil contaminated sites. The constituents of oil differ distinctly in volatility, volubility, and susceptibility to biodegradation. Some compounds are easily degraded, some resist degradation and some are non-biodegradable. The biodegradation of different petroleum compounds occurs simultaneously

but at different rates because different species of microbes preferentially attack different compounds. This leads to the successive disappearance of individual components of petroleum over time. This is because the various biotechnology methods used work by increasing degradating and/or detoxifying the petroleum products in soil. Biological methods of bioremediation through microorganisms such as bacteria and fungi are very efficient, but the low solubility and adsorption of high molecular weight hydrocarbons limits their availability to microorganisms. The microbes present in the soil which first recognize the oil and its constituent are the bio-surfactants and bio emulsifiers. These will eventually attach themselves to the hydrocarbon present in the petroleum and use them as a source of energy and carbon. Microorganisms produce enzymes in the presence of carbon sources which are responsible for attacking the hydrocarbon molecules. Many different enzymes and metabolic pathways are involved in the degradation of hydrocarbons contained in petroleum. The bacteria most frequently used in the bioremediation of oil and tar contaminated sites include species of *Aeromonas, Moraxella, Beijerinckia, Flavobacteria, Chrobacteria, Nocardia ,Corynebacteria, Atinetobacter, Mycobactena, Modococci, Streptomyces, Bacilli, Arthrobacter, Aeromonas, Cyanobacteria etc.* Most of these are commercially available as frozen dried bacteria. A minimum of 2×108 CFU/ml of bacteria is required to initiate and sustain bioremediation. Where this density does not exist, bio-augumentation by means of nutrient optimisation may be carried out to assist bacteria population growth. This involves carbon and macronutrient supplementation. The essential micronutrients needed are nitrogen and phosphorous and the optimum nutrient ratio is Carbon: Nitrogen: Phosphorus of 100:10:4. This ratio may be achieved by adding at least 1 ppm of ammonium nitrogen and 0.4 ppm of orthophosphate to the soil.

3.5 Remediation of Land Contaminated with Asbestos and Mining Dust

Asbestos is a useful material made of six different fibrous minerals: chrysotile, crocidolite, amosite, tremolite, anthophyllite, and actinolite. These minerals come from mines throughout the world including Nigeria. Asbestos has a very high heat retardant capacity, for which reason it is used in the manufacture of heat insulating products like roofing shingles, automobile brake pads, floor tiles, assorted gaskets, wraps for insulation of heating ducts and water pipes in homes, offices, and other buildings. These inert asbestos-containing products are not dangerous and constitute no hazards to health, but once they are damaged or breached, or during manufacturing processes, they release asbestos dust, which people can inhale. Asbestos dust contains fragmented particles considered hazardous because they can cause lung

problems, including the development of mesothelioma, a form of lung cancer.
On its own, mine dusts are dust emissions from mining activities. The mine dust and also the asbestos dust mix with particles in air, becoming part of what is generally called particulate matter (PM). Particulate matter contain both naturally- occurring particles and emissions from different human activities, including vehicle exhaust, quarrying, wood processing, industrial processes, power stations, farming and biomass burning. Particulate matter is classified into three major classes on the bases of particulate sizes - greater than 10 µm (PM10+), 10 µm and 2.5 µm (PM 2.5). Each of these is associated with health risks for which reason control of asbestos and mine dust is an important component of environmental health practice.

Asbestos dust contains fibres which are made of pathogenic elements like iron and other metals. Crocidolite, one of the most potently carcinogenic components of asbestos, contains up to 29 % iron, which has the capacity to form highly reactive free radicals that damage DNA and eventually trigger cancers in humans and animals. Experiments in vitro demonstrate that iron removal makes the asbestos considerably less hazardous by reducing their potential to generate radicals and to damage DNA. Several fungi species have the capacity to extract iron from crocidolites and are therefore very good candidates for bioremediation of asbestos contaminated land (Figure 1). Fungi species perform this task in several ways. First, species such as *Fusarium oxysporum*, *Mortierella hyalina* and *Oidiodendron maius*, a mycorrhizal fungus, extract iron from crocidolites. Second, some such as the fungal hyphae form a web of thin strands that bind asbestos fibres, making them less liable to escape into the air. Third, fungal chelators modify fibre surfaces in vitro, destroying active sites involved in the triggering of the carcinogenic mechanisms. As a result of these, fungi species, either naturally occurring or genetically-engineered are widely used in the bioremediation of asbestos contaminated sites.

4.0 CONCLUSION

Several pollutants including heavy metals, toxic chemical substances, oil and tar as well as asbestos and mining dust usually cause contamination. Because of this, steps in effective remediation must begin with determining the type and sources of contamination. Once the type of pollutant is identified and probably the source too, appropriate remediation technologies are chosen. Although, there are several physical and chemical methods of remediating contaminated sites, biotechnology methods are always preferred for several reasons. They are cheaper, simpler and above all more environmentally friendly. Bioremediation of contaminated sites may involve several methods

which are either in situ (treatment at the site of contamination) or ex situ (removal of contaminated soil to another site for treatment). The most important in situ methods are bio-asparging, bio-venting, bio-augumentation and phyto-remediation, while the *ex situ* methods include forms of composting such as windrows, land farming and bio-piling. Each of these methods uses either resident microorganisms at the site or introduced species which may be naturally-occurring or genetically-engineered. Both naturally- occurring and genetically-engineered species are commercially available in different parts of the world.

5.0 SUMMARY

In this unit, you have learnt about the different biotechnology methods that can be applied to remediate and decontaminate land sites contaminated by different types of pollutants such as oil and heavy metals. You learnt that a piece of land is said to be contaminated when there are substances in, on or under it that actually, or potentially, constitute a hazard to health or the environment. Contaminated land may be restored to its original state using either bio-remediating or non-bio-remediating techniques. However, bio-remediating methods are cheaper and more environmentally- friendly.

We discussed several bio-remediating methods on contaminated land . In the next unit, you will learn about the concepts of merits and demerits, i.e. how to determine what constitutes merit and demerit of an action or issue.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe the concept of land contamination and the process involve in remediation of hydrocarbon polluted soil.
2. Explain six sources of land contamination and their methods of polluting the land.
3. Discuss the role of heavy metals in soil contaminantion.
4. Define the term phyto-remediation and outline its advantages and disadvantages

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MODULE 4 MERITS AND DEMERITS OF BIOTECHNOLOGY METHODS AND APPLICATIONS

UNIT 1 MERITS AND DEMERITS OF BIOTECHNOLOGY

CONTENTS

1.0 INTRODUCTION

In the previous units, you learnt about biotechnology, its methods and applications to various fields of human endeavour especially environmental management. You learnt that biotechnology methods are based on the use of living organisms, some naturally occurring, others genetically engineered to perform specific tasks. In this unit, you will learn about the merits and demerits of biotechnology applications to different branches of environmental health practice.

2.0 OBJECTIVES

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

- explain what is merit and demerit
- explain the advantages of biotechnology especially to environmental health practice
- explain the disadvantage of biotechnology especially to environmental health practice.

3.0 MAIN CONTENT

3.1 What is Merit and Demerit?

In its simplest form, merit denotes advantage while demerit denotes disadvantage, at least in the context of our discussion in this unit. Advantage has been severally defined as the stage or an instance of being in a favourable circumstance or condition, or any condition, circumstance, opportunity that is particularly favorable to success, to any desired end; benefit or a gain or having the good side of something. Others say it is simply a state of benefit i.e. gaining something, acquiring asset or an achievement of success that gives a feeling of joy, self-fulfillment, self-satisfaction. Disadvantage is construed as the opposite of each of the above situations. Thus, each time a venture we embark on is advantageous or has merit, we are encouraged to thrive harder, explore more and continue in the path we have chosen. On the other hand disadvantage is a signal that all is not well with our venture(s). An outcome that is disadvantageous signals a bad omen, a failure and reason to discontinue with whatever venture it is we have undertaken, or at least to change our approach. In spite of these, the concept of advantage and disadvantage or merit and demerit is sometimes difficult to define, and even when we do it is subjective.

This is because, the classification of a venture as advantageous or disadvantageous, successful or a failure, may change with situations, persons and circumstances. Besides, most ventures collectively and individually may be both advantageous and disadvantageous depending on the context, circumstance, person and situation at hand. For instance, establishment of a cement producing factory in an area is beneficial and advantageous to business and economic development but a disadvantage to the environment and environmental quality. Again, establishing a dam in an area is beneficial for water supply, but a huge disadvantage for diseases transmission, e.g. malaria and schistosomiasis. Thus, judgement on the merits and demerits of establishing a cement factory or a dam must first define the premise of assessment and the beneficiaries. What this suggests clearly is that the overall decision on

the merit and demerit of any venture must involve well defined criteria of assessment for both the merits and demerits of a venture to establish a balance. It is, therefore, the net balance of such an assessment that will determine the overall classification of the venture as advantageous or disadvantageous. Thus, absolute advantage or disadvantage does not exist in reality; only relative value exists, this depending on the circumstance and context of assessment. Furthermore, merit and demerit also vary according to criteria used in the assessment. For instance, motor vehicles are advantageous when considered from the viewpoint of transportation, movement of goods and services and migration. But it is a disadvantage when viewed from the point of view of road traffic accidents and environmental pollution.

Merit and demerit are also very important guidelines for making choices. This is most pronounced in the employment sector where it has remained an important tool for hiring and firing staff, and for assessing performance and promotion. In this sector, the merit system is seen as a method of personnel management designed to promote the efficiency and economy of the workforce and the good of the public by providing for the selection and retention of employees, in-service promotional opportunities, and other related matters, on the basis of merit and fitness. In a nutshell, merit and demerit provide for us a platform for deciding for a given context, what is good and what is bad, what should be used and what should not be used, what to retain and what should be discarded. We will apply these principles as we consider the merits and demerits of the various biotechnology methods to decide on the basis of environmental health, whether these methods are good or bad, whether they should be retained and pursued, or whether they should be discarded. Finally, in the big debate in the next unit, we will take the big decision on whether biotechnology is a good scientific innovation or a bad one that should be thrown out.

3.2 Advantages of Biotechnology Application to Environmental Health

Advantages of biotechnology to environmental health may be considered from the standpoint of the different advances that have been made in the different sectors described below:

3.2.1 Benefits of Biotechnology Application to Health and Healthcare Delivery

Medical biotechnology has benefitted more than 350 million patients around the world through the use of genetically -modified medicines to treat and prevent every day and chronic illnesses including heart attack, stroke, multiple sclerosis, breast cancer, cystic fibrosis, leukaemia,

diabetes, hepatitis and other rare or infectious diseases. It enables the development of therapies for rare diseases that are often debilitating and life-threatening and that affect millions of people around the world. Medical biotechnology is estimated to account for more than 20% of all marketed medicines and it is estimated that by 2015, 50% of all medicines will come from biotech. Healthcare biotech increases the effectiveness and safety of treatments as well as reducing the use of ineffective treatments and adverse reactions through its approach on Personalised Medicine that works to diagnose what one patient's problems are precisely and then work to better adapt the healthcare deliveries to suit individual and specific needs. Healthcare biotech comprises more than 1700 companies and a market worth billions of dollars. It is therefore an important economic sector. It creates jobs for several skills in all departments of companies involved. Medical biotechnology has offered new, cheaper, sensitive and better diagnostic test kits for rare and devastating diseases such as HIV, diabetes, heart diseases etc. It has also offered new opportunities for the development of far more effective vaccines against several childhood and adult diseases.

Most importantly, biotechnology offers the potential to increase the effectiveness of genetic selection, even for traits that are difficult or take a long time to measure. This makes it possible to identify individual animals for breeding, and select offspring, with the best overall combination of gene variants (alleles) rather than focusing on just one or two traits.

Biotechnology has unraveled the whole genomes helping unravel the genetic components of many multi-gene diseases in both humans and animals. This is made possible by our understanding of the genome sequences and the single nucleotide polymorphism (SNP) and the single point variations between the DNA of individuals of a species that determine traits. Due to a clearer understanding of the existence of different versions of some genes, called alleles, and how these variants in some cases arise in an individual through mutations in a single nucleotide, it is now possible to pinpoint mutations across the whole genome quickly and study how the associated genes interact. Such information is used to investigate disease in animal and human species.

One of the most exciting discoveries of in biotechnology in recent years is the fact that rods and cones are not the only light receptors in the eye, overturning the long established view. There is also a receptor, called phototropin that recognises blue light at much lower levels, even operating in some people who are otherwise blind, playing an important role in setting the circadian clock.

Genes determine individual traits not just through their variations, or alleles, but also through differing levels of expression. Biotechnology is also leading the way in our understanding of how genes work. It is unraveling the important role of microRNAs in controlling gene expression. RNAs are normally the intermediate molecules between DNA and their products, proteins, in gene expression. It is now known that microRNA is a type of RNA that instead of being involved in protein production, feeds back into the DNA coding process to regulate the expression of other genes. This raises an opportunity to further predetermine gene expression by controlling mutations in the genes coding for the microRNA itself.

3.2.2 Benefits of Biotechnology Application to Agriculture

As already described in preceding Units, several crops have been genetically engineered to be more productive, grow on zero-till land and to be pest (insect and weed resistant) resistant. The impact of these attributes to environmental quality is enormous. It offered increased food production and improved food security without the need for increased land clearance and tillage. It is estimated that the world needs at least 70% more food by 2050 when the global population is expected to reach 9 billion. Improvements in agricultural practices and technologies have achieved huge successes in helping to meet the food, feed and fibre needs of this growing population. However, by its very nature, agriculture is disruptive to the environment and much work and research is now taking place to limit and decrease the "environmental footprint" the expected rapid increase in production would leave.

Development of resistant crops is helping to achieve this goal because they are grown without the need for increased land clearing and tillage. They are insect and herbicide resistant and offer an alternative to chemical inputs and have allowed development of more targeted, flexible, effective and sustainable integrated pest management programmes. For instance, between 1996 and 2009 it reduced pesticide spraying by 393 million kg (i.e. 8.7%), as a result, decreased the environmental impact associated with herbicide and insecticide use on the area planted to biotech crops by 17.1%. During the same period, biotech crops contributed to sustainability and climate change by: 1) increasing crop production and value to US$65 billion, 2) providing a better environment by saving 393 million kilogram active ingredients of pesticides, 3) in 2009 reducing CO_2 emissions by 18 billion kilograms, equivalent to taking 8 million cars off the road, 4) conserving biodiversity by saving 75 million ha of land, and 5) helping alleviate poverty by assisting 14.4 million small farmers, among the poorest people in the world. Furthermore, by leaving the soil undisturbed, more moisture is retained, which is good for water conservation. Other

indirect benefits of zero-tillage in biotech crops production are improved conservation of beneficial soil insects and earth worms. By using fewer fuel powered agricultural machines required in land clearance and tillage, carbon dioxide emissions to the atmosphere are decreased and fossil fuels are conserved. Less tractor traffic also causes indirect benefits to soil quality, and hence a reduced contribution towards global warming.

Using biotechnology in the growth and production of fruits and vegetables has enabled scientists to change the way they ripen. Normally fruits and vegetables continue to ripen after harvesting; they must be rushed to market and sold quickly while they are fresh. Genetically-modified produce can be harvested when ripe, and the ripening process stops, giving them a longer shelf life. These genetic modifications also increase a plant's resistance to disease, pests, insecticides, herbicides and even extreme weather conditions. Genetic engineering has also altered a plant's nutritional makeup, making it richer in certain vitamins or minerals.

3.2.3 Benefits of Biotechnology Application to Industrial Production

Industrial biotechnology thrives to boost manufacturing outputs, create more jobs and at the same time minimise anthropogenic impact on the environment. This goal is achieved in several ways.

Industrial biotech uses enzymes and micro-organisms to make the production of several good such as paper and pulp, food, clothing, chemicals and bio-energy cheaper, more efficient and safer in a more environmentally efficient way using less energy, less water and producing less waste. It helps create wealth from waste e.g. transforming agricultural products and organic waste into other substances that help reduce dependence on crude oil as a starting material for production and fossil fuel as the sole source of energy. This technology is environmentally- friendly because it helps fight global warming. Besides, industrial biotech can save energy in production processes and lead to significant reductions in greenhouse gas emissions, as result of estimated reduction of 1-2.5 billion tonnes of $C0_2$ equivalent per year between now and 2030.

Industrial biotechnology enables the introduction of more efficient, less energy-intensive processes. This includes the use of fermentation and enzymatic processes in the fine chemicals sector, to produce for example vitamins, pharmaceutical intermediates and flavours. The technology is now being extended into larger volume segments such as polymers, bulk chemicals and bio-fuels, and many other industrial

sectors. Together, the environmental and economic benefits of industrial biotechnology will contribute towards a more sustainable society, with greater opportunities for job creation and retention, and a reduced dependence on fossil fuels.

3.3 Disadvantages of Biotechnology Application to Environmental Health

The general impression with advancement in biotechnology is that it is safe and a panacea to world's problems. Recently, however, a detailed review of biotechnology developments suggests that there are several issues to warrant serious concern. The review catalogued what it called list of harms of biotechnology into several sections, namely health, environment, farming practices, economic/political/social implications, and issues of freedom of choice. Read on

3.3.1 Disadvantages of Biotechnology Health and Healthcare Delivery

In 1989, 37 deaths were reported and approximately 1500 were disabled after taking genetically- modified version of the food supplement L-tryptophan which caused an ailment known as Eosinophilia myalgia syndrome (EMS) . This is attributed to the release of the supplement without safety tests. It was also reported that several animals died as a result of exposure to the very first commercially- sold GM product (Flavr Savr). There were also near-deaths and food allergy reactions. In 1996, Brazil nut genes were spliced into soybeans to provide the added protein methionine by a company called Pioneer Hi-Bred. Some individuals, however, are so allergic to this nut that they can go into anaphylactic shock (similar to a severe bee sting reaction) which can cause death. Fortunately, the product was withdrawn before it entered the market. This probably suggests that the rising case of food allergy in the United States for instance can be linked to the increasing genetically-modified foods in the market. For instance, two research studies independently show evidence of allergenic reactions to GM Bt corn. Also, farm workers exposed to genetically-modified Bt sprays exhibited extensive allergic reactions. Another study showed that genetically-modified potatoes expressing cod genes were allergenic, while a decade-long study of GM peas was abandoned when it was discovered that they caused allergic lung damage in mice. It was also reported that allergic reactions to soymilk increased by 50 % following introduction of genetically-modified brands. There is also a link between the advent of biotechnology and the prevalence of cancer and degenerative disease. GH is a protein hormone which, when injected into cows stimulates the pituitary gland to produce more milk; thus making milk production more profitable for the large dairy corporations.

One of such products in the market is Monsanto's genetically-modified rBGH, a genetically-altered growth hormone. However, this hormone also increases the secretion of IGF-1 IGF-1 (a potent chemical hormone that with a 2.5 to 4 times higher risk of human colorectal and breast cancer) by 70%-1000%. Prostate cancer risk is considered equally serious - in the 2.8 to 4 times range. It also has an indirect, non-traceable effect on cancer rates. The potential of new ways of rearranging the natural order of organisms with genetic mutations may lead to non-traceable influences. It may reduce the natural immunity and resistance to diseases. This is particularly so with cancer causing chemicals to which we are exposed to on daily basis. Recently, studies have shown that chemicals which otherwise appear safe may be dangerous when it synergistically react to other chemicals. A typical example is the chemicals ascorbic acid and sodium benzoate found in soft drinks. Separately, these chemicals are safe but together they form benzene which is carcinogenic. Research has shown that exposure to genetically- modified foods may lower our ability to resist these effects.

The increasing rate of viruses mixing with the gene of other viruses and retroviruses such as HIV to form more deadly viruses known as superviruses is bad news for healthcare delivery. There is also increasing rate of antibiotic threat via milk or plants. Cows injected with rBGH have a much higher level of udder infections, about 25% higher. Since this hormone causes infections, farmers use loads of antibiotics to contain this ailment. However, these antibiotics eventually end up in the dairy products we consume, resulting in a public health hazard. Similar risk is encountered using antibiotic markers to track gene movement in cells during genetic engineering. Another concern is the case of resurgence of infectious diseases, the rate of which has been rising since the advent of biotechnology. Although, there is no clear cut evidence to conclusively blame biotechnology for this, the coincidence is too obvious to ignore. Although most biotechnology developer claim all is well with the technology and there is nothing to worry about, the increasing rate of food allergies is definitely a concern. The loss of biodiversity in our food supply has grown in parallel with the increase in food allergies. Recently, the foods we eat and crave are almost the same at all times and precisely those testing positive for food allergies. Allergic reactions are misguided defense reactions against incoming parasites and in GM food cases; the body senses an unnatural invasion. Cells in our body recognise this lack of vitality, producing antibodies and white cells in response; the correlation between biotechnology development and birth defects and shorter life spans. We know that rBGh in cows causes a rapid increase in birth defects and shorter life spans and the number of calves born with birth defects to dairy cows has increased significantly. The concern came from animal studies which are very scary. For instance, when GM soy was fed to female rats, most

of their babies died within three weeks—compared to a 10% death rate among the control group fed natural soy. The GM-fed babies were also smaller, and later had problems getting pregnant. When male rats were fed GM soy, their testicles actually changed color—from the normal pink to dark blue. Mice- fed GM soy had altered young sperm. Even the embryos of GM- fed parent mice had significant changes in their DNA. Several such examples abound.

There is also a serious concern about the ingestion of "Pesticide foods." These are foods that contain genes that produce toxic pesticides. Originally, plants producing the foods were engineered to produce their own built-in pesticide in every cell which produces a poison that splits open a bug's stomach and kills them when the bug tries to eat the plant. It is feared that ingestion of such foods might expose humans to the same hazards as bugs. Although, there is little knowledge of the potential long-term health impacts of these products, it is still a cause of serious concern. Some GM foods are said to have lower levels of vital nutrients - especially phytoestrogen compounds thought to protect the body from heart disease and cancer.

3.3.2 Disadvantages of Biotechnology the Environment

While the general belief is that genetically -engineered herbicide and pesticide crops are environmentally- friendly because they require less herbicide and pesticide applications, the reality is that they actually require more because crops growing around them quickly become resistant to such herbicides and pesticides. Also GM bacterium (*Klebsiella planticola*) meant to break down wood chips, corn stalks and lumber wastes to produce ethanol - with the post-process waste to be used as compost, end up rendering the soil sterile. This is because it kills essential soil microbes especially nitrogen capturing fungi. Reliance on genetically engineered seeds means that only few seeds are available as against varieties that have been known over time. This trend will destroy natural selection as changes in seed quality will depend on what humans want. Genetically- modified Bt endotoxin remains in the soil at least 18 months after harvest and can be transported to wild plants creating superweeds - resistant to butterfly, moth, and beetle pests - potentially disturbing the balance of nature. A study in Denmark and UK showed superweeds growing nearby in just one generation. A US study showed the superweed resistant to glufosinate (which differs from glyphosate) to be just as fertile as non-polluted weeds. Also GM trees or "supertrees" are being developed which can kill literally all life around it. Such trees will destroy our natural forest where a single tree is habitat to thousands of animals and lower plants. Yet again, experiments indicate that common plant pests such as cottonboll worms will evolve into superpests which are immune to Bt sprays used by organic farmers.

Fish and marine life are threatened by accidental release of GM fish currently under development in several countries - trout, carp, and salmon several times the normal size and growing up to 6x times as fast. One such accident has already occurred in the Philippines - threatening local fish supplies. Studies have shown that GM products can kill beneficial insects - most notably the monarch butterfly larvae. Bt crops genetically engineered to kill insect pests such as cotton worms, also kill non- target insects like lacewings, honeybees, springtails and ladybird beetles.

In a study with GM potatoes, spliced with DNA from the snowdrop plant and a viral promoter (CaMV), the resulting plant was poisonous to mammals (rats) - damaging vital organs, the stomach lining and immune system. CaMV is a pararetrovirus. It can reactivate dormant viruses or create new viruses - as some presume have occurred with the AIDES epidemic. CaMV is promiscuous with very wide adverse consequences. Accidents of biotechnology could be disastrous as happened with the pig number 6706 supposed to be a "superpig, " but which eventually became a "supercripple" full of arthritis, cross-eyed, and could barely stand up with its mutated body. Accidents of this nature when released to the environment may cause more problems than it can solve. There is also a potent fear of polluting the environment with genetic engineered pest such as GM pollen now being carried by wind, rain, birds, bees, insects, fungus, bacteria. Once released, unlike chemical pollution, there is no cleanup or recall possible. Thus there is no containing such genetic pollution. Experiments in Germany have shown that engineered oilseed can have its pollen move over 200 meters. As a result German farmers have sued to stop field trials in Berlin. In Thailand, the government stopped field tests for Monsanto's Bt cotton when it was discovered by the Institute of Traditional Thai Medicine that 16 nearby plants of the cotton family, used by traditional healers, were being genetically polluted. US research showed that more than 50% of wild strawberries growing inside of 50 meters of a GM strawberry field assumed GM gene markers. Another showed that 25-38% of wild sunflowers growing near GM crops had GM gene markers. A recent study in England showed that despite the tiny amount of GM plantings there (33,750 acres over two years compared to 70-80 million acres per year in the US) wild honey was found to be contaminated. This means that bees and other insects are likely to pollinate organic plants and trees with transgenic elements.

3.3.3 Disadvantages of Biotechnology on Agriculture

In 1850, 60% of the working population in the US was engaged in agriculture. By the year 1950 it was 4%. Today it is 2%. From a peak of 7 million farms in 1935, there are now less than one-third or 2 million

left. In many urban areas, the situation is starker where family farms are becoming largely extinct. For example, Rockland Country, New York (1/2 hour from New York City) had 600 family farms in 1929. Exactly seventy years later only 6 remained. Similar declines have occurred throughout the US and abroad. Of the one-third remaining US farms, 100,000 or 5% produce most of our foods. The trend is for fewer farmers to produce most food using GM crops that pose risk to human health. GM seeds sell at a premium, unless purchased in large quantities, which creates a financial burden for small farmers. This problem is however, more of developed nations' crisis than those of developing nations like Nigeria. At the present rate of proliferation of GM foods, within 50-100 years, the majority of organic foods may no longer be organic. There is always the risk of genetic contamination in GM foods. For instance, a Texas organic corn chip maker, Terra Prima, suffered a substantial economic loss when their corn chips were contaminated with GM corn and had to be destroyed. Organic farmers have long used "Bt" (a naturally- occurring pesticidal bacterium, *Bacillus thuringiensis)* as an invaluable farming aide. It is administered at only certain times, and then sparingly, in a diluted form. This harms only the target insects that bite the plant. Also in that diluted form, it quickly degrades in the soil. By contrast, genetically-engineered Bt corn, potatoes and cotton - together making up roughly a third of US GM crops - all exude this natural pesticide. It is present in every single cell, and pervasively impacts entire fields over the entire life span of crops. This probably increases Bt use at least a million fold in US agriculture. According to a study conducted at NYU, BT residues remained in the soil for as much as 243 days. As an overall result, agricultural biologists predict this will lead to the destruction of one of organic farming's most important tools. It will make it essentially useless. One of the most misleading hopes raised by GM technology firms is that they will solve the world's hunger. This has not happened and small holder farming systems engaged in multi seed farming are being destroyed at the expense of large-scale, monocrop commercial production of industrialised nations. With loss of biological diversity there is an inevitable development of fragility of agriculture. This has given rise to lower yields and more than anticipated use of pesticides.

4.0 CONCLUSION

Biotechnology is used to minimise waste generation at source and to manage waste more effectively and efficiently. It also leads to more food productivity leading to food security and higher quality of life. There are also established biotechnology techniques for better diagnosis and treatment of chronic and debilitating animal and human diseases. This in the long term means better healthcare delivery and longer life expectancy. In spite of these advantages, biotechnology raises many

concerns that are yet to be addressed. Some of the gains of biotechnology are still too recent for their overall long-term effect to be fully understood. Consequently, many hold the opinion that the various supposedly benefits of biotechnology must be held with a lot of caution until their implications are fully understood. This view is substantiated by recent speculations that some of the gains are actually not benefits on the long term. Critics of biotechnology argued that all the optimism about the new technology is unfounded. They suggest that contrary to expectations, biotechnology will worsen environmental conditions, lower life expectancy and make people poorer. Some convincing arguments were actually offered to support this position. For instance, they point to the fact that genetic modification to make crops herbicide and pesticide resistant will in reality lead to the application of more herbicides and pesticides because more crops and pests will over time become resistant to those herbicides and pesticides, thus requiring more for unit control. They also argue that the alteration of the natural balance through genetic engineering may have unimaginable consequences for the future. For instance, some opinions has been expressed to the effect that herbicide and pesticide resistance, expected to make crops resist weeds and pest effects, actually increase their immunity to these herbicides and pesticides. As a result, more chemicals will actually be required per hectare to control weeds and pest in farms where such crops were planted. All these conflicting opinions on the merits and demerits of biotechnology raise a big question on whether biotechnology should be continued or discontinued. We will attempt to answer this question in the next unit.

5.0 SUMMARY

In this unit, you have learnt all about the merits and demerits of biotechnology and its application to environmental health. Merit and demerit were explained as denoting advantage and disadvantage respectively. That merit denotes one side of an event that is good and pleasing while demerit denotes bad and anguish. It was also explained that no event is absolutely advantageous and none is disadvantageous. That classification of an issue as advantageous or disadvantageous depends on the context. While in one context it has merit in another context, the same event may disadvantageous. With this understanding, we had gone to assess the advantages and disadvantages of biotechnology and its application to environmental health. You learnt that several biotechnological developments are both advantageous and disadvantageous. Several advantages and disadvantages of the different branches of biotechnology were therefore outlined.

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss the advantages and disadvantages of biotechnology to health care delivery.
2. Explain the advantage and disadvantages of biotechnology to agricultural production.
3. What is the importance biotechnology to industrial production?
4. Write a concise essay on the advantages and disadvantages of biotechnology to environmental health.

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UNIT 2 THE BIG DEBATE: TO BE OR NOT TO BE

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt about the merits and demerits of biotechnology applications to different branches of environmental health practice. In this unit, you will learn about the various issues and concerns that have formed the platform upon which people have assessed biotechnology to determine its merit and demerit on the one hand and its acceptance or rejection on the other hand.

2.0 OBJECTIVES

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

- explain the issues involved in the big debate
- explain the ethical concerns involved in biotechnology
- explain the religious concerns involved in biotechnology
- explain the moral concerns involved in biotechnology.

3.0 MAIN CONTENT

3.1 Issues Involved in the Big Debate

The issues involved in the big debate on biotechnology are at the heart of the technology itself. Biotechnology as has already been described, is the application of living organisms or parts of living organisms or substances from living organisms in production or product processing. This application involves several issues that are viewed differently by different experts. As a result, proponents and opponents of

biotechnology hold very strong divergent opinions about the technology. To the proponents, biotechnology is a saviour of the modern world. It provides us with the ability to change what we don't like about ourselves, about animals around us, about our environment and about almost anything else. Those changes involve identifying what we don't like, the causes of what we don't like and whether such are genetic or not. If they are genetic, as many are, to identify the exact gene(s) involved, change it (like we change spare parts in machines), or repair it or reinforce it to work better. This is the heart of genetic engineering. Since the advent of genetic engineering, milestone achievements have been made in many important fields which the proponents believe would have been unthinkable without biotechnology. These achievements are in the areas of agriculture, health and healthcare delivery and environmental management. In the area of agriculture, herbicide and pesticide resistant crops have been developed to withstand the adverse effects of weeds and pests, to grow faster and to yield many times more than were previously known. Perennial trees have also been genetically engineered to fruit many years earlier than they use to. In the area of healthcare, it is now possible to control disease-causing agents like mosquito by genetically interfering with their reproductive abilities or their ability to transmit diseases. Advancement in healthcare delivery has also led to the production of better and more effective drugs and diagnostic techniques for managing what previously were life threatening, chronic and terminal diseases such as cancer, diabetes, arthritis and many more. In the area of environmental management, it is now possible to minimize waste from source and manage waste in a more efficient manner using genetically modified organisms that will degrade waste faster and better. Above all, biotechnology now provides techniques for bioremediation of contaminated soil and water and restoring them to their original states. All these sound beautiful and impressive but only to the proponents. To the opponents, the above achievements are more of a burden to humanity than a blessing. They attack the very root of biotechnology questioning the rationale for altering the genetic composition of organisms. They reason that many issues in biotechnology are not clearly understood and until answers are provided for many of such issues, biotechnology should be treated with caution. They suggest that by genetically making some crops resistant herbicides and pesticides, we have made the environment worse than it was. In their opinion, weeds and pests around herbicide and pesticide resistant crops will be harder to control because they would have been resistant to such herbicides and pesticides and will require higher than usual concentrations to control. This will then mean more applications of herbicides and pesticides to the environment. The same logic goes for pesticide resistant insects. Their greatest worry, however, is the issue of gene modification which touches on the very fundamental existence of

organisms on earth. In their opinion, alteration of genes in whatever manner and for whatever reason raises important ethical, religious and moral questions that must be addressed before biotechnology can be fully accepted. The problem, however, is what constitutes these concerns. To call something a moral concern describes the rightness or wrongness of an issue, while ethical concerns are about the reasons and justifications for judging those things to be right or wrong. On its own, religious concern is the conformity of such judgement with existing belief systems. These issues are discussed in more details in the preceding sections.

3.2 The Major Concerns

3.2.1 Religious Concerns

Some opponents hold the religious views that modern biotechnology is blasphemous. This view is based on the belief that God has created a perfect, natural order and that for people to attempt to "improve" that order by manipulating DNA, the basic ingredient of all life, and in some cases crossing species boundaries instituted by God, is not merely presumptuous but sinful. Some religions place great importance on the "integrity" of species, and object to any attempts to change them by genetic modification. The essence of this concern, then, is that modern biotechnology is trying to "displace the first Creator", or to "play God". This opinion is, however, not universally shared among all religious believers. Some other believers also hold that humanity has been given by God an approved, privileged position of "dominion" over nature and biotechnology is a positive opportunity for humans to work with God to further the path of creation. Such religious leaders also hold that there are no sacred boundaries between species neither did God set any such boundaries. To them gene crossing is perfectly normal and another example of God's perfection in man. The Jewish religious laws view this in two divergent ways: (i) whether genetic engineering can be considered as interference with God's creation, and (ii) whether the transfer of genes from one species to another constitutes a non-permissible cross-breeding (*kilayim*). The first aspect is interesting because the *Jerusalem Gmara* (part of the Oral Bible) predicted the ability of humans to cause vast changes in organisms. One of the most respected Jewish leader, Rabbi Yehoshua Ben Hananya said: *I could take melons and water-melons and convert them into deer and gazelles and these deer and gazelles will breed deer and gazelles.* On the issue of interference with God's creation, another respected leader Rabbi Yehuda Leob Ben Bezalel who lived from 1518-1607 claimed that God created creatures in a fully functional and beautiful form and created humans to further improve the world. The word improve is therefore a very fluid one that form pivot in the Jewish law and thinking. On the

basis of this, some Jewish thinkers arrived at an interim suggestion about the question of interference with God's creation in the production of transgenic plants. They suggest that this production is permissible if (i) there is no direct law against it, and (ii) the activity is expected to benefit humans. The second condition is interesting because it indicates that transgenic plants for better food, better feed, better crops, and medical products are permissible, but producing transgenic plants for biological experiments that are not obviously leading to an advantage to humanity may not be permitted--unless we accept the philosophy that increased knowledge improves humanity. Similar view was expressed by the former Catholic pontiff Pope John Paul II. In his address at the Jubilee of the Agricultural World on November 11, 2000, he said "men and women of the agricultural world, you are entrusted with the task of making the earth fruitful". He reminded us that Genesis 1:28, urged humans to "Fill the earth and subdue it; and have dominion over the fish of the sea and over the birds of the air". He, however, warned that this does not allow us to do as we please with the Earth." He commanded that biotechnology applications "must be submitted beforehand to rigorous scientific and ethical examination, to prevent them from becoming disastrous for human health and the future of the earth". These views are reflected in the outcome of a survey of different religious sects around the world. When asked specifically about their own religious or moral views in regards to agricultural biotechnology, a majority of Christians (Protestants, born-again Christians and Catholics) and a plurality of Muslims say they are opposed to moving genes from one species or organism to put into another. Jews were the only religious group that had a majority that supported this technology. Overall, 57 per cent of Protestants (62 percent of Evangelicals) oppose the technology based on their religious or ethical views while 37 per cent are in favor; Catholics followed closely behind with 52 per cent opposed and 42 per cent in favour. Among Muslims, 46 per cent said they are opposed, with 32 per cent in favour. Jews were the most favorable of the technology, with 55 per cent in favor and 35 per cent opposed. However, a majority in all religious groups believes that humans should use their knowledge to improve the life of other humans. On whether man has been empowered by God to use science to improve life or whether man is "playing God," majority felt humans have been empowered by God to improve life. Jews and Muslims agreed the most strongly with the statement on empowerment (62 per cent and 61 per cent agreed, respectively), followed by Catholics (55 per cent) and Protestants (54 per cent). In addition, most of those surveyed, regardless of religion, felt it is important to improve the world or strike a balance between improving and preserving it. Jewish adults feel most strongly that humans have an obligation to improve the world (60 per cent). Protestants are more likely than other religious groups to say that

humans should strike a balance (43 per cent), with nearly half of born-again Christians (48 per cent) saying humans should strike a balance.

3.2.2 Ethical and Moral Concerns

As already described, moral denotes the right or wrong of an action while ethics describes our reasons for doing them. Simple mathematical combinations suggest we have four clear options looking at morality and ethicality of actions. These are, (i) morally right and ethical; (ii) morally right and unethical; (iii) morally wrong and ethical and (iv) morally wrong and unethical. While (ii) and (iv) pose no problems of understanding and acceptance, we have problem with (i) and (iii). Is it truly morally right to do unethical things or ethically right to do immoral things. The problem we face many times is whether we ever have good reasons for doing what is morally wrong, and when we think we have such reasons, do the reasons make such actions ethical. This is the major consideration in the moral and ethical consideration of biotechnology. There are two major issues with serious ethical and moral concerns in biotechnology. These are cloning and gene crossing. Cloning is one of the biggest concerns because it suggests creation through a new line. While human and animal populations have been sustained by germ cell fusion in fertilisation, cloning involves raising a new population of species through the stem cell fertilisation. This has serious ethical and moral implications. Gene crossing on its own involves mixing genes from one species with those of the same or other species. Many argue that the product of inter specific gene mixes no longer represent whatever we know in nature, not the gene donor nor the receiver organism, thus, it is described as transgenic. The major moral and ethical concerns expressed about biotechnology include but not limited to:

(i) whether it is ethical and moral for humans to be engaged in manipulations that lead to production of transgenic plants and animals
(ii) whether it is ethical and moral for humans to consume transgenic plants and animals (or the products derived from them).
(iii) Are we blurring the lines between species by creating transgenic combinations?
(iv) What are the known health risks associated with transgenics?
(v) What are the long-term effects on the environment when transgenics are released in the field?
(vi) What ethical, moral social, and legal controls or reviews should be placed on biotechnology research?
(vii) Are we inflicting pain and suffering on sentient creatures (organisms that have feelings though not humans) when we

create certain types of chimeras (organism containing genetically different tissues, tissues made of genes of different origin)?

(viii) Will transgenic interventions in humans create physical or behavioral traits that may or may not be readily distinguished from what is usually perceived to be "human"?

(ix) If the blending of nonhuman animal and human DNA results, intentionally or not, in chimeric entities possessing degrees of intelligence or sentience never before seen in nonhuman animals, should these entities be given rights and special protections?

(x) What unintended personal, social, and cultural consequences could result?

(xi) Will these interventions redefine what it means to be "normal"?

(xii) Who will have access to these technologies, and how will scarce resources be allocated?

The question on whether humans should consume transgenic foods from plants and animals expressing human genes deserve special mention. A committee set up by the British government in 1993 to consider the "Ethics of Genetic Modification and Food Use" encountered important questions while considering the ethics of introducing human and animal genes into organisms that are used as food. Can the consumption of plants and animals that express human genes be considered cannibalism? Also can vegetarians consume plants that express animal genes and what about dietary restrictions for people who do not eat certain animals? By extension, this also raises the ethical issue of people eating plants and animals expressing genes of animals forbidden by their religions and taboos. These confusions were partly answered by yet another group that believes genetic code is only significant when operating in the context of a living cell. In isolation, genes are simply complex chemicals. This means that if a human gene were transferred to a pig cell, it would, in that context, become simply a pig gene, although admittedly one of human origin.

3.3 Decision Making

The discussions so far have shown that divergent views exist on virtually every issue concerning biotechnology and clear cut decision can be made on any issue. Several national, regional and global agencies also recognised that there is no single set of considerations sufficient for building a more equitable, ethical and moral principles. However, it recommends the following actions that individuals, states, corporations and voluntary organisations in the international community can take:

i. Creating the mechanisms to balance interests and resolve conflicts

ii. Supporting and encouraging broad stakeholder participation in policies, programs, and projects
iii. Encouraging individuals, communities and nations to engage in dialogue, and ultimately, to do what is ethically and morally acceptable by the majority
iv. Undertaking appropriate public health education to make people aware and capable of taking good decisions
v. Developing and disseminating widely the information and analyses necessary to make wise and ethical decisions
vi. Ensuring that decision-making procedures in international food and agriculture policy are well understood and transparent
vii. Fostering the use of science and technology in support of a more just and equitable food and agriculture system
viii. Ensuring that programs, policies, standards and decisions always take ethical and moral considerations into account so as to lead to enhanced well-being, environmental protection and improved health
ix. Developing codes of ethical and moral conduct for biotechnology where they do not currently exist.
x. Periodically reviewing ethical and moral commitments and determining whether or not they are appropriate, in the light of new knowledge and changes in circumstances
xi. Ensuring appropriate labeling of transgenic products to ensure that people are fully aware of their contents.

4.0 CONCLUSION

Opinions on the application of biotechnology are divergent, some in support others against. These opinions bother on the effect of various biotechnological methods and products on the belief systems of different religious groups, especially belief in the sanctity of life, nature and creation by God. Furthermore, critics of biotechnology also raise concern about the mixing of human genes with other species, especially those products that enter into human food chain. They ask if eating such food will constitute cannibalism, if chimeras resulting from such actions (when and if they do), such be treated equally as humans. Answers to many of these questions are still left unanswered.

5.0 SUMMARY

In this unit, you have learnt about the religious, ethical and moral issues and concerns people have about biotechnology. You learnt that all religious sects around the world hold very serious opinions about biotechnology. We discussed the ethical concerns based on the conformity of many of the biotechnology methods and products with

religious beliefs held by the people for thousands of years. We also discussed ethical and moral concerns about gene crossing and cloning.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe the various concerns expressed by the different religious groups on biotechnology.
2. Write a concise essay on the ethical and moral concerns of biotechnology.
3. Write a logical essay on one of the following topics:

    i. "biotechnology is beneficial and should be advanced"
    ii. "biotechnology is detrimental and should be outlawed"

7.0 REFERENCES/FURTHER READING

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