COURSE GUIDE

EMT 401

ENVIRONMENTAL MONITORING SYSTEMS AND TECHNIQUES

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UNIT 1: DEFINITION, GENERAL PRINCIPLES OF ENVIRONMENTAL MONITORING

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1.0 Introduction

Environment is a very broad concept. Everything that surround affects us during our life-time is collectively known as environment. As human beings we are often concerned with our surrounding conditions that affect people and other organisms (plants and animals). Today, all over the world there is growing concern about the deteriorating quality of the environment and efforts are being made to stop the widespread abuse of environment and improve its quality.

2.0 Objectives

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

- explain what the term environment entails
- discuss the components of the environmental
- discuss the nature and characteristics of the hydrosphere
- explain the nature and characteristics of the lithosphere
- discuss the nature and characteristics of the atmosphere
- discuss the nature and characteristics of the biosphere.

3.0 Main Content

3.1 Environment

The word Environment is derived from the French word “Environ” which means “surrounding”. Our surrounding includes biotic factors like human beings, Plants, animals, microbes, etc. and abiotic factors such as light, air, water, soil, etc. The environment is considered as multifaceted of many variables, which surrounds man as well as other living organisms. Environment includes water, air and land and the interrelationships which exist among and between water, air, land, human beings and other living creatures such as plants, animals and micro-organisms. Environment consists of an inseparable whole system constituted by physical, chemical, biological, social and cultural elements, which are interlinked individually and collectively in myriad ways (Kautsky, 2001).

The natural environment consist of four intermingle systems namely, the atmosphere, the hydrosphere, the lithosphere and the biosphere. These four systems are in constant change and such changes are affected by human activities and vice versa (Kärnbränslehantering, 2004).

3.2 Components of Environment

The environment can be classified into four major components which are hydrosphere, lithosphere, atmosphere and the biosphere.

3.2.1 Hydrosphere

Hydrosphere includes all water bodies such as lakes, ponds, rivers, streams and ocean etc. Hydrosphere functions in a cyclic nature, which is termed as hydrological cycle or water cycle. The world hydrosphere overlaps and is contained by the other environmental spheres of the earth (Aritola, and Pepper, 2004).

The earth hydrosphere includes

a. Surface waters (oceans, lakes, rivers, swamps);
b. Underground water (locked in soil pores, cracks fractures and openings in bedrock, and in unconsolidated sediment);
c. Frozen water in form of ice, snow, and high cloud crystals;
d. Water vapor in the atmosphere; and
e. Moisture bound by organisms of the biosphere.

Water continually circulates between Earth’s surface and atmosphere in what is called the hydrologic cycle. The hydrologic, or water, cycle is one of the basic processes in nature. Responding to heat from the sun and other influences, water from oceans, rivers, lakes, soils and vegetation evaporates into the air and becomes water vapor. Water vapor rises into the atmosphere, cools, and turns into liquid water or ice to become clouds. When water droplets or ice crystals get large enough, they fall back to the surface as rain or snow (Aritola and Pepper, 2004).

Once on the ground water filters into the soil and is either absorbed by plants or percolates downward to groundwater reservoirs. If water does not filter into the soil, it runs off into streams and rivers and eventually into oceans, while some of it evaporates. Waters in a lake, snow on a mountain, humid air or drops of morning dew are all part of the same system. Total annual water loss from the surface equals Earth's total annual precipitation. Changing any part of the system, such as the amount of vegetation in a region or land cover, affects the rest of the system (Saxena, 2004).

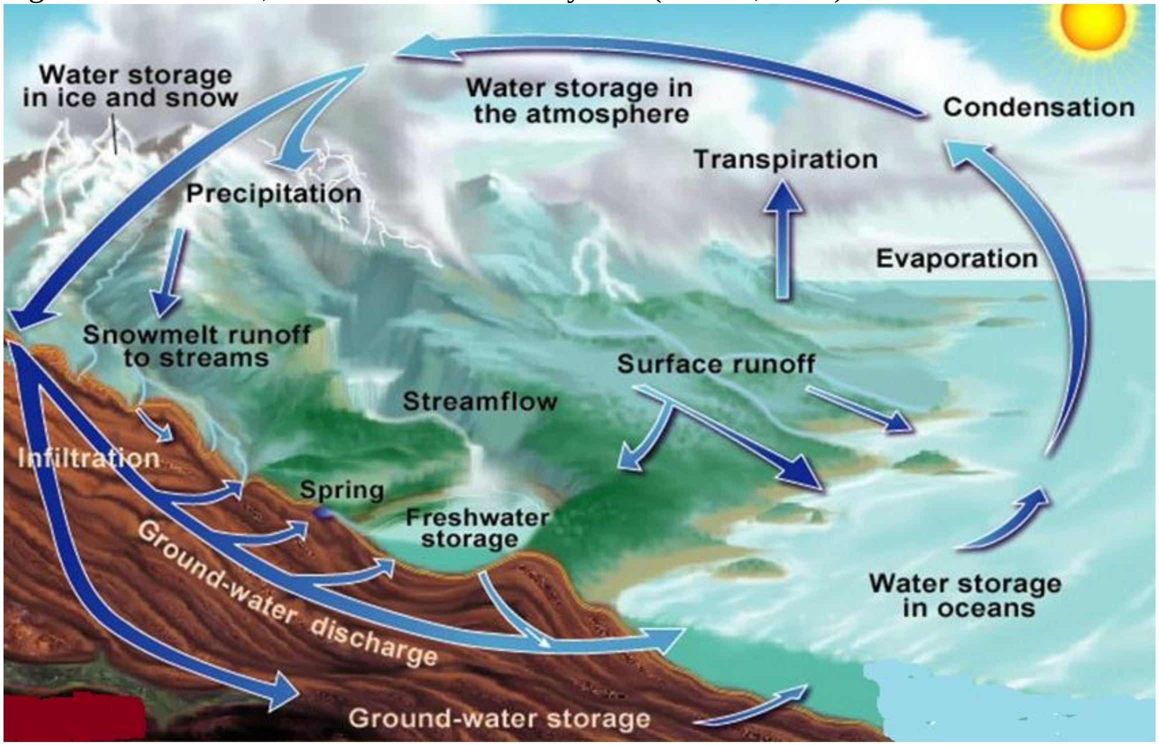

Figure 1.1: Water Cycle

3.2.2 Lithosphere

Lithosphere means the mantle of rocks constituting the earth's crust. Lithosphere is divided into three layers-crusts, mantle and core (outer and inner). The lithosphere is where many of the geologic processes that affect us originate. The movement of large pieces of the lithosphere account for the global locations of volcanoes, earthquakes, and mountain ranges, as well as the shape and location of our modern continents. The lithosphere is made up of rocks from two of the Earth's major layers. It contains all of the outer, thin shell of the planet, called the crust, and the uppermost part of the next-lower layer, the mantle. The thickness of the lithosphere varies; it's thickest below the continents and thinnest at the mid-ocean ridges, raised areas of the seafloor where new seafloor crust is formed (Saxena, 2004).

The thing all of the rocks in the lithosphere have in common is the way in which they respond to forces applied to them. At the relatively low temperatures found near the Earth's surface, rocks tend to break under stress. Farther down, as temperature and pressure increase, the more likely it is that rocks will be able to accommodate stress by changing shape, or deforming, compressing, stretching, and bending, rather than breaking (Erle, 2016).

At some critical depth, the temperature will be high enough that rocks actually start behaving like a viscous fluid rather than a brittle solid. That depth is defined as the bottom of the lithosphere. Below the base of the lithosphere, rocks are hot enough that they actually deform by flowing, even though they remain solid due to the high confining pressure produced by the weight of the rocks above. That layer on which the lithosphere rests is known as the asthenosphere (Erle, 2016).

3.2.3 Atmosphere

The cover of the air, that envelopes the earth is known as the atmosphere. Atmosphere is a thin layer which contains gases like oxygen, carbon dioxide etc. and which protects the solid earth and human beings from the harmful radiations of the sun. There are five concentric layers within the atmosphere, which can be differentiated on the basis of temperature and each layer has its own characteristics. These include the troposphere, the stratosphere, the mesosphere, the thermosphere and the exosphere (Kärnbränslehantering, 2004). The atmosphere is a critical system that helps to regulate earth's climate and distribute heat around the globe.

The atmosphere is a complex system in which physical and chemical reactions are constantly taking place. Many atmospheric processes take place in a state of dynamic balance, for example, there is an average balance between the heat input to, and output from, the atmosphere. This condition is akin to a leaky bucket sitting under a faucet: when the tap is turned on and water flows into the bucket, the water level will rise toward a steady state where inflow from the tap equals outflow through the leaks. Once this condition is attained, the water level will remain steady even though water is constantly flowing in and out of the bucket (Kärnbränslehantering, 2004).

Today human actions are altering key dynamic balances in the atmosphere. Most importantly, humans are increasing greenhouse gas levels in the troposphere, which raises Earth's surface temperature by increasing the amount of heat radiated from the atmosphere back to the ground (Erle, 2016).

The atmosphere is composed of nitrogen, oxygen, argon, water vapor, and a number of trace gases (Table 1.1). This composition has remained relatively constant throughout much of Earth's history. Chemical reactions maintain the ratios of major constituents of the atmosphere to each other. Many gases play critical roles in the atmosphere even though they are present in relatively low concentrations.

Table 1.1. Atmospheric gas composition (average).

Gas	**Mole fractions**
Nitrogen (N)	0.78
Oxygen (O)	0.21
Water (HO)	0.04 to < $5x10^{-3}$; $4x10^{-6}$ — strat
Argon (Ar)	0.0093
Carbon Dioxide (CO_2)	$370x10^{-6}$ (date: 2000)
Neon (NE)	$18.2x10^{-6}$
Ozone (O_3)	$0.02x10^{-6}$ to $10x10^{-6}$
Helium (He)	$5.2x10^{-6}$
Methane (CH_4)	$1.7x10^{-6}$
Krypton (Kr)	$1.1x10^{-6}$
Hydrogen (H)	$0.55x10^{-6}$
Nitrous Oxide (N_2O)	$0.32x10^{-6}$
Carbon Monoxide (CO)	$0.03x10^{-6}$ to $0.3x10^{-6}$
Chlorofluorocarbons	$3.0x10^{-9}$
Carbonyl Sulfide (COS)	$0.1x10^{-9}$

Earth's atmosphere extends more than 560 kilometers (348 miles) above the planet's surface and is divided into four layers, each of which has distinct thermal, chemical, and physical properties (Fig. 1.2). (Erle, 2016).

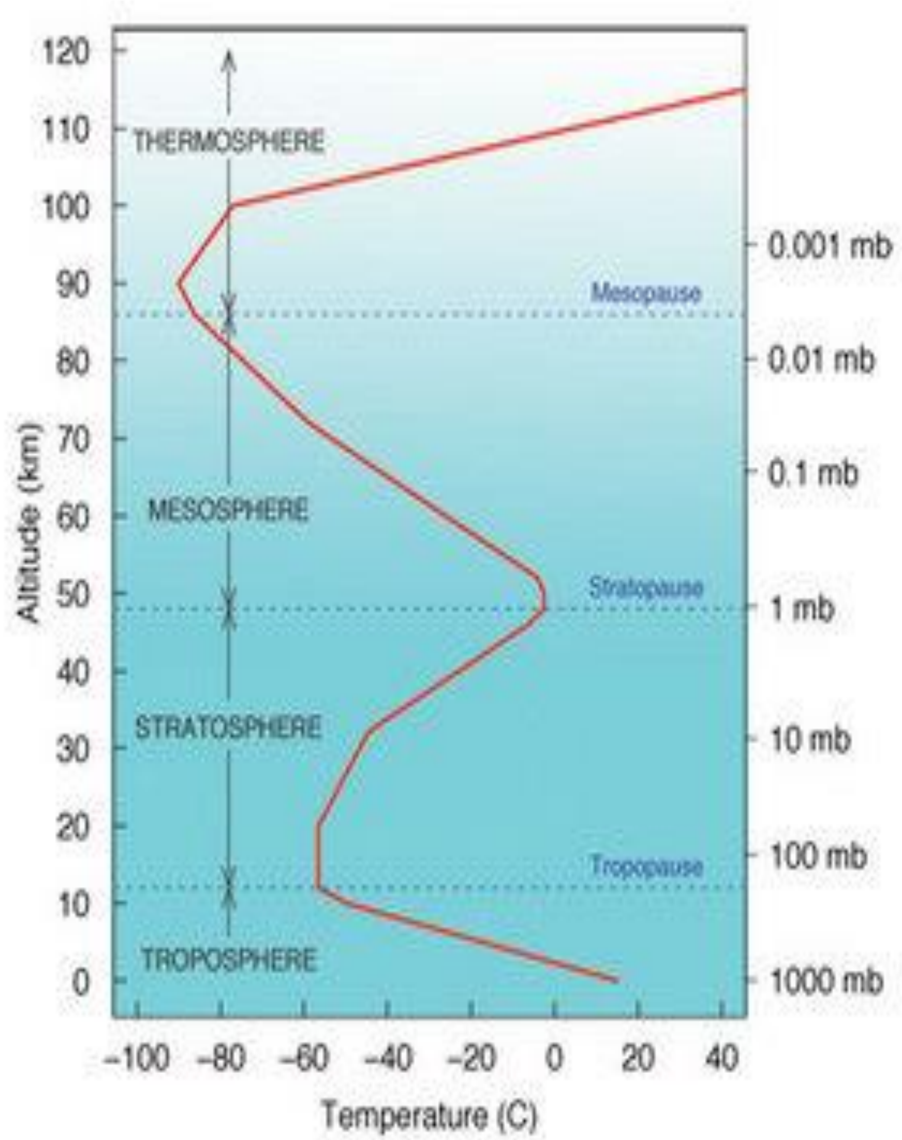

Figure 1.2: The Atmosphere

Almost all weather occurs in the troposphere, the lowest layer of the atmosphere, which extends from the surface up to 8 to 16 kilometers above Earth's surface (lowest toward the poles, highest in the tropics). Earth's surface captures solar radiation and warms the troposphere from below, creating rising air currents that generate vertical mixing patterns and weather systems, as detailed further below. Temperatures decrease by about 6.5°C with each kilometer of altitude. At the top of the troposphere is the tropopause, a layer of cold air (about -60°C), which forms the top of the troposphere and creates a "cold trap" that causes atmospheric water vapor to condense (Erle, 2016).

The next atmospheric layer, the stratosphere, extends upward from the tropopause to 50 kilometers. In the stratosphere temperatures increase with altitude because of absorption of sunlight by stratospheric ozone. (About 90 percent of the ozone in the atmosphere is found in the stratosphere) (Erle, 2016).

The stratosphere contains only a small amount of water vapor (only about one percent of total atmospheric water vapor) due to the "cold trap" and the tropopause, and vertical air motion in this layer is very slow. The stratopause, where temperatures peak at about -3°C, marks the top of the stratosphere.

In the third atmospheric layer, the mesosphere, temperatures once again fall with increasing altitude, to a low of about -93°C at an altitude of 85 kilometers. Above this level, in the thermosphere, temperatures again warm with altitude, rising higher than 1700°C.

The atmosphere exerts pressure at the surface equal to the weight of the overlying air. Figure 1.1 also shows that atmospheric pressure declines exponentially with altitude—a fact familiar to everyone who has felt pressure changes in their ears while flying in an airplane or climbed a mountain and struggled to breathe at high levels. At sea level, average atmospheric pressure is 1013 millibars, corresponding to a mass of 10,000 kg (10 tons) per square meter or a weight of 100,000 Newtons per square meter (14.7 pounds per square inch) for a column of air from the surface to the top of the atmosphere.

Pressure falls with increasing altitude because the weight of the overlying air decreases. It falls exponentially because air is compressible, so most of the mass of the atmosphere is compressed into its lowest layers. About half of the mass of the atmosphere lies in the lowest 5.5 kilometers (the summit of Mt. Everest at 8850 m extends above about roughly two-thirds of the atmosphere), and 99 percent is within the lowest 30 kilometers.

3.2.4 Biosphere

The term "biosphere" originated with the geologist Eduard Suess in 1875, who defined it as "the place on earth's surface where life dwells". Vladimir I. Vernadsky first defined the biosphere in a form resembling its current ecological usage in his long overlooked book of the same title, originally published in 1926. It is Vernadsky's work that re-defined ecology as the science of the biosphere and placed the biosphere concept in its current central position in earth systems science (Kautsky 2001).

The biosphere also known as the ecosphere is the worldwide sum of all ecosystems. It can also be termed the zone of life on Earth, a closed system (apart from solar and cosmic radiation and heat from the interior of the Earth), and largely self-regulating. By the most general biophysiological definition, the biosphere is the global ecological system integrating all living beings and their relationships, including their interaction with the elements of the lithosphere, geosphere, hydrosphere, and atmosphere. The biosphere includes all living organisms on earth, together with the dead organic matter produced by them. The biosphere is postulated to have evolved, beginning with a process of biopoiesis (life created naturally from non-living matter, such as simple organic compounds) or biogenesis (life created from living matter), at least some 3.5 billion years ago.

The biosphere is commonly defined as the region of the Earth and its atmosphere in which life exists the biosphere is usually defined as the region above the rock surface, and may, therefore, more appropriately be referred to as surface ecosystems. It is sometimes difficult to make a clear distinction between biosphere and geosphere and some sets of processes e.g. those relating to hydrology and near-surface hydrogeology interact across the interface of the geosphere and the biosphere. The biosphere includes regolith, hydrological and subsurface hydrogeological systems, biota (including humans), and the overlaying atmosphere (Kautsky 2001).

The surface is often divided into distinct ecosystems distinguished by the importance of certain common processes. The biosphere consist of an ecosystem comprises biota e.g. plants, animals and microbes that live in a defined zone and their physical environment (Porteous, 2000). Examples of ecosystems are lakes, seas, mires, agricultural land, and forests. The division into distinct ecosystems makes it easier to identify interactions in the biosphere system.

The biosphere concept is common to many scientific disciplines including astronomy, geophysics, geology, hydrology, biogeography and evolution, and is a core concept in ecology, earth science and physical geography. A key component of earth systems, the biosphere interacts with and exchanges matter and energy with the other spheres, helping to drive the global biogeochemical cycling of carbon, nitrogen, phosphorus, sulfur and other elements. From an ecological point of view, the biosphere is the "global ecosystem", comprising the totality of biodiversity on earth and performing all manner of biological functions, including photosynthesis, respiration, decomposition, nitrogen fixation and denitrification. The biosphere is dynamic, undergoing strong seasonal cycles in primary productivity and the many biological processes driven by the energy captured by photosynthesis. Seasonal cycles in solar irradiation of the hemispheres is the main driver of this dynamic, especially by its strong effect on terrestrial primary productivity in the temperate and boreal biomes, which essentially cease productivity in the winter time.

The biosphere has evolved since the first single celled organisms originated 3.5 billion years ago under atmospheric conditions resembling those of our neighboring planets Mars and Venus, which have atmospheres composed primarily of carbon dioxide. Billions of years of primary production by plants released oxygen from this carbon dioxide and deposited the carbon in sediments, eventually producing the oxygen rich atmosphere we know today. Free oxygen, both for breathing (O_2, respiration) and in the stratospheric ozone (O_3) that protects us from harmful UV radiation, has made possible life as we know it while transforming the chemistry of earth systems forever (Kautsky 2001).

As a result of long term interactions between the biosphere and the other earth systems, there is almost no part of the earth's surface that has not been profoundly altered by living organisms. The earth is a living planet, even in terms of its physics and chemistry. A concept related to, but different from, that of the biosphere, is the Gaia hypotheses, which posits that living organisms have and continue to transform earth systems for their own benefit.

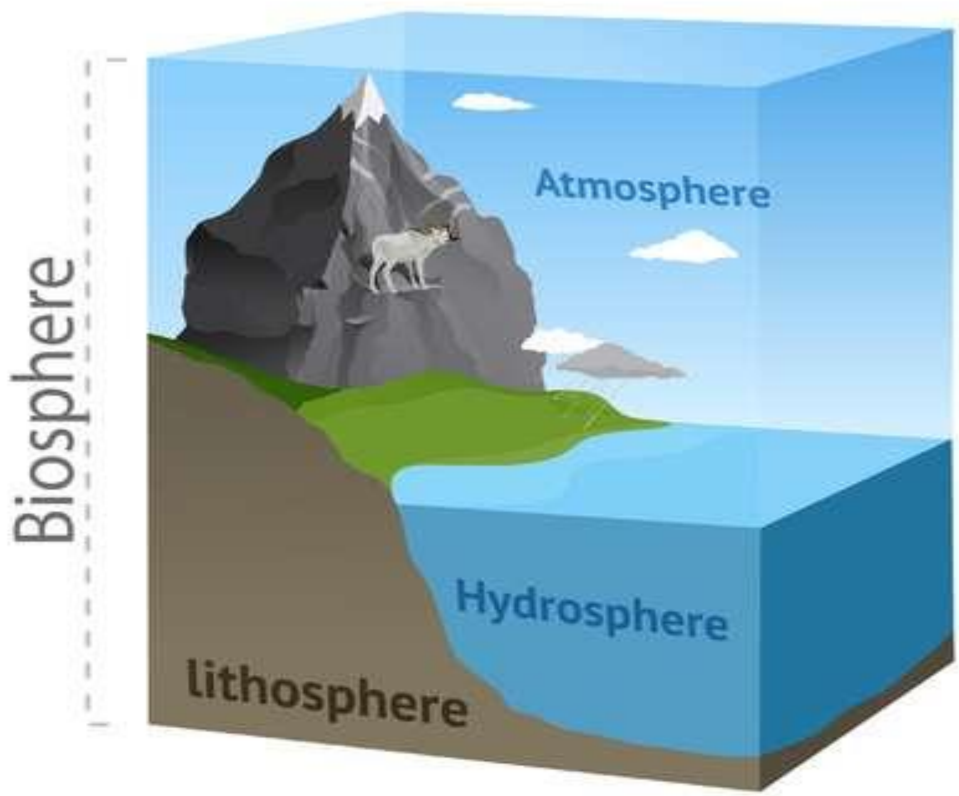

Figure 1.3: The Biosphere

4.0 Conclusion

The knowledge of the environment and its components will enable mankind understand the interconnectivity its various components. The fragility of the environment could equally be seen clearly despites the fact that all the resources required by man in his socio-economic and technological development centres around these environmental resources (components).

5.0 Summary

In this unit we have leant that:

i. The environment is the most important surrounding of man
ii. The environment is made up of the atmosphere, hydrosphere, lithosphere and biosphere as its major components.
iii. All the resources needed by man in his development are found within the environment.

6.0 Tutor-Marked Assignments

1. Explain the term environment

2. Explain the major components of the environment.
3. Identify the various atmospheric gases.
4. Identify the major components of earth hydrosphere.

7.0 References

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UNIT 2: GENERAL PRINCIPLES OF ENVIRONMENTAL MONITORING

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2.0 Introduction

Environmental monitoring is a conventional tool for assessing environmental conditions and trends, support policy development and its implementation, and develop information for reporting to national policymakers, international forums and the public. Over the past few decades, only a few countries of Europe and Central Asia have been able to maintain existing monitoring activities. The monitoring of the environmental conditions is a paramount issue among nations. This is because gaseous waste, liquid and solid and hazardous waste monitoring is weak and industrial emissions are also not well monitored, reducing the effectiveness of policy instruments such as emissions charges and fines. Monitoring of trans boundary pollution also needs strengthening. Despite all desire for environmental monitoring, many countries lack uniform national methodologies across different monitoring areas, and their classification systems are often incompatible with international standards.

2.0 Objectives

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

- discuss the concept of auditing, environmental impact assessment, and environmental monitoring
- explain the impetus and history of environmental monitoring

- state the objectives of environmental monitoring
- mention the purpose of environmental monitoring
- discuss the components of environmental monitoring
- explain the use of environmental monitoring information
- discuss the environmental monitoring information outside the government
- discuss the environmental monitoring information within government.

3.0 Main Content

3.1 Definition of Terms

3.1.1 Auditing

This is usually monitoring done (typically during the construction or operations stages) to determine how the status of one or more variables compares with requisite or desired standard(s) (Cutler, 1984; Aritola and Pepper, 2004). A check list is frequently used if several criteria are being audited. In order for the effort to truly be an audit there must be a follow-up enforcement process for variables that did not meet the criteria. Depending on what is being monitored, auditing can be one-time (e.g) grading to a certain contour) or periodic (e.g. for water quality). Similar terms include surveillance and compliance inspection (Beanlands and Duinker, 1984).

3.1.2 Impact Assessment

This is monitoring done during the project planning. Stage in order to obtain an inventory of data for use in predicting project impacts. The data collected is factored into the decision-making process to design a project with minimal adverse effects (Buffington, 1980; Canter, 1984).

3.1.3 Monitoring/Environmental Monitoring

Monitoring is the systematic process of observing, tracking, process of collecting, analyzing and using information to track a program's progress toward reaching its objectives and to guide management decisions. While environmental monitoring is defined as the observation of the presence of harmful factors such as toxins, bacteria, chemicals and other pollutants in a specific location (Wiersma, 2004). In another vein, Environmental monitoring means collecting a representative portion of soil, water, waste or air from an area to ascertain its quality and characteristics.

In a detail, monitoring is the collection of data during construction or operations stages for one or more of the following purposes:

a. To determine status or trends, e.g. an inventory or successive inventories.

b. To determine if expected effects have occurred, i.e. prediction monitoring.

c. To determine project impacts whether anticipated or not, i.e. impact monitoring, tracking.

d. To determine if objectives for management are being achieved, if measures were applied and with what effect, i.e. mitigation success monitoring.

3.2 Impetus and History of Environmental Monitoring

The impetus to environmental monitoring comes from two sources:

(a) Research and conceptual needs for ex post factual analysis, and

(b) Administrative requirements to compliance to environmental agreements.
The concept of conducting an environmental analysis along with comparing observed to predicted impacts, has been discussed among environmental interests since the mid 1930's as scientists recognized that natural resources are limited. Environmental monitoring project impacts, required that environmental monitoring be done by Federal agencies to help ensure that planned mitigation measures are in fact carried out once a project begins (Bisset, 1980, Wiersma, 2004).

Both the concept and the requirement for environmental monitoring were furthered in November 1978 when the Council on Environmental Quality issued regulations for implementing Environmental Protection Agency. These regulations are binding on Federal agencies in countries all over the world. They require monitoring and enforcement programs for projects for which an Environmental Impact Statement (EIS) is filed. Agencies are required to issue a "Record of Decision" that specifies all factors considered in reaching a decision on the proposed project, the alternatives considered, the environmentally preferable option, and the factors used in reaching the project decision. Also, the Record "must state whether all practical means of mitigating or preventing environmental harm have been adopted and if not, why not."

Finally, to ensure that preventive/mitigating measures are applied. The record requires that agencies must monitor projects: the lead agency must condition funding of mitigative actions; upon request, agencies must inform other agencies of mitigation progress; and, the lead agency must make environmental monitoring results available to the public (Bisset, 1980).

Project monitoring is required by Federal regulations only to check that mitigation measures are implemented and to assure that criteria to assess the performance of these measures are met. There are no Federal environmental monitoring requirements to perform audits and to improve the quality of future EISs. While evidence is sparse, some cases have surfaced where injunctions were issued against continuing project work until the agreed upon environmental mitigation actions have been achieved; this may encourage agencies to monitor their performance in mitigating or preventing impacts ((Wiersma, 2004).

During the 1970s, with continued environmental problems and feelings that the regulatory reaction had not been as effective as hoped, the concept of the environmental audit emerged (Palmisano, 1983). This concept stems from the recognition that resources are limited and that safekeeping the environment is the responsibility of all segments of society, industry as well as government.

Although the up the 1980s, environmental audit concept is still new to environmentalists, most feel that it has potential to be a useful tool in shared environmental safekeeping Enforcement alone cannot be relied upon to ensure environmental performance. Industry knows this and welcomes self-auditing as a cost-effective and more reliable compliance technique than can be obtained by external policing (Cutler, 1984). As the environmental monitoring concept emerged, governmental interest in the ability of resources to meet long-term needs resulted in periodic appraisals of most natural resources. Laws such as the Soil and Water Conservation Act of 1976 require periodic appraisals. As the environmental monitoring/auditing concepts mature, they will become standardized, institionalised, and integrated to the mainstream of environmental planning (Cutler, 1984).

3.3 Objectives of Environmental Monitoring

The main objectives of environmental monitoring are;

- To establish a base-line of exposure.
- To co-relate with a suspected source of contamination.
- To estimate the changes in levels of the pollutants in the environment.
- Confirming and reconfirming the success of the pollution control measures.
- Collection of meaningful and relevant information.
- Know the nature and degree of pollution from various sources.
- Recommendation of improves mitigation measures to be undertaken.

3.4 Purpose of Environmental Monitoring

The main purpose of environmental monitoring are;

- Adopt and design specific purification for plants
- Check the industries/developmental projects for compliance (as per the regulations) of emission/pollution standards.
- To prevent health hazards and disasters in relation to industries/developmental projects.
- Progressively improving the state of the environment with regards to industries/developmental projects

3.5 Components of Environmental Monitoring

The major components of the environmental Monitoring process include: monitoring design, quality assurance, data management, data analysis, research and development in support of data collection and .interpretation, coordination of agency activities, and the review, dissemination and use of the resulting information (Buffington, 1980). Some put particular emphasis on the need for techniques for analyzing data and Making decision.

The key elements to be contain in environmental monitoring program are summarize to include;

1. Terms should be define and definitions should be consistently used.
2. Specific objectives and management goals should be defined Since these enable the system and its methodology to be mat effective. he logical steps for applications then follow:
    a. Define study area
    b. State project objectives (e.g., water supply)
    c. Identify actions and impacts to be evaluated
    d. Develop management strategy (e.g., mitigation, enhancements, etc.)
    e. Collect data and analyze.
    f. Evaluate results considering project effects and management goals.

3. A mechanism for early detection of problems, remedial actions, cost estimates, and prompt reporting of any adverse environmental conditions should be included.
4. Measures on elements/environmental indices which includes;

a. Measures of existing conditions to allow comparison with the effects of management.
b. Measures of effects; these should include the key variables that are identified as resource objectives, environmental standards, or indicators of land health and productivity.
c. Measures of impacts predicted. "...these should be testable, and free of ambiguities and should be stated as hypotheses which can be tested with an appropriate study plan. In this respect, a predictive analysis should strive to include quantified details on impact magnitude, duration, and spatial distribution.

5. Data:

- **Consistent data.**

In implementing audits, it is vital to have monitoring data that have been obtained consistently through time. For example, data on phytoplankton biomass collected pre-operationally should be comparable with data collected during operation. It would be useless if other aspects of phytoplankton were monitored halfway through a program. Similarly, data have to be collected in a standardized manner. Sampling locations and techniques must not be changed, otherwise statistical analysis is rendered speculative" (Bisset, 1980).

- **Quantitative elements.**

A quantitative approach should prevail in baseline and monitoring studies and other field investigations (Beanlands and Duinker, 1984). Factors and parameters to include in the evaluation methodology are: (a) engineering data on type of project and physical effects; (b) descriptive physical data on various habitats within the project area; (c) primary producers; and (d) support populations.

- **Baseline data.**

"For most projects with a long operational life, monitoring is a lengthy, expensive, and time—consuming business. Operational monitoring is required for at least two years, and in most cases longer, before trends can be identified. To compare operational monitoring data with preoperational data, monitoring must carried out for a considerable time prior to operation. Most commentators consider that baseline data should cover more than one year to determine seasonal variations and natural longer term fluctuations. Achieving this is difficult as there is often no time available to obtain the requisite preoperational data" (Bisset, 1980).

- **Data suitable for statistical analysis.**

Data suitability can be an unknown factor; data can be subject to a variety of contingent factors, which might render conclusions at worst irrelevant-or at best only indicative of a particular result. To audit properly, it is necessary to determine in advance the likely impacts, their geographic coverage, and the types of changes in environmental parameters or processes expected. It helps also if certain degrees or sizes of change are established as "benchmarks" to be identified by monitoring schemes. With this knowledge, monitoring must be devised to enable statistically valid analyses of both. Pre

and post operational data (however, experience shows that monitoring schemes have rarely been devised in this manner).
Haphazard monitoring schemes or schemes set up to detect "every occurrence" will result in much data which is not suitable for application of statistical techniques to interpret their meaning" (Bisset, 1980).

6. Components arrangement

There are two important implications in the content and arrangement of the components. The immediate implication is that the assessment information can be synthesized in .an incremental fashion. This incremental approach is useful because the success of the assessment does not 'depend entirely on answering the question of what level the impact is likely to reach. Although this is the implied and desired goal of every impact assessment project, it is seldom attained, leading to assessments that leave the manager at a loss for management guidance. But, if impact information is -developed in the .proposed incremental fashion, each compartment can provide information that is useful to the administrator .even without completion of the entire sequence. Since useable information, is already assembled for the first rather than - the-latter compartments, at least a degree of rational assessment -is highly probable for most assessment projects" (Bolling, 1978).

3.6 The Use of Environmental Monitoring Information

According to Bruce and Peter (2011) environmental monitoring is critical to understanding whether the quality of our environment is getting better or worse. Information gathered through environmental monitoring is important to many decision makers, outside and inside the government of any nation.

3.6.1 Environmental Monitoring Information outside the Government

Outside the government, many people and organizations use the results of environmental monitoring to manage the environment for sustainable development (Bruce and Peter, 2011). Some of the usage include;

- **Health professionals.** Public health officials are concerned about short-term environmental impacts, such as poor air quality and the need to issue smog advisories. They are also concerned about long-term health effects, such as the presence of toxic substances in the environment and human bodies.
- **Planners.** Municipal engineers responsible for designing flood control systems need to know the maximum height to which water levels could rise. When they set premiums, insurance companies need accurate information about current and future environmental risks. If they lack sound information, they pay a real financial cost.
- **Emergency responders.** When environmental occurs or a major industrial accident occurs, it is vital to know without delay exactly where it occurred and how severe it is; armed with accurate and timely information, responders can deliver rapid and targeted assistance. Monitoring information can help emergency managers predict and respond to such events.

- **Resource managers.** For example, farmers need to know the short-term weather scenario to help them decide when to plant and when to harvest their crops. They also rely on information about long-term climate trends for example, when deciding how to respond to declining water supplies. Mining companies in the Nigeria also need to know whether changes and how it stimulates flood occurrences and the extent it can jeopardize access to resources.
- **Industries.** Major industries all mover the world need to monitor their own industrial environmental effects to ensure that they comply with regulations. For example, the National Environmental Standards and Regulations Enforcement Agency requires many businesses in Nigeria to measure and report how much pollution they release into the environment from their facilities. National Environmental Standards and Regulations Enforcement Agency is an environmental agency of the Federal Government of Nigeria that was established by law in 2007 to ensure a cleaner and healthier environment for Nigerians.

3.6.2 Environmental Monitoring Information within Government

Bruce and Peter (2011) assert that the federal government relies on environmental monitoring for crucial management information. Within the federal government, environmental monitoring generates information that is essential for several core management functions which include;

- **Designing environmental management programs.** Environmental monitoring describes the starting point against which targets can be set and progress evaluated. One key step in developing an environmental management program is assessing the current state of the environment. This could be done by assessing particular environmental status and trends over a period of time
- **Designing environmental predictive models**. Environmental monitoring results provide a basis for designing models that can be used to predict the future consequences of management actions. The predictions could be of the weather characteristics or climate trend in years, or the quantity of minerals that could be mine sustainably given exploitation projections. Monitoring results are also used to check and improve the model predictions over time. These kinds of predictive tools can then be used to compare alternative management actions.
- **Allocating resources efficiently.** Government knowledge of where resources are needed makes it possible for efficient a sustainable usage environmental resources. For example, population monitoring in Nigeria can help in environment sustainability drive with high population density low income earners and forest damage, and proffering solutions towards direct corrective action.
- **Assessing the environmental effects of past and present projects.** When projects are assessed under the National Environmental Standards and Regulations Enforcement Agency for their possible environmental effects, follow-up programs may be required to determine whether the observed effects are consistent with the predictions and whether actions to mitigate the possible effects are working as planned. Such monitoring programs are put in place for about 5 percent of environmental assessments. The environmental effects are typically

restricted to a single location; however, when the effects of more than one project are combined, as in the case of the oil mining region of Nigeria Delta, project planners may need to consider the cumulative effects of the different projects. In the case of contaminated sites related to completed or abandoned projects, such as mines, continuing attention may be required if pollutants are being released into the environment.

- **Evaluating compliance with environmental regulations.** Environmental monitoring produces the information to evaluate performance in relation to regulations. For example, oil spills in Niger Delta region of Nigeria has been increasing right from the early days of mining in the region till date. By comparing spills levels with regulatory limits, authorities can make decisions about how they should respond to protect public health and environmental quality. Compliance monitoring is usually based on specific regulations by National Environmental Standards and Regulations Enforcement Agency of Nigeria.
- Monitoring also provides a way of determining whether regulations and enforcement actions are working as expected. If the regulations are being followed but the state of the environment is not improving as planned, changes may be needed to the regulatory approach.
- **Promptly identifying problems by government.** Environmental monitoring may also produce information about emergencies that require an immediate response, as well as processes that take longer to unfold. For example, government managers may need to act very quickly in response to a disease in environment that is threatens or hazards that potentially will affects food security of the country.
- **Complementing scientific research by government institutions.** Environmental monitoring is closely tied to scientific research. Research can identify and describe the cause-effect relationships that underlie monitoring programs. For example, when managers of a monitoring program choose particular types of water pollutants for measurement, the decision is based on the research documenting the effects of those pollutants on aquatic plants and animals. Researchers can also help design the equipment and methods that allow monitoring programs to ask new questions or obtain more accurate results. In turn, unexpected results from monitoring can trigger new research by government institutions.

4.0 Conclusion

Environmental monitoring remain the most conventional tool for assessing environmental conditions and trends, support policy development and its implementation, and develop information for reporting to national policymakers, international forums and the public. In vitually all developmental project, monitoring is required by all national regulations of all nations of the world to help check that mitigation measures are implemented and to assure that criteria to assess the performance of these measures are met. Environmental audit and projects impact assessment as help in sustainable development of the world. In environmental monitoring, the objectives and purpose of the monitoring must be succinctly clear and it must be centre around the components of environmental monitoring.

5.0 Summary

In this unit we have leant:

i. The concept of auditing, environmental impact assessment, and environmental monitoring.
ii. The impetus and history of environmental monitoring
iii. The objectives of environmental monitoring
iv. The purpose of environmental monitoring
v. The components of environmental monitoring
vi. The use of environmental monitoring information
vii. The environmental monitoring information outside the government and within government

6.0Tutor-Marked Assignments

1. Appraise impetus and history of environmental monitoring.
2. Identify the main objectives of environmental monitoring.
3. What are the purpose of environmental monitoring?
4. Highlight the components of environmental monitoring.
5. What are the uses of environmental monitoring information?

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UNIT 3: STRATEGIES OF ORGANIZING AND MONITORING PROGRAMMES FOR SITE AND RESOURCES

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main content

3.1 Organization of Monitoring Programmes

3.2 Specific strategies for monitoring sites and resources

3.2.1 Off-site Monitoring Assessment

3.2.2 On-site Monitoring Assessment

1.1 Classification of monitoring techniques
4 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignments
7.0 References and other Resources

1.0 Introduction

The environment provides man with various resources that are crucial for survival. Monitoring of these resources has evolved to determine how the environment is affected by human activities, and the need for sustainability (Aritola and Pepper, 2004). The pressure on environmental resource has become overwhelmingly high. In most cases, the unsustainable use of environmental resource has led to scarcity in both local, regional and global scale. The implementation of a monitoring and assessment programme must focus on the spatial distribution of environmental resources. Therefore, strategic programme for monitoring the resources must be site specific. The monitoring system should be developed in close consultation with the various levels of stakeholders to enable them to provide feedback and observations.

2.0 Objectives

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

- explain the process of organizing a monitoring program
- discuss the specific strategies for monitoring site and resource
- classify the various monitoring techniques based on resources.

3.0 MAIN CONTENT

3.1 Organization of Monitoring Programmes

Monitoring are integral and distinct parts of programme preparation and implementation. It is a critical tools for forward-looking strategic positioning, organizational learning and for sound management. This could be in the form of long-term, standardized measurement and observation of environmental resource in order to define status and trends. Monitoring are meant to influence decision-making, including decisions to improve, reorient or discontinue the evaluated intervention or policy; decisions about wider organizational strategies or management structures for policy makers and funding agencies (Aritola and Pepper, 2004). The entire process of carrying out a monitoring program may be tedious and in most cases time consuming. Therefore, the success of a monitoring program depends on how appropriate the program/project is organized. Appropriate program/project must be streamlined in-respect to specific steps. These steps according to Telfair and Mulvihill (2000) can be classified into:

- Define the preferred goal of the program
- Define the desired objective(s) for each goal
- Define one or more indicators/measures for each objectives
- Identify the source(s) of the data for each measure
- Define steps/activities (methodology) that are effective toward achieving the objectives
- define the tools/instrument for carrying out each steps/activities
- Measure progress of the steps/activities/intervention.

The first operational task for carrying out a resource-monitoring program is the definition of goals. The organizers must addresses the challenges/opportunity of the program. In most instances questions such as 'What, Why, Where, When" are formulated and addressed. Goals may not necessarily be measurable, but they must be consistent with the general purpose and intent of what is to be accomplish. A precondition for assessment of monitoring program is the development of a plan with quantifiable objectives that are rationally related to each other's and to the goals defined for the program. All project objectives should specify what is to be done and by when. The indicators/measures for each objectives must be defined. This may incorporate the target objects/phenomena to be evaluated. For resource monitoring, this may include air, water, soil, vegetation, minerals. On the other hand, this may be waste dumpsite, agricultural farmland, mining facility, and tracks in the case of site monitoring (Beanlands and Duinker, 1984).

The source of data for each measures and the specific tools for obtaining such data are also important to note – particularly when the monitoring program has to do with an onsite evaluation exercise. For in-situ assessment, physical observation is critical, but the use of instrument provides better assessment/result. A standard for measuring/evaluating the progress of the program is important to determine how effect the program is.

A well-organized monitoring programme for environmental assessment must encompasses the contribution of the various professionals to form a coherent team. This must incorporates professionals of various fields such as; ecologist/biogeographers, climatologist/meteorologist, geomorphologist/geologist, sociologist/demographers and environmentalist. A united monitoring team with expert in diverse field is important for a successful monitoring programme.

Therefore, the organization of monitoring programmes must start with team management, precise goal and objects to execution of the program.

3.2 Specific strategies for monitoring sites and resources

According to Wiersma, (2004), for effective resource conservation and sustainability, monitoring of site and resource must not be a "one-time event," the operation must be a routine exercise incorporating planning, implementation, evaluation, and follow-up specified within a timeframe. Site and resource monitoring is conducted in two phases i.e. off-site (pre-field preparation, site mapping, laboratory analysis and report preparation) and on-site (reconnaissance, field evaluation exercise, recording/measurement/data collection).

3.2.1 Off-site Monitoring Assessment

1. Pre-field preparation: This phase incorporates the program definition, implementation, and consultation with stakeholders. All machineries for site/resource monitoring exercise are put into consideration prior to the proper evaluation. Important resources such as instrument for measurement/evaluation, team specialists, assessment schedules, finance, and other relevant materials and logistics such as feeding, transportation, accommodation, are defined and made available. All these are prerequisite for in-situ assessment.

2. Laboratory analysis and report preparation: Activities such as laboratory assessment are carried out in the lab after field investigation and data collection. Generally, the field can be seen as the major laboratory for a geographer, but not every data obtained directly from field assessment can be used; some need further examination, which is carried out in scientific laboratory. Soil nutrient assessment and water quality assessment are among such assessment carried out in scientific lab. Final data/result collation, sorting and report preparation/presentation are also off-site assessment. Out of this, the outcome of the monitoring evaluation, its implication and policy recommendation are provided.

3.2.2 On-site Monitoring Assessment

1. Reconnaissance: a preliminary survey to gain information especially an exploratory inventory on a particular phenomenon. This survey must be brief and conducted in the study area with the focus of providing the evaluation team with valuable information to help plan the field data collection and the best approach/technique to be adopted. All source points for data collection are delineated and the phenomena to be investigated are identified during the survey.

2. Field evaluation exercise: Most important stage for site-specific resource monitoring is the field evaluation/exercise (Fieldwork). The data collection exercise is

carried out on-site. The process includes physical observation, recording, and direct measurement of the phenomenon of interest. Depending on the phenomenon to be assessed, different method may be adopted to examine the target population. For vegetation studies, lines and quadrat method are most suitable, while the census survey may be adopted to investigate human phenomenon with small population, the stratified, random and systematic sampling method may be adopted for large population. For source point the purpose/judgmental approach is most suitable. This approach is used to investigate pollution of various kinds (industrial discharge, sewage discharge, spill of hydro-carbons, dumpsite, landfill, erosion site) (Wiersma, 2004).

3.3 Classification of monitoring techniques

Wiersma, (2004) assert that monitoring techniques differs considerably and in accordance to the phenomena of interest. Therefore, monitoring techniques is categorized based on the resources thus;

- Physical, chemical, biological radioactive (global sources)
- Sinks and transport (mass balance) of both man-made and natural atmospheric trace components.
- Ocean-atmosphere interactions
- Reversible effect of human activities on the global environment e.g. greenhouse effect, climate change, depletion of stratosphere ozone layer, acid rain.

(a) Physical, chemical, biological and radioactive (global sources)

The environment is made up of the physical, chemical, biological, and radioactive components. Component such as hydrosphere (stream, river, lake, sea, and ocean), landforms (hills, lowland, plateau, mountain, valley, rock, soils), and the atmosphere (air, gas element, radiation, water vapor) formed the physical resource of the earth. These components are also made of chemical elements (N_2, Ar, O_2, CO_2) and other trace gases which are germane for survival of life here on earth. The biological resource constitutes all plant and animal community, ranging from terrestrial to aquatic, aerial, and arboreal. Monitoring evaluation of these resources differs respectively, while routine observation may be enough for monitoring animal resources, intensive measurement is required to monitor plants and atmospheric gases (Aritola and Pepper, 2004).

i. Physical resources: Direction field observation and measurement is carried out to assess physical resources. The use of specific tools is necessary to accomplish the measurement exercise. Amongst these resources includes;

- Landforms: assessment is carried out through direct field measurement/evaluation using appropriate tools –surveying equipment for precise evaluation.
- Watercourse (stream, river, lake, sea, and ocean): Direct measurement with the use of different equipment/mathematical model in the case of discharge, runoff, velocity and volume measurement.
- Atmospheric resource: Monitoring of atmospheric resources such as air and its constituents gas element, solar radiation, water vapor etc, is becoming most significant in recent time. Increasing industrialization and its attendant's atmospheric pollution is the major debate of current climate change, and public health concerns. Inventory assessment of these resources required a rigorous scientific approach. The quality of atmospheric constituents is monitored with

both mobile devices and stationary monitoring device. Basically, the meteorological station is used to carry out routine atmospheric evaluation. For source point pollution control, a mini-met station can be install, while the mobile devices can also be used to detect trace of atmospheric pollutants (SPM, SO_2, NO_x, VOC). In some cases clean-up mechanism can be utilized.

ii. The biological resource: The adverse effect of over-dependence of plant and animal resources by man is manifested in its unsustainable exploitation. The state of both resources is becoming worrisome considering the increase of human population. Restoration/reclamation is thus, an important policy to ensure the future state of the resources is not compromised. This can only be achieve through direct field investigation. Indigenous inventory of plant/animal species are prevented through establishment of reserve and restriction from human exploitation. Afforestation program can further improved the management of indigenous plant species.

(b) Sinks and transport (mass balance) of atmospheric trace components

The atmosphere is composed of various gas elements which can range from a few parts per trillion (ppt) by volume to several hundred parts per million by volume (ppm) (Wallace, and Hobbs, 2006). The source points of the atmospheric gas are natural or anthropogenic. Natural sources are caused by processes that occur in nature. Volcanoes are the main natural source for trace gases from solid earth. Trace gas can also be present in the atmosphere through biogenic process, solid Earth (outgassing), the ocean, industrial activities, or in situ formation (Wallace, and Hobbs, 2006). The biogenic sources include photosynthesis, animal excrements, termites, rice paddies, and wetlands. The global ocean is also a source of several trace gases, in particular sulfur-containing gases. In contrast, human related activities such as fossil fuel combustion (e.g. in transportation), fossil fuel mining, biomass burning, and industrial activity are point source of gas emission. Some of the atmospheric gases include NO_x, CO_2, CH_4, O_2, H_2, O_3, SO_2, and He.

The atmospheric transportation of these gases differs from one area to another depending on the prevailing atmospheric window in the area. The atmospheric gases are transformed into another state, while in some cases they are removed from the atmosphere through chemical reactions mainly with the OH radical, gas-to-particle conversion forming aerosols, wet deposition, dry deposition, and biological activity (Wallace, and Hobbs, 2006). The process is referred to as Sink. This is the state of removal of gases from the atmosphere or a form of reservoir for atmospheric gases. The major carbon sinks are the oceans and plants and other organisms that use photosynthesis to remove carbon from the atmosphere by incorporating it into biomass. See table 3.1 below for more source and sink.

Table 3.1: Source and Sink of Atmospheric gas

Gas	**Chemical Formula**	**Residence Time or Lifetime**	**Major Sources**	**Major Sinks**
Carbon	CO_2	3 – 4 years	Biological, oceanic,	photosynthesis

Dioxide			combustion, anthropogenic	
Helium	He	-	Radiogenic	-
Methane	CH_4	9 years	Biological, anthropogenic	OH
Hydrogen	H_2	~ 2 years	Biological, HCHO photolysis	soil uptake
Nitrous Oxide	N_2O	150 years	Biological, anthropogenic	$O(^1D)$ in stratosphere
Carbon Monoxide	CO	~ 60 days	Photochemical, combustion, anthropogenic	OH
Sulfur Dioxide	SO_2	Days	Photochemical, volcanic, anthropogenic	OH, water-based oxidation
Ammonia	NH_3	2 – 10 days	Biological	gas-to-particle conversion
Ozone	O_3	Days – Months	Photochemical	photolysis

(c) Ocean-atmosphere interactions

The ocean and atmosphere are in constant exchange of heat, salt, water, and momentum. The complementary exchange of heat, water, and momentum between the ocean and earth-atmosphere resulted to the general circulation of the atmosphere. The ocean gained heat energy from solar radiation. The prevailing wind over the ocean transfers this energy to the surface layers, some of which then drives ocean currents (Xie, 2010). During this process, water evaporation will take place, removing heat from the ocean. This process is called the cooling effect. The evaporate vapor will then condensed under certain conditions to form a cloud droplet in the atmosphere. The process of condensation will lead to heat loss from the vapor contents into the atmospheric air. This process occurs in a continuous loop between the ocean and the atmosphere, distributing both heat energy and water at a time. The ocean contains salt minerals, which are derived from the subsequent rivers, carrying minerals dissolved from the rocks they run over, which is deposited as sediment on the ocean floor. During the process of evaporation, water containing dissolved salt minerals from the ocean is transformed into vapor, which are driven into the atmosphere and condensed to form cloud (atmospheric moisture).

(d) **Reversible effect of human activities on the global environment**

Human activities ranging from industrial activities, agriculture, transportation, construction, to mention but just a few have some negative feedback on the environment, most of which are of global effect. Common effects include greenhouse effect, climate change, depletion of stratosphere ozone layer, acid rain. Some of these are the direct result of human activities, whereas others are secondary effects that are part of a series of actions and reactions.

i. **Greenhouse Effect**: Major component of the greenhouse effect is caused by man's activities that emit greenhouse gases to the atmosphere. The most important of these is the burning of fossil fuels (IPCC, 2007). Fossil fuels contain carbon, and when they are burnt, this carbon combines with oxygen in the atmosphere to form carbon dioxide. The global transportation sectors generates the largest share of greenhouse gas emissions. Greenhouse gas emissions from transportation primarily come from the combustions of fossil fuel for our cars, trucks, ships, trains, and planes (Kahn, Kobayashi, Beuthe, Gasca, Greene, Lee, Muromachi, Newton, Plotkin, Sperling, Wit, and Zhou, 2007).

Changes in land use are also important sources of greenhouse gas emissions. For example deforestation results in the emission of carbon dioxide to the atmosphere that was previously stored on the Earth's surface in the form of trees and other vegetation, or locked up in soils. The second culprit gas is methane, commonly known as natural gas. It is produced as a result of agricultural activities such as livestock digestion, paddy rice farming and use of manure. Methane is also produced due to improper management of waste. Nitrous oxides are generated mainly by fertilizers. Moreover, fluorinated gases such as chlorofluorocarbons (CFCs) are chiefly a result of various industrial processes and refrigeration. Man's activities results to the emission of carbon dioxide into the atmosphere are so widespread, making carbon dioxide the most important gas in the man-made component of the greenhouse effect. The major burden of the greenhouse effect is the current global warming with its antecedent effects such as excess heat resulting to heat stress and blood pressure in the human body, and dehydration, which is a major cause of kidney stones and heart diseases (Riphah, 2015). Crop failures, stress on animal and possibly famines. Under conditions of global warming, the spread of certain animal diseases are favored, leading to death of wildlife and animal species.

ii. Climate change: Human activities are largely responsible for an increase in temperature around the globe, primarily due to carbon dioxide and other greenhouse gas emissions. This increase in temperature is leading to changes in the global climate regime. The predicted effect of climate change include:

- more drought and more flooding
- less ice and snow
- more extreme weather incidents
- rising sea level

The extent of climate change effects on individual regions vary over time and with the ability of different societal and environmental systems to mitigate or adapt to change According to the (IPCC, 2013). When the weather gets warmer, evaporation from both land and sea increases. This can cause drought in areas of the world where the increased evaporation is not compensated for by more precipitation.

In some regions of the world this will result in crop failure and famine especially in areas where temperatures are already high. The extra water vapor in the atmosphere will fall again as extra rain, which can cause flooding in other places in the world.

Worldwide, glaciers are shrinking rapidly at present. Ice appears to be melting faster than previously estimated. In areas that are dependent on meltwater from mountain areas, this can cause drought and lack of domestic water supply. Up to 6% of the world's population lives in areas that will be affected by meltwater reduction (IPCC, 2007)

The warmer climate will probably cause more heatwaves, more violent rainfall, and an increase in the number and/or severity of storms. Sea level is also expected to rise because of melting ice and snow and because of the thermal expansion of the sea (water expands when warmed). Areas that are just above sea level now, may become submerged. Coastal and shallow marine plants and animals will be affected, for example mangroves, delta, and coral reefs.

In countries with large areas of coastal low-land there will be a dual risk of river floods and coastal flooding, which will reduce the area for living and working. Coastal defense will need to be strengthened, and river levees will need to be developed. The increase in standing water may allow more insects like mosquitoes and diseases spread by insects, such as Lyme's disease. Most of these scenarios are already affecting the low-land areas in Nigeria.

iii. **Depletion of stratosphere ozone layer**:
The ozone layer is a naturally occurring gas in the stratospheric region of the atmosphere where ozone particles are accumulated. This layer protects the earth from the direct effect of Ultra Violet rays of the sun. However, the effectiveness of the ozone layer is declining due to human activities. The term "Ozone hole" is used to describe the depletion of the ozone layer. Since the year 2000, the rate of ozone depletion is increasing by 0.5 percent per year (Rozema, Boelen, and Blokker, 2005). The effect of the ozone layer depletion is the escape of UV rays into the earth resulting to negative impact on both human health and the environment. Among these includes; skin diseases, blindness, and the distortion of developmental and physiological processes of plant/animal lifeform.

iv. **Acid rain:** Acid rain is a general term that includes any form of precipitation with acidic components, such as sulfuric or nitric acid that fall to the ground from the atmosphere in wet or dry forms. This can include rain, snow, fog, hail, or even dust particles that are acidic. Acid rain is formed when sulfur dioxide (SO_2) and nitrogen oxides (NO_X) are emitted and transported into the atmosphere by wind and air currents. The SO_2 and NO_X react with water, oxygen and other chemicals to form sulfuric and nitric acids. These then mix with atmospheric water to form cloud, and subsequently precipitate either as liquid or solid to the ground.

While a small portion of the SO_2 and NO_X that cause acid rain is from natural sources such as volcanoes, most of it comes from the burning of fossil fuels. The major sources of SO_2 and NO_X in the atmosphere are:

- Burning of fossil fuels to generate electricity. Two thirds of SO_2 and one fourth of NO_X in the atmosphere come from electric power generators.
- Vehicles and heavy equipment.
- Manufacturing, oil refineries, and other industries.

In acid-sensitive landscapes, acid deposition can reduce the pH of surface waters and lower biodiversity. It weakens trees and increases their susceptibility to damage from other stressors such as drought, extreme cold, and pests. In acid-sensitive areas, acid rain

also depletes soil of important plant nutrients and buffers, such as calcium and magnesium, and can release aluminum, bound to soil particles and rock, in its toxic dissolved form. Acid rain contributes to the corrosion of surfaces exposed to air pollution and is responsible for the deterioration of limestone and marble buildings and monuments.
Other environmental problems caused by human activities includes but not limited to overexploitation of natural resources, pollution of the environment, deforestation, and degradation of natural landscape. These problems may range from local to regional scale. However, their accumulative effects can have a global effect. Therefore, strategic programme for monitoring the resources must be site specific
Therefore, strategic programme for monitoring resources must be both locally and globally oriented.

4.0 Conclusion
The existence of life depends on the abundant natural resources, which are provided by the environment. The availability and quality of these resources are hampered by various human activities ranging from agriculture, commercial activities, constructions, and industries. The intensification of these human activities differs from one location to another. Considering this fact, organization of monitoring program for site/resources must be site-specific depending upon the goals of the proposed program and the resource to be evaluated.

5.0 Summary
In this unit we have leant that:

- The organization of monitoring programmes for Site and resource must start with team management, precise goal, and objects to execute the program.
- Site and resource monitoring is conducted in two phases (off-site and on-site).
- Monitoring techniques differs considerably and in accordance to the phenomena of interest.
- Human activities have negative feedback on the natural resource, most of which are of global effect.

6.0 Tutor-Marked Assignments

1. Identify the specific steps that project must be streamlined for a better monitoring
2. What are the specific strategies for monitoring sites and resources?
3. Attempt a classification of monitoring techniques

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UNIT 4: METEOROLOGY AIR POLLUTION

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1.0 Introduction

Air pollution occurs when gases, dust particles, fumes or smoke or odour are introduced into the atmosphere in a way that makes it harmful to humans, animals and plant. Air pollution threatens the health of humans and other living beings on earth. Air pollution creates smog and acid rain which causes several environmental issues such as depletion of the ozone layer which is a major instigator of global warming and the enhancer of climate change. In another hand, several health challenges are linked to air pollution. In this age technological and industrial advancement, air pollution cannot be eliminated completely, but steps can be taken to reduce it and its impact on other aspects of the environment and human health. Several governments of nations over the world have developed guidelines for air quality and ordinances to restrict emissions in an effort to control air pollution. The central aim of this unit is understanding air pollution meteorology with particular reference on chemical and biological air pollutants and their impact to human health.

2.0 Objectives

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

- state what is air pollution meteorology is
- state chemical air pollutants and their impact to human health
- state biological air pollutants and their impact to human health
- state the metrological factors which affects concentration of pollutants
- state the measures to reduce air pollution
- discuss Government and individual level pollution prevention

- discuss pollution prevention Control devices.

3.0 Main Content

3.1 Definition of Terms

Meteorology is the branch of science concerned with the processes and phenomena of the atmosphere, especially as a means of forecasting the weather. Simply meteorology is defined as the study of atmospheric phenomena (Wallace and Hobbs, 2006). This study consists of physics, chemistry, and dynamics of the atmosphere. It also includes many of the direct effects the atmosphere has upon Earth's surface, the oceans, and life in general.

Air pollution is the contamination of the indoor or outdoor air by a range of gasses and solids that modify its natural characteristics. Key health harmful pollutants include particulate matter (PM2.5 and PM10), carbon monoxide (CO), ozone (O_3), black carbon (BC), sulfur dioxide and nitrogen oxides (NOx) (WHO, 2018).

Air pollution is often not visible to the naked eye as the size of the pollutants are smaller than the human eye can detect. They can become visible in some situations for example in the form of sooty smoke from the open burning of crop residues or other waste, as well as from burning wood, coal, petrol and diesel fuels for cooking and heating, transport or power production. The fact that you cannot see the air pollution does not mean that it does not exist (WHO, 2018).

3.2 What is Air Pollution Meteorology?

Meteorology has an important, practical application in the area of control and management of air quality. Its significance was first realized when the increasingly heavy use of coal for home heating and industrial power led to episodes of extreme sulfur pollution during certain weather conditions (Sorbjan, 2003). Air pollution meteorology deals with meteorological processes occurring close to the earth's surface, including the effects of meteorology on air pollutants and the effects of pollutants on meteorology. Meteorological parameters such as temperature, precipitation, and wind speed play a pivotal role in air pollutants dynamics and distribution in many different ways (Tekla, 2007).

The pollutants can be classified in several ways according to their origin (natural or anthropogenic, or chemical or biological), residence time (persistent, changing or considerably changing), and formation mechanism (primary and secondary pollutants), phase (solid, liquid, gaseous), and the effect on human health (toxic, carcinogenic, allergic). Concentration of these pollutants has increased in the atmosphere with the development of technology, industry, transportation and the large-scale spread of cultivation of industrial crops. Therefore monitoring of air quality became very important due to the harmful effects on the biosphere thus on human health. In this lecture note air pollutants are classified into chemical and biological (Tekla, 2007).

3.2.1 Chemical Air Pollutants and their Impact to Human Health

According to Tekla, (2007).The most frequently measured chemical parameter in air due to their impact to human health are CO, O3, SO2, NOX, DUST (PM10, SOOT, ASH).

a. Carbon-monoxide

Carbon-monoxide is extremely poisonous for people and animals. Breathing it in, it attaches to haemoglobin and squeezes out oxygen. Haemoglobin becomes carbonmonoxide haemoglobin, which causes lack of oxygen in the nervous system and heart muscle. Acute poisoning brings on headache, heavy breathing, heart problems, in serious case unconsciousness and even breath paralysis. Survivors usually suffer from slowly healing nerve injuries. Chronic symptoms are headache, dizziness, insomnia, heart ache, nervous system symptoms and increase of heart attack frequency. Elderly people, pregnant women, people who work in polluted air are most exposed.

b. Sulphur-dioxide

Sulphur-dioxide is harmful to people and animals if they inhale it. SO_2 is adsorbed to the mucous membrane, of which the acidic reaction has irritant effect. If it enters the bloodstream, haemoglobin becomes sulfo-haemoglobin; hereby it hinders taking oxygen. Acute effects are lung, nose and throat mucous membrane irritation, and asthmatic spasm. In chronic case respiratory illnesses (bronchitis) occur. Children and adults suffering from asthma are the most endangered.

c. Nitrogen-oxides

Nitrogen-oxides irritate the mucous membrane, cause coughing, nausea, headache, dizziness and acute poisoning. These symptoms disappear in a few hours then some hours later pneumonia, pneumonoedema may develop. Nitrogen-dioxide has twofold impact mechanism. Attached to the mucous membrane, it forms nitrous or nitric acid, which damages the tissues locally. If it enters the bloodstream, haemoglobin is oxidized to methehemoglobin, thus it becomes unable to carry oxygen to the organs. Therefore, longer exposure reduces resistance ability against infections, aggravates asthmatic diseases, causes frequent respiratory illnesses, and, later on, decreased lung-functions occur. Children and adults who suffer from asthmatic illnesses, cardio-vascular diseases and respiratory diseases are the most endangered.

d. Ozone

Ozone is strongly poisonous to human health. Eyes, nose and throat mucous membrane are irritated due to ozone. It causes coughing and headache if the time of exposition is short. In chronic cases it contributes to asthma and reduces lung capacity. People suffering from asthma, other respiratory diseases, furthermore those with heart problems, elderly people and manual workers are the most endangered.

e. Dust particles

Dust particles can irritate and hurt eye and upper respiratory tracts. Dust particles bigger than 10 µm are purified by the ephitelium of the respiratory tracts; while dust particles smaller than 10 µm (PM10) can enter the lungs. The chemical composition, physical properties and concentration of the dust determine the effect on the respiratory system. Breathing in dusty air aggravates the state of people with asthma; reduces the ability of resistance against infections and toxic materials. Dust particles can adsorb viruses, bacteria, fungus, toxic materials and so help them to enter the organs. Those suffering from respiratory or cardio-vascular diseases as well as elderly people are the most endangered.

3.2.2 Biological Air Pollutants and their Impact to Human Health

Biological air pollution is air dominated or associated with bacteria, molds, viruses, animal dander and saliva, dust mites, insects' parts, and pollens. The biological pollutants can travel through the air for a long distance and are not always easy to see. The sources of biological pollutants are many such as pollens and fungi come from plants; while viruses and bacteria are spread by people and animals. Animals are sources of saliva and animal dander. Dust mites can develop in damp and warm places. Humidifiers that are not properly clean can spread fungi, bacteria, and other biologicals in an indoor environment.

Biological air pollutants are everywhere; however; nutrients and moisture are needed for biological pollutants to grow. These conditions are found in rooms such as bathrooms or damp or flooded basements. They can also be found in wet appliances (humidifiers or air conditioners), and even wet carpets and furniture. The effects of biological air pollutants on human health depend upon the type and amount of biological air pollution and the individual health status. People with certain health problems may get instigated by some certain biological air pollutants, while others may have allergic, infectious, or toxic reactions to some biological air pollutants (Eötvös, 2007).

Asthma attacks which is life threatening are usually triggered by some biological air pollutants. Some of the widespread symptoms of allergic reactions associated with biological air pollution include; watery eyes, runny nose, coughing, trouble breathing and itching body. Flu, measles and chickenpox are infectious illnesses associated with some biological air pollutants. Some of these biological air pollutants such as fungi release toxins that can hurt many organs and tissues in the human body (Tekla, 2007).

Exposure to biological air pollution, particularly indoor biological air pollution could be reduced through;

- Fixing of pipe leakages and water seepage.
- Putting a plastic to cover over dirt in crawl spaces.
- Using of exhaust fans in bathrooms and kitchens as well as vent clothes dryers outside.
- Using dehumidifiers and air conditioners appropriately.
- Raising the temperature of cold surfaces where moisture usually accumulate and open doors between rooms in the house.
- Using of fans and move furniture from wall corners to increase air and heat circulation.
- Giving critical attention to carpet, particularly on concrete floors because carpet can absorb moisture and aid biological pollutant growth.
- Cleaning moist surfaces, such as showers and kitchen counters regularly.
- Removing of mold from walls, ceilings, floors and paneling.
- Replacement of moldy shower curtains, or remove them and scrub them regularly.

3.3 Metrological Factors Which Affects Concentration of Pollutants

Meteorological factors have an important effect on the amount of pollution in the atmosphere. Temperature and solar radiation affect the quantities of pollutant emitted by their influence on the amount of space heating required. Sunshine is required in a photochemical production of oxidants forming smog. The wind velocity, turbulence and stability affects the transport, dilution and dispersion of the pollutants. The rainfall as a scavenging effects in washing out ("rainout") particles in the atmosphere. Finally, the humidity is a frequent and important factor in determining the effect that concentrations of pollutants have on property, vegetation and health (Riphah, 2015).

Of all the meteorological parameters which have the most important influence on the diffusion of pollutants in the atmosphere are wind direction and speed, turbulence and stability (Gaffney and Marley, 2003; Elminir, 2005).

(a) Wind Direction

The wind direction and its persistence are very important factors in predicting the air pollution potential of an area when the principal sources of the pollutants are high-level emitters located near each other in an industrial-zoned portion of the city. These factors are not important for areas in which low-level emitters cause the greater proportion of the pollution.

Since the wind directs the travel of the pollutants, the expected persistence of the wind direction, as related to the topographic features and the locations of the receptors, must be considered both in forecasting the air pollution potential as well as in selecting sites for plants. For example, in an area which has the principal source of a pollutant on a lakeshore site, high air pollution potential conditions could be expected only when persistent on-shore winds are forecast. For a city such as Sarnia which has most of its large industries located to the south, the concentrations of pollutants are not high except during periods with persistent southerly winds.

Topographical features such as valleys cause winds to persist in certain directions much more frequently than in others. Obviously, such localities should be avoided, if possible, in selecting sites for large industries.

(b) Wind Speed

The effect of an increase in wind speed on the concentrations resulting from low-level sources of emissions is to dilute the pollutants - the concentration of pollutants in a downwind location from a ground-level source is inversely proportional to the wind speed. High air pollution potential forecasts for most large urban areas where low level emissions are the principal sources of pollution include light wind speed as one of the criteria.

In contrast, with high-stack sources of hot emissions, an increase in the wind speed will lower the plume rise and tend to increase ground level concentrations. There is a critical wind speed for each stack design a t which concentrations downstream reach a maximum.

In view of these effects, meteorologists are involved in the following aspects of air pollution control measures:

i. Forecasting air pollution potentials so that air pollution control agencies may alert industry to carry o u t temporary abatement action.
ii. Selecting sites and designing emission systems for large industrial sources.
iii. Establishing air monitoring surveys.
iv. Carrying out research in air pollution control methods.

3.4 Measures to reduce Air Pollution

Solving effects of atmospheric air pollution is always a serious problem. This is the reason why prevention interventions are always a better way of controlling air pollution. According to Wallace and Hobbs, (2006), prevention methods particular can either be through government laws or by individual actions.

3.4.1 Government level prevention

- Governments throughout the world have already taken action against air pollution by introducing green energy. Some governments are investing in wind energy and solar energy, as well as other renewable energy, to minimize burning of fossil fuels, which cause heavy air pollution.
- Governments are also forcing companies to be more responsible with their manufacturing activities, so that even though they still cause pollution, they are a lot controlled.
- Automobile companies are also building more energy efficient cars, which pollute less than older car models.

3.4.2 Individual Level Prevention

- Where available, people should be encourage to use the bus, train or bike when commuting. If we all do this, there will be fewer cars on road and less fumes.
- People should be encourage to use energy (light, water, boiler, kettle and fire woods) wisely. In recent times, lots of fossil fuels are burned to generate electricity, and cutting down of the usage of fossil fuels will also cut down the amount of atmospheric pollution generated.
- People should be encourage to recycle and re-use resources. Recycle and re-use resources will reduce the dependence of producing new products and since manufacturing industries create a lot of pollution, re-use things like shopping plastic bags, clothing, paper and bottles will be a significant drive towards air pollution control.

3.4.3 Control devices

Several equipment's are used as pollution control devices by manufacturing industry or the transportation industries. This pollution control devices can either destroy contaminants or remove them from an exhaust stream before it is emitted into the atmosphere. Some of these devices include;

i. Mechanical collectors (dust cyclones, multi-cyclones). This collector facilitate the procedures that allow, using cyclones and multi-cyclones is the optimal choice for reducing costs related to the operation and upkeep of your dust collecting and pneumatic conveying systems. The cyclone and the multi-cyclone use centrifugal action as the basis of operation for air pollution reduction.

ii. Electrostatic precipitators: An electrostatic precipitator (ESP), or electrostatic air cleaner is a particulate collection device that removes particles from a flowing gas (such as air) using the force of an induced electrostatic charge. Electrostatic precipitators are highly efficient filtration devices that minimally impede the flow of gases through the device, and can easily remove fine particulates such as dust and smoke from the air stream.
iii. Bag houses: The bag houses are designed to handle heavy dust loads a dust collector in the bag house consists of a blower, dust filter, a filter-cleaning system, and a dust receptacle or dust removal system.
iv. Particulate scrubbers: Wet scrubber is a form of pollution control technology and this term describes a variety of devices that use pollutants from a furnace flue gas or from other gas streams. In a wet scrubber, the polluted gas stream is brought into contact with the scrubbing liquid, by spraying it with the liquid, by forcing it through a pool of liquid, or by some other contact method, so as to remove the pollutants.

4.0 Conclusion

The understanding of meteorological air pollution is very important in our contemporary world. The pollution of the atmosphere with gases, dust particles, fumes or smoke or odour which are introduced into the atmosphere in a way that makes it harmful to humans, animals and plant is of key concern. Generally, air pollution threatens the health of humans and other living beings on earth. This air pollution creates smog and acid rain which causes several environmental issues such as depletion of the ozone layer which is a major instigator of global warming and the enhancer of climate change.

5.0 Summary

In this unit we have leant that:

i. Air pollution is the major is harmful to human health and other living organism on earth.
ii. Air pollution creates smog and acid rain which causes several environmental issues such as depletion of the ozone layer which is a major instigator of global warming and the enhancer of climate change.
iii. Meteorological factors have an important effect on the amount of pollution in the atmosphere.

6.0 Tutor-Marked Assignment

1. Identify five chemical air pollutants and their impact to human health
2. What are the meteorological factors have an important effect on the amount of pollution in the atmosphere.
3. What are the measures towards reducing air pollution?

7.0 References/Further Reading

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UNIT 5: ATMOSPHERE DISPERSION MODELS

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1.0 Introduction

The concentration of an air pollutant at a given place is a function of a number of variables, including the emission rate, the distance of the receptor from the source and the atmospheric conditions. The most important atmospheric conditions are wind speed, wind direction and the vertical temperature structure of the local atmosphere. Atmospheric air quality dispersion models are usually used to estimate just how much reduction has occurred during the transport of pollutant from an industrial source and consequently to project the pollution concentration at ground level. Dispersion models usually incorporate meteorological, terrain, physical and chemical characteristics of the effluent and source design to simulate the formation and transport of pollutant plumes. In this unit, we shall present the Gaussian-plume models and the new generation dispersion models. We shall equally consider issues to consider when applying advanced dispersion model in air quality assessment.

2.0 Objectives

By the end of this unit, students will be able to:

- discuss the types of atmospheric dispersion models.
- explain the gaussian-plume models and it characteristics.
- mention the new generation dispersion models and issues to consider when applying advanced dispersion model in air quality assessment

- discuss the uses of atmospheric dispersion models.

3.0 Main Content

3.1 Atmospheric Dispersion Models

A model is a simplified picture of reality. It doesn't contain all the features of the real system but contains the features of interest for the management issue or scientific problem we wish to solve by its use. Models are widely used in science to make predictions and/or to solve problems, and are often used to identify the best solutions for the management of specific environmental problems. Models can be physical (a scaled-down representation of reality) or mathematical (a description of the system using mathematical relationships and equations) (New Zealand Ministry for the Environment, 2004).

Atmospheric dispersion modelling is an essential tool in air quality management by providing the link between environmental effects and discharges to air. Contaminants discharged into the air are transported over long distances by large-scale air-flows and dispersed by small-scale air-flows or turbulence, which mix contaminants with clean air. This dispersion by the wind is a very complex process due to the presence of different sized eddies in atmospheric flow. Even under ideal conditions in a laboratory the dynamics of turbulence and turbulent diffusion are some of the most difficult in fluid mechanics to model. There is no complete theory that describes the relationship between ambient concentrations of air pollutants and the causative meteorological factors and processes (Hurley, 2002).

Tolga (2003) in a very simple term, assert that an atmospheric dispersion model is a:

- Mathematical simulation of the physics and chemistry governing the transport, dispersion and transformation of pollutants in the atmosphere.
- Means of estimating downwind air pollution concentrations given information about the pollutant emissions and nature of the atmosphere.

Atmospheric dispersion models can take many forms. The simplest forms of which atmospheric dispersion model models can take could be in form of graphs, tables or formulae. In recent years, dispersion models more commonly take the form of computer programs, with user-friendly interfaces and online help facilities.

Most modern air pollution models are computer programs that calculate the pollutant concentration downwind of a source using information on;

i. Contaminant emission rate
ii. Characteristics of the emission source
iii. Local topography
iv. Meteorology of the area
v. Ambient or background concentrations of pollutant.

A broad overview of how this information is used in a computer-based air pollution model is shown in Figure 5.1.

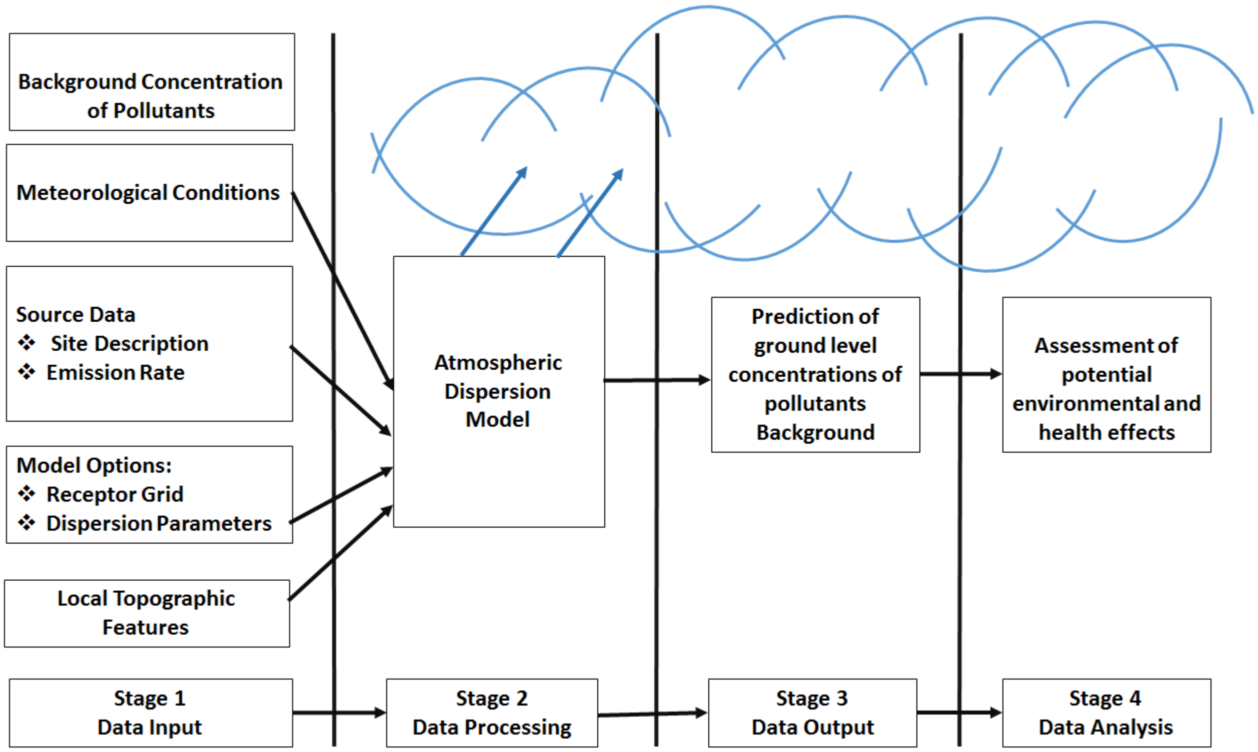

Figure 4.1: Overview of the air pollution modelling procedure
Source: New Zealand Ministry for the Environment (2004).

The process of air pollution modelling contains four stages (data input, dispersion calculations, deriving concentrations, and analysis). The accuracy and uncertainty of each stage must be known and evaluated to ensure a reliable assessment of the significance of any potential adverse effects.

Currently, the most commonly used dispersion models are steady-state Gaussian-plume models. These are based on mathematical approximation of plume behaviour and are the easiest models to use. They incorporate a simplistic description of the dispersion process, and some fundamental assumptions are made that may not accurately reflect reality. However, even with these limitations, this type of model can provide reasonable results when used appropriately.

More recently, better ways of describing the spatially varying turbulence and diffusion characteristics within the atmosphere have been developed. The new generation dispersion models adopt a more sophisticated approach to describing diffusion and dispersion using the fundamental properties of the atmosphere rather than relying on general mathematical approximation. This enables better treatment of difficult situations such as complex terrain and long-distance transport.

3.2 Types of atmospheric dispersion models.

Ross (2001) identify that there are two major types of atmospheric dispersion models which are Gaussian-plume models and the new generation dispersion models.

3.2.1 Gaussian-plume models.

Gaussian-plume models are widely used because they very easy to understand and easy to apply. Due to its simplicity, it has recently received international approval for use. This is also to the fact that the assumptions, errors and uncertainties of these models are generally well understood. Despite their strength they still suffer from misuse. The Gaussian-plume formula is derived assuming ‘steady-state’ conditions. The Gaussian-plume dispersion formulae do not depend on time, notwithstanding the Gaussian-plume dispersion formulae do represent an ensemble time average. The atmospheric conditions are assumed to remain constant during the dispersion from source to receptor, which is effectively instantaneous. Emissions and atmospheric conditions can vary from hour to hour but the model calculations in each hour are independent of those in other hours. Due to this mathematical derivation, it is common to refer to Gaussian-plume models as steady-state dispersion models. In practical situations, the plume characteristics do change over time, because they depend on changing emissions and atmospheric conditions. Plume formulation has one consequence, each hour the plume extends instantaneously out to infinity. In view of this, concentrations may then be found at points too distant for emitted pollutants to have reached them in an hour. Gaussian-plume formula provides a better representation of reality if conditions do not change rapidly within the hour being modelled. The Gaussian-plume models believe that conditions are reasonably steady and do not deviate significantly from the average values for the hour being modelled.

3.2.1.1 Characteristics of Gaussian-plume models.

Some of the characteristics of the Gaussian-plume models includes the following;

i. The models do not require significant computer resources. The models can be run on almost any desktop PC and can usually process a complete year of atmospheric data in a matter of minutes.

ii. The models are easy to use. This because they come with user-friendly graphical interfaces and a relatively small number of input variables are required.

iii. The models are widely used and has capacity to generated well developed knowledge due to the fact that many users and results can easily be compared between different studies.

iv. The models have simple atmospheric data requirements. Input data set can be developed from standard atmospheric recordings, and commercially developed data sets are readily available for a number of the metropolitan areas in many developed countries and few developing countries.

v. The models also have conservative results for short (<100 m) or low-level sources. The models are more likely to over- rather than under-predict ground-level concentrations, which offers some degree of safety in the regulatory environment when assessing discharges from short or low-level sources.

3.2.1.2 Limitations of Gaussian-plume models

Luhar and Hurley, (2002 and 2003) identify the following limitations are associated with the Gaussian-plume models;

i. Causality effects

Gaussian-plume models assume pollutant material is transported in a straight line instantly like a beam of light to receptors that may be several hours or more in transport time away from the source. They make no account for the fact that wind may only be blowing at 1 m/s and will only have travelled 3.6 km in the first hour. This means that plume models cannot account for causality effects. This feature becomes important with receptors at distances more than a couple of kilometres from the source.

ii. ***Low wind speeds***

Gaussian-plume models usually break down during low wind speed or calm weather conditions due to the inverse wind speed dependence of the steady-state plume equation, and this limits their application. These conditions bring about the worst-case dispersion results for many types of sources because these models usually set a minimum wind speed of 0.5 or 1 m/s and sometimes overwrite or ignore input data below this with this lower limit.

iii. ***Straight-line trajectories***

In moderate terrain areas, these models will typically overestimate terrain interrupting effects during stable conditions because they do not account for turning or rising wind caused by the terrain itself. CTDM and SCREEN are designed to address this issue.

iv. Spatially uniform meteorological conditions

Gaussian steady-state models have to assume that the atmospheric condition is uniform across the entire modelling environment, and that transportation and dispersion conditions exist unchanged long enough for the material to reach the receptor. In the atmosphere, uniform conditions does not exist. Water bodies, hills and other terrain features, differences in land use, surface characteristics, and surface moisture (e.g. irrigated and unirrigated agricultural fields) all produce uniformity in the structure of the boundary layer which can affect pollutant transport and dispersion.

Convective conditions are one example of a non-uniform meteorological state that Gaussian-plume models cannot emulate. For tall stacks (>100 m) under convective conditions – overseas studies have shown that under prediction can occur in the near field. The notable exception to this is AERMOD, which has a specially developed, 'add-on' probability density function.

v. No memory of previous hour's emissions

In calculating each hour's ground-level concentration the plume model has no memory of the contaminants released during the previous hour(s). This limitation is especially important for the proper simulation of morning inversion break-up, fumigation and diurnal recycling of pollutants over cities.

3.2.2 The new generation dispersion models

According to New Zealand Ministry for Environment (2004).The use of advanced models usually use much greater meteorological/atmospheric data. It is possible to overcome some of the limitations of a plume model without using a complete advanced model run. One potential approach is to use single-surface meteorological data (AUSPLUME/ISC type files with an advanced model). An example of using CALPUFF meteorological data from a single site ('screening mode') is given in Analysis of the CALMET/CALPUFF Modelling System in a Screening Mode (US EPA 1998). Detailed technical advice on how to run CALPUFF using AUSPLUME/ISCST3 type meteorological files is provided in the CALPUFF manual.

Though the screening mode is not recommended by the developers of CALPUFF. They suggest that better-quality results can be achieved using CALMET/CALPUFF run with a proper representation of the terrain and three-dimensional meteorological fields.
Advanced dispersion models may be grouped into three categories depending on the way the air pollutants are represented by the model.

i. Particles Models

Pollutant releases, especially those from point sources, are often represented by a stream of particles which are transported by the model winds and diffuse randomly according to the model turbulence. Particle models are computationally expensive, needing at least 10^5 particles to represent a pollutant release, but may be the best type to represent pollutant concentrations close to the source.

ii. Puffs Models

Pollutant releases can also be represented by a series of puffs of material which are also transported by the model winds. Each puff represents a separate amount of pollution, whose volume increases due to turbulent mixing. Puff models are far less calculatedly expensive than particle models, but are not as realistic in their description of the pollutant distribution. However, they are often more than adequate, and are used for regulatory purposes.

iii. Grid Points Models

Pollutant distributions are represented by concentrations on a three-dimensional grid of points. This is the cheapest formulation computationally, but difficulties arise when the scale of the pollutant release is smaller than the grid point spacing. This method is commonly used for airshed modelling, and the simulation of chemical transformations is most straightforward in a grid model.
Efforts to increase computational efficiency while still retaining a realistic description of pollutant dispersion mean that many models are a combination of the above-mentioned types. For example, the 'PARTPUFF' approach (Hurley, 1994) represents the pollutants as Gaussian puffs in the horizontal and particles in the vertical, particle models usually convert particles to a gridded distribution when the particles have dispersed sufficiently (Lyons et al., 1994), and grid point models often represent sub-grid-scale releases as particles or puffs (Morris et al., 1992).

The fundamental difference between advanced models and Gaussian-plume models is that the advanced models require three-dimensional meteorological fields rather than measurements at a single point, and an assumption of spatial uniformity.

3.2.3 Issues to consider when applying new generation dispersion model in air quality assessment

There are a number of issues to be considered when applying new generation dispersion model in air quality assessment (Hurley, 2002). These include;

i. There is need for detail understanding of boundary-layer meteorology, atmospheric turbulence, mesoscale meteorology and atmospheric chemistry and particle dynamics.

ii. There is need for high-specification desktop PC with more memory, disk space and processing time than required for Gaussian-plume models this is because output files are usually in the order of megabytes and run times can reach hours or days.

iii. There is a complex user interface because of more input parameters, which means visualization of output can also require post-processing software to handle large output files.

iv. There is usually an increased risk of model misuse because of the small base of understanding and expertise created by fewer people using advanced models compared to Gaussian-plume models.

v. In applying the advanced dispersion model**,** fully three-dimensional, time-dependent meteorological data set is usually required, which needs a good understanding of air pollution meteorology. Despite this, not all assessments will require a full three-dimensional, spatially varying meteorological data set, and under some circumstances a simple plume model meteorological data set can be used effectively with a puff model run in screening mode.

The advanced dispersion models are more sophisticated than Gaussian-plume models, and the aim is to produce more realistic results. Despite this, results from advanced models are not automatically assumed to be better than those gained from Gaussian-plume models. One situation where this situation may arise when a feature that has been added to a plume model is not included in advanced models.

3.3 The uses of atmospheric dispersion models.

The atmospheric dispersion models can be set up to estimate downwind concentrations of contaminants over varying averaging periods either short term (three minutes) or long term (annual). In most developed nations of the world, the most common use of dispersion modelling is to assess the potential environmental and health effects of discharges to air from industrial or trade premises. Such assessments are required to be undertaken in compliance with nation environment act or laws for discharge permits. The atmospheric dispersion models are particularly valuable for assessing the impacts of discharges from new activities and to estimate likely changes as a result of process modifications as well as impact to human health (New Zealand Ministry for Environment, 2004).

Generally atmospheric dispersion modelling results can also be used for;

i. Assessing compliance of emissions with air quality guidelines, criteria and standards
ii. Planning new facilities
iii. Determining appropriate stack heights
iv. Managing existing emissions
v. Designing ambient air monitoring networks
vi. Identifying the main contributors to existing air pollution problems
vii. Evaluating policy and mitigation strategies
viii. Forecasting pollution episodes
ix. Assessing the risks of and planning for the management of rare events such as accidental hazardous substance releases
x. Estimating the influence of geophysical factors on dispersion (e.g. terrain elevation, presence of water bodies and land use).

4.0 Conclusion

In this unit, we have examined the various types of atmospheric dispersion models with particular reference to Gaussian-plume models and the new generation dispersion models. The characteristics of the gaussian-plume models as well as its imitations were all treated in this units. Issues to be consider when applying the advanced dispersion model in air quality were presented in this unit also. Despite the strength and weaknesses of these models, the concentration of an air pollutant at a given place is a function of a number of variables, including the emission rate, the distance of the receptor from the source and the atmospheric conditions. Generally, the most important atmospheric conditions are wind speed, wind direction and the vertical temperature structure of the local atmosphere.

5.0 Summary

In this unit students have leant that:

i. The concentration of an air pollutant at a given place is a function of the emission rate, the distance of the receptor from the source and the atmospheric conditions.
ii. The characteristics of the gaussian-plume models as well as its limitations.
iii. The new generation dispersion models and issues to be considered when applying new generation dispersion model in air quality assessment.
iv. The most important atmospheric conditions are wind speed, wind direction and the vertical temperature structure of the local atmosphere.

v. An atmospheric dispersion model is a mathematical simulation of the physics and chemistry governing the transport, dispersion and transformation of pollutants in the atmosphere a means of estimating downwind air pollution concentrations given information about the pollutant emissions and nature of the atmosphere.

6.0 Tutor-marked assignments

1. Discuss the characteristics and limitations of the gaussian-plume models.
2. Discuss the new generation dispersion models and issues to be considered when applying new generation dispersion model in air quality assessment.

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UNIT 6: ELEMENTS OF AIR POLLUTION CONTROL

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
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3.2 Elements of Atmospheric Control
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3.4 Instruments for Air Quality Monitoring
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1.0 Introduction

Among the environmental resources (water, land, sun, and air), the primary existence of man, and other living component on the earth is a function of atmospheric air. The primary constituents of atmospheric air (oxygen, nitrogen, and carbon dioxide) are the life supporting mechanism of all living things on both land, water, and soil. However, this vital role is under grave threat due to human-driven activities that result in the introduction of pollutants into the atmosphere (Hunter *et. al.,* 2002). Drivers of atmospheric air pollution include industrialization, urban growth, population growth, and changing consumption patterns as well as catastrophic natural event such as volcanic eruption, landslide. Significant sectors contributing to atmospheric degradation are transport, power generation, incineration, waste, and biomass burning. According to the Clean Air Act (CAA) of 1970, six common air pollutants of concern are classified as *criteria pollutants*. The criteria pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.

Air pollution has become a global concern with its adverse effects on human health (Matooane *et. al.,* 2004) such as persistent asthma and poorer lung function notably among children and chronic bronchitis, wheezing with shortness of breath, and hypertension among adults. The effect of air pollution also affects the wellbeing of animals. Animals are exposed to air pollutants through inhalation of gases or small particles, ingestion of particles suspended in food or water and absorption of gases through the skin, with adverse effect on the circulatory, respiratory, gastrointestinal, and central nervous systems of animals. The most affected organs are the kidney, liver, and brain.

Acid rain resulting from air contamination also pollutes surface water bodies, leading to loss fish populations and amphibians as well as farmlands. Most worrisome is the amount of CO_2 released into the atmosphere and its antecedent effects as a greenhouse gas. In a bid to tackle cases of air pollution, national air quality standards have been defined for allowable concentrations of these substances in ambient air concentration. However, the quality standards are restricted to the criteria pollutants.

2.0 Objectives

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

- explain the causes and effects of air pollution
- discuss the element of atmospheric control
- explain the procedure and techniques for air quality monitoring.

3.0 Main Content

3.1 What is Atmospheric Control?

Atmospheric control is a scientific process of monitoring and regulating the composition of major constituents and trace pollutants of the atmosphere. Chief pollutants include carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. The atmospheric control allows for numeral simultaneous and modelling of the actual state of atmospheric gas pollutants, which provides the platform for future projection. The bane of global air pollution saw the emergence of the Clean Air Act (CAA) in 1970, which set the initiation of the concept of atmospheric control. The Act of 1970 (1970 CAA) authorized the development of comprehensive federal and state regulations in the United State of America to limit emissions from both stationary (industrial) sources and mobile sources. In consonance to this, developing nations begin to see need to establish policies for air quality control –notably, Nigeria. The policy regulations established by the Nigeria Government in regulating air quality includes;

- The National Guidelines and standards for environmental pollution control in Nigeria.
- National Environmental Protection (pollution abatement in industries and facilities generating wastes) Regulation 1991.
- The Management of Solid and Hazardous Wastes Regulations 1991 which gave a comprehensive list of dangerous and hazardous wastes (UNEP, 2015).

These regulations is issued and overseen by the National Environmental Standards and Regulation Enforcement Agency.

3.2 Element of atmospheric control

The concentration of pollutant above permissible limit in the atmosphere is the major element of atmospheric control. The science of air pollution focuses on measuring, tracking, and predicting of the concentrations of key chemicals in the atmosphere. The major process that affect air pollution levels are;

(1) **Emissions:** Chemicals are emitted to the atmosphere by a range of sources. Anthropogenic emissions come from human activities, such as burning fossil fuel. Biogenic emissions are produced by natural functions of biological organisms, such as microbial breakdown of organic materials. Emissions can also come from nonliving natural sources, most notably volcanic eruptions, and desert dust.

(2) **Chemistry:** Many types of chemical reactions in the atmosphere create, modify, and destroy chemical pollutants.

(3) **Transport:** Winds can carry pollutants far from their sources, so that emissions in one region cause environmental impacts far away. Long-range transport complicates efforts to control air pollution because it can be hard to distinguish effects caused by local versus distant sources and to determine who should bear the costs of reducing emissions. •

(4) **Deposition:** Materials in the atmosphere return to Earth, either because they are directly absorbed or taken up in a chemical reaction (such as photosynthesis) or because they are scavenged from the atmosphere and carried to Earth by rain, snow, or fog.

3.3. Sampling and air monitoring techniques

Ambient air monitoring provides valuable data for determining current and background concentrations of air pollutants, describing long term trends in air pollutant concentrations, and evaluating the effectiveness of air control strategies.

Air pollutants can be measure directly when they are emitted —for example, by placing instruments on source points (factory smokestacks) —or as concentrations in the ambient outdoor air. To track ambient concentrations, networks of air-monitoring stations are most reliable, which can be ground based or attached on vehicles, balloons, airplanes, or satellites. In the laboratory, tools such as laser spectrometers and electron microscopes can be used to identify specific pollutants. They measure chemical reaction rates in clear plastic bags ("smog chambers") that replicate the smog environment under controlled conditions, and observe emission of pollutants from combustion and other sources. Air pollutant data are numerical in nature. This can be incorporated into computer simulations ("air quality models") to predict how specific actions, such as requiring new vehicle emission controls or cleaner-burning fuels, will benefit ambient air quality. Air dispersion and photochemical grid models are useful tools for predicting project specific impacts on air quality, predicting the potential effectiveness of control measures and strategies, and forecasting trends in regional concentrations of air pollutants.

However, air pollutants pass through many complex reactions in the atmosphere and their residence times vary widely, depending on the atmospheric window and direction of airflow –so it is not always straightforward to estimate how emission reductions from specific sources will impact air quality over time.

To carry out a successful air quality assessment, the following tasks are to be considered:

- Selection of suitable sensors and evaluation devices
- Configuration and parameterization of the measuring devices
- Selection of suitable measuring positions (sampling point)
- Measurement of atmospheric pollutants
- Processing and plausibility check of measurement values
- Determination and execution of maintenance measures for the preservation of the functionality and accuracy of the measurements.

3.4 Instruments for air monitoring techniques

Rudimentary assessment of meteorological parameters such as rainfall, humidity, temperature, pressure, vapor, as well as gas pollutants is carried out in meteorological station. The meteorological station has been the laboratory for assessing the physical atmospheric processes. However, for rigorous assessment, mobile instruments can be used to detect the prevailing condition of the atmosphere in a local scale. This instrument varies considerably, depending on the atmospheric parameters of interest and the required accuracy. This includes;

(1) Hannah Instruments: this instrument is used to carryout in-situ monitory assessment of water contamination. Parameters such as pH, Total Dissolve Solid, Electrical Conductivity, Temperature, Total Suspended Solid and Biochemical Oxygen Demand etc.

(2) Extech Meteorological Device: This device performs various functions such as detecting the amount of atmospheric Relative Humidity, Surface Temperature, Wind velocity, Noise Pollution, etc.

(3) GasAlert Instrument: Pollutants such as Particulate matter (PM_{10} and $PM_{2.5}$), Ozone (O_3), Nitrogen dioxide (NO_2), Carbon monoxide (CO), Sulphur dioxide (SO_2), Volatile Organic Compound (VOC), Ammonia, $NH_{3,}$ etc. See Table 5.1

Table 6.1: Atmospheric Pollution Monitoring Device

 Hannah Instrument	 PM Meter

 GasAlert Instrument	 Extech Meter

Remote sensing techniques are best applied in areas that are remotely inaccessible. This technique may be somewhat difficulty, requiring advance technology that is cost effective.

4.0 Summary

The postindustrial human economy characterized by different activities ranging from transport, power generation, waste, biomass burning, volcanic eruption are point sources of the release of pollutants into the atmosphere – degrading the quality of air. This in particular has adverse effect on both human health's and the wellbeing of animals and plant life through its interference with the ecosystem. Thus, monitoring of atmospheric condition is inevitable, the major reason for the enactment of the Clean Air Act.

5.0 Conclusion

In this unit we have leant that:

- The air atmosphere is on constant threat from the release of pollutant into the atmosphere resulting from both natural and anthropogenic activities.
- Major pollutant of concern includes carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. These pollutants can be detected through direct sampling and, monitoring evaluation using mobile devices and meteorological station equipped with sophisticated technologies.
- The release of these pollutants above permissible threshold has been accounted for the increasing rate of chronic diseases among humans –particularly asthma and poorer lung function notably among children and chronic bronchitis, wheezing with shortness of breath, and hypertension among adult.
- At the international level, the Clean Air Act (CAA) was enacted as a legal framework for regulating air pollution. In consonance to this, policies for air quality control was established and overseen by NESREA in Nigeria.

6.0 Tutor-Marked Assignments

1. Human wellbeing is a function of air quality, discuss.
2. With specific example, explain the source and process of the release of atmospheric pollutant.
3. Explain the process of monitoring the release of the pollutant discussed in question II.

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UNIT 7: MECHANISM OF POLLUTANT INTERACTION WITH SOIL AND VEGETATION

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1.0 Introduction
2.0 Objectives
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3.2 Mechanism Of Pollutant Interaction With Soil
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3.5.2 Vegetation monitoring techniques

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1.0 Introduction

The major problem of modern society is environmental pollution. All spheres of environmental resource (water, air, soil, vegetation) are victims of pollution of different kinds, from various points, which are induced by anthropogenic activities. Notable anthropogenic activities leading to environmental pollution includes indiscriminate disposal of wastes ranging from solid, liquid to gaseous wastes –both of domestic and industrial origin. Most fragile resource to pollutants is soil and vegetation. This is because soil and vegetation are native (immobile) to a particular region, and goes through long time resilience from disturbances to its natural state. The increasing rate of substances that pollutes the soil and vegetation cannot be under-estimated at the rate of globalization. Current struggles of the world international organization to replace the "*Brown Economy*" with *"Green Economy"* has been derailed in the spite of globalization and increasing industrialization from developed region to developing nations. Therefore, the need to document the mechanism of soil and vegetation interaction with pollutants, to propagate the prevention, remediation, and to ensure the sustainability of soil and vegetal resources is of premium in contemporary academic research. This is in reflection of the importance of soil and vegetation resource on the world economy.

2.0 Objectives

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

- explain the sources, process, and interaction of pollutants with soil and vegetation.
- explain the sampling and monitoring techniques of soil and vegetation.
- mention the various instruments used for Soil quality and vegetation monitoring.
- use the instruments above.

3.0 Main Content

3.1 Pollutant Interaction With Soil

Pollutants released into soil may either be retained by adsorption on the surface of soil grains, or be accumulated in their inter-granular space, to form concentrations retaining their original chemical composition, or substances that have been altered by various chemical reactions. Pollutants retained on the soil surface, or in its interstitial space, may be organic, inorganic, or a mixture or complexes of both. Pollutants reach the soil in various physical conditions as solutes, water, immiscible liquids, or suspended particles. The mechanisms of pollutants interaction with the soil depend upon the physical parameters prevailing in the soil medium, such as temperature, moisture content, or salinity of the soil water, as well as upon their own physical, chemical, and biological processes that take place in all three (solid, gas and liquid) components of the soil medium. They generally include three main groups of processes:

i. Retention on, and within the soil body
ii. Infiltration, diffusion and transport by soil solutions
iii. Alteration, transformation, and initiation of chemical changes within the soil.

(1) **Retention on, and within the soil body:** At the initial state of the introduction of pollutants into the soil, pollutants are transported and distributed in the soil. The medium (liquid, gas, and solid) at which the pollutant is introduced into the soil depends on the rate of its distribution. Pollutants are distributed through pores and capillary depending on the size of soil grains, soil structure, and density. At a favorable condition, pollutants may penetrate deep into the innermost layer of the soil. However, this depends on other conditions such as adsorption. Adsorption and its accompanying phenomena are considered as the most important physical and chemical mechanisms of pollutant retention on the surface of soil grains. Molecules of pollutants are retained on the surfaces of soil grains in two ways.

- **Physio-sorption or physical adsorption**: Molecules of pollutants will be attached to the surfaces of soil grains by Van der Waal forces, which are known to be weak long range forces. The amounts of energies involved in such attachments are normally of low magnitudes and are not sufficient for bond breaking. Thus, pollutant molecules sticking to the soil surface will retain their chemical identities, although they might be stretched or bent because of their proximity to the surface.
- **Chemisorption or chemical adsorption**: the pollutants attach themselves to the grain surfaces as a result of the formation of a chemical (usually covalent)

bond. In this case, the energy of attachment is very much greater than in physical adsorption. Thus, a molecule undergoing chemisorption can be torn to satisfy valiancy considerations arising from bond formation with the surface atoms.

Although it is very difficult to distinguish between physical and chemical adsorption, but it can generally be concluded that the amount of physically adsorbed material decreases with increasing temperature, while for chemical adsorbed material, it is the reversed. The retention of contaminants in the soil may occur through the passing of contaminants from a dissolved form to an insoluble form, resulting from geochemical reactions taking place within the soil pores. Precipitation reactions are controlled by acid base equilibria and redox conditions. They are reversible and may lead to the dissolution of formerly precipitated compounds, if conditions are altered (See figure 7.1).

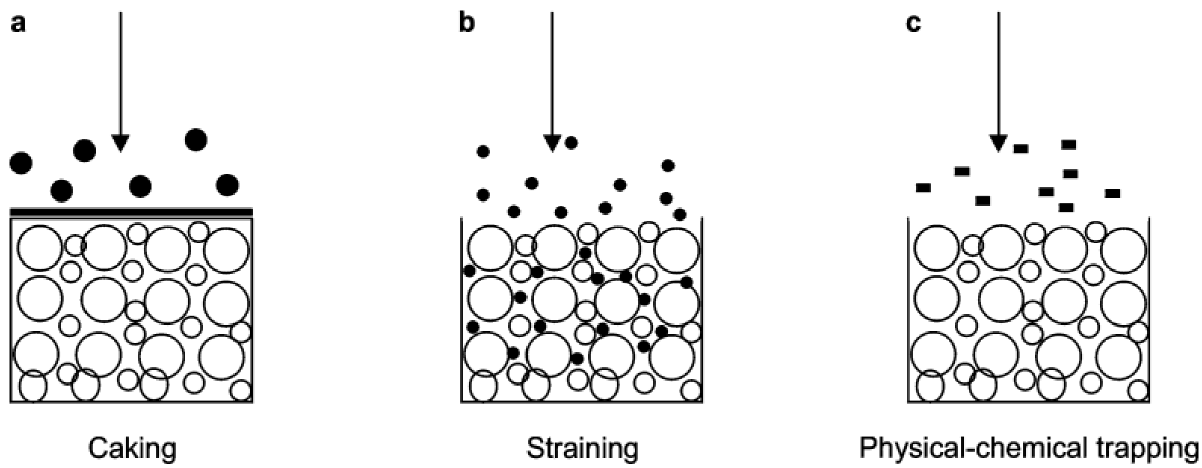


Figure 7.1: Trapping mechanisms in porous media (based on Boulding 1995, after Palmer and Johnson 1989).

(2) **Infiltration, diffusion and transport by soil solutions**:

This is perhaps the most common mechanism of contamination of soil solutions in the vadose zone, as well as deeper regions of the saturated zones of the groundwater. As fluids move downward under the influence of gravity, they dissolve materials to form leachates that contain inorganic and organic constituents. As they reach the saturated zone of the groundwater, the contaminants spread horizontally and vertically by joining the main cycles of the geochemical flows. Fortescue (1980), following the pioneering work of Kozlovskiy (1972), classified the patterns of material flow in landscapes into three main categories, which may be described as follows:

- Main migrational cycle (MMC): This flow is similar to geochemical cycles, i.e. the chemical substances are predominantly transported in a vertical direction upward from the soil to plants and animals, and then downward from plants and animals to the soil, approaching a steady state (Fig. 7.2a).
- Landscape geochemical flow (LGF): This involves a progressive transport of material parallel to the soil surface (see Fig. 7.2b). It takes place within a prism (Landscape prism: An example of chemically active air migrants in the

LGF is carbon dioxide and other gases that would dissolve in soil water, causing a shift in its chemical constitution.

- Extra landscape flow (ELF): This is the flow of chemical substances into the soil where they would be accumulated (+ve flow), or lost (–ve flow), see Fig. 7.2c.

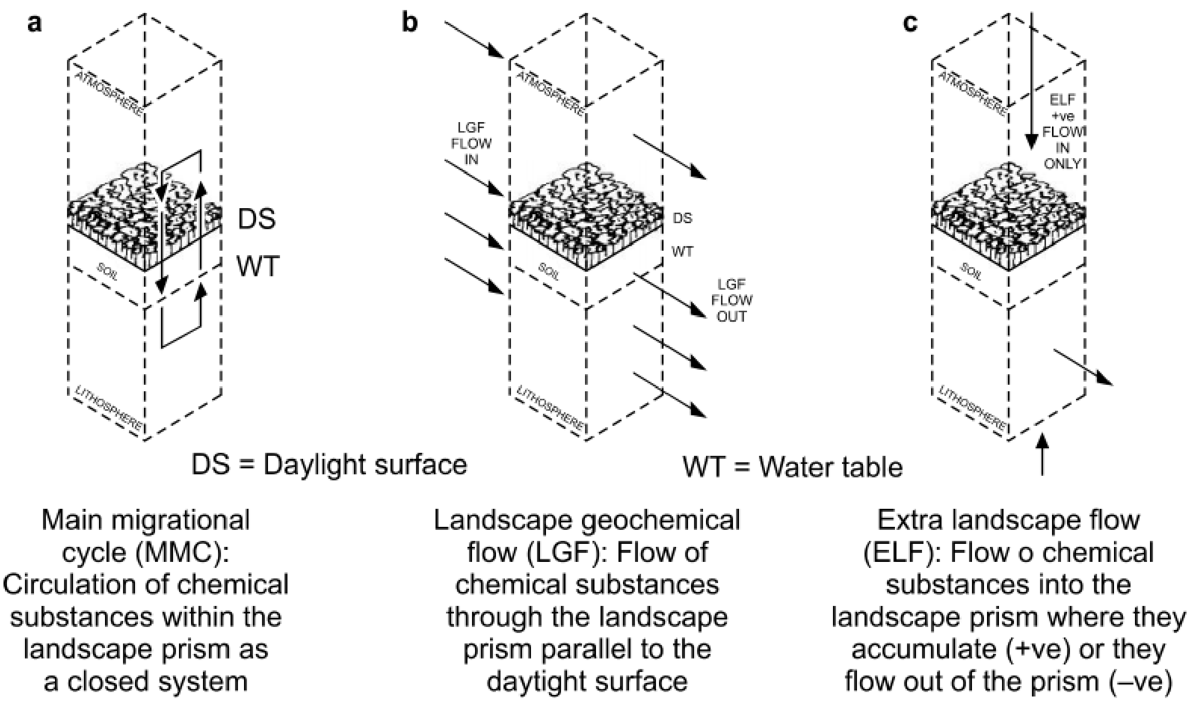


Figure 7.2 Illustration of the three flow patterns according to Fortescue (1980).

(3) **Alteration, and transformation of pollutants within the soil**:

In highly complicated system of different phases, such as soil subsurface, penetrating substances will go through countless transformation of chemical, physical, and biological processes that will determine their fate –besides controlling as well the degree of their toxicity to the environment. Such subsurface processes are broadly classified into:

a. Physical processes (processes related to chemical mobility)
b. Chemical processes
c. Biological processes

a. Processes Related to Chemical Mobility

These include processes in which no net chemical change occurs. They normally affect physical conditions that control phase distribution of the substance, i.e. its association with aqueous or solid phases under given environmental conditions. This process is collectively known as distribution processes. Distribution processes include processes such as advection, dispersion and volatilization, as well as all those processes that may affect the mobility of a substance in the subsurface environment.

b. Chemical processes

Unlike the distribution processes, which mainly affect the mode of association of a given substance, chemical transformation will in the first place change the chemical structure of the substance, bringing about a net chemical change. Both may happen parallel to one another, and in a positive relationship in the soil. A typical example is the precipitation processes of metals. This includes;

- Oxidation type: An example of this is the precipitation of iron and manganese oxides by the oxidation of reducing waters.
- Reducing type: Examples are given by the precipitation of uranium, vanadium, copper, selenium, and silver, as metals, or lower valency oxides, by the reduction of oxidising waters. This is usually caused by encountering organic matter or by mixing with reducing waters or gases.
- Reducing sulphide type: Sulphate waters carrying ions of copper, silver, zinc, lead, mercury, nickel, cobalt, arsenic, or molybdenum, may be reduced to precipitate sulphides of these metals. This occurs usually by the action of sulphate-reducing bacteria, or through an encounter with organic matter.
- Sulphate and carbonate type: Alkali metals such as barium, strontium, and calcium, may be precipitated as carbonates following a shift in equilibrium relations.
- Alkaline type: Percolation of acidic solutions into carbonates and silicates, as well as their encounter with alkaline solutions, lead to precipitation of metals like calcium, magnesium, strontium, manganese, iron, copper, zinc, lead, and cadmium.
- Adsorption type: This type encompasses all transition metals which are susceptible to adsorption on clays and other particulate substances.
- Oxidation – reduction type: Mobility of trace metals in aquatic solutions is largely influenced by the redox status of their environment, even though they generally are not directly involved in oxidation-reduction reactions. Oxidising conditions induce the precipitation of amorphous iron and manganese oxihydrides, which later, as adsorbents, affect tremendously the mobility of trace metals in the solution. Reducing conditions induce the reduction of Mn^{4+} to Mn^{2+} and Fe^{3+} to Fe^{2+}, thereby solubilising their associated and adsorbed trace metals.

c. **Biodegradation and Biologically Supported Transformations**:

Soil organisms form a very important integrative constituent of soil, and as such they play a decisive role in determining the fate of foreign substances added deliberately or accidentally to the soil body. They normally respond to the addition of xenobiotics by initiating two main types of reactions:

- Primary metabolic reactions (also known as phase I biotransformation), during which the foreign substance is rendered more soluble in water by the addition or exposure of functional groups on it.
- Secondary metabolic reactions (phase II biotransformation), through which the products of the primary reactions are conjugated with endogenous groups to facilitate their excretion. On passing into solution, the foreign substance will be capable of penetrating the organism with rates, which are specific for organisms and their anatomical and biological peculiarities. In case of high rates of penetration, i.e. if a foreign substance enters the organism more quickly than it

can be eliminated, it accumulates in some of its organs, and, if the substance is toxic, this goes on until a toxic concentration is reached. At normal rates of penetration, secondary metabolic transformations will lead, by conjugation with endogenous compounds, to the formation of substances that may be used as energy sources by the organism, or to ones that are easily eliminated by excretion.

The level of metabolism is a principal factor in determining the persistence, or degradation, of the foreign substance in the soil, thus forming one of the most important conditions under which pollutants interact with soil through biodegradation processes.

Conclusively, physical processes of soil/pollutant interactions include transport and retention. They depend mainly upon the physical parameters of the medium (temperature, grain size, electric charges, etc.), while chemical processes depend largely on the type of pollutants and their chemical nature. Both groups of processes are further classified according to the mechanisms involved. As for biological, or biologically controlled, soil pollution processes, we may include all processes of biotransformation and biodegradation, each depending on the microbial ecology, the depth, and the oxygen availability at the polluted site.

3.2 Mechanism Of Pollutant Interaction With Soil

Soil is polluted through the introduction of toxic pollutant into its sphere. This can be human induced –through industrial activities resulting to effluent discharge; agrochemicals, and improper disposal of domestic wastes –both of wastes from consumable materials and human faeces. On the other hands, Soil can be polluted by air pollution when precipitation deposits acidic compounds such as sulfur dioxide and nitrogen oxide. Acidic drainage resulting from mining activities is also a point source of soil pollution. Whatever the cause, soil pollution has widespread negative effects on soil quality, plants, and the organisms that depend upon them.

3.3 Sampling and Soil monitoring techniques

3.3.1 Soil monitoring techniques

Monitoring is the continuous investigation and quantification of the amount of pollution present in the soil system of a particular region at specific time. It should be carried out in a way that enables the detection of spatial as well as time variations in the concentration of pollutants at the site of investigation. Monitoring provides information on the following:

- Nature of the pollutants, their quantities, sources and distribution;
- Effect of the pollutants;
- Concentration patterns, pedological changes and their causes;
- Possibility and feasibility of remediation.

Prior to setting up of monitoring plans, important information about the site such as geological, pedological, hydrogeological, and historical data about land use in the area should be carefully collected and analyzed. This saves a great deal of effort and financial costs, and allows a suitable selection of the monitoring technical installations. Geological and hydrogeological information can be taken from geological maps or from information supplied by the local geological survey. For pedological information, soil maps or individual field investigations is best suited (Ibrahim, 2008).

Soil monitoring program begins with preliminary investigation of the proposed site, to known if the site is already contaminated with the alleged pollutant, and to classify the monitoring processes either as part of a follow-up plan to evaluate the success of remediation efforts, or as a monitoring project to detect the presence or absence of a given contaminant and extents of pollution.

The steps follow a general strategy, starting with site characterization, followed by determining the objectives of monitoring, and finally determining the techniques and field measurements suitable for the objectives and type of monitoring to be conducted – in short, the proposal of a sampling and monitoring plan.

An integrated sampling/monitoring plan comprises generally of the following essential parts:

- Site characterization
- Data acquisition
- Data quality control
- Interpretation
- Reporting

(a) Site Characterization: Obtaining all available data about the site of interest should be the prime of all fieldwork in a monitoring project; this includes reviewing all published information about geomorphic and pedological characteristics of the area. If no maps are available, the area should be mapped using any of the known standard techniques (GIS, Land Survey, Remote Sensing, and Cartography), and whereby the following types of maps should be obtained:

- Base map: A base map provides information about the morphology of the site and shows the run-off conditions, including water bodies, which might be influencing hydrologic flows in the site. In a later stage, all sampling stations should be plotted on the base map. If biological monitoring is also planned, the stands of all trees and plant communities used for measurements are to be marked.
- Geologic map: Soil types are related to the bedrock and the weathering processes that produced them, a geologic map of the area, detailing the main rock types, thus, provide valuable information about the soil chemistry and the background concentration of heavy metals in the unsaturated zone of groundwater. It also helps in determining the potential for flow, adsorption, and retainment of pollutants in the soil material at the site of investigation.
- Hydrologic map. Based on the interpretation of all geologic information about the area, they supply information on groundwater relations such as availability of groundwater, the depth to the water table and the direction of groundwater flow.
- Overburden map (soil material): Pedological maps or soil maps provide information on soil types prevailing in the area. They provide a means of interpreting any differences in the soil chemistry of the area and help in

understanding any inconsistency in chemical characteristics at different parts of the investigation site.

(b) **Data Acquisition:** The principal step following the preliminary preparation and characterizations of the area, consists of data acquisition and generation, should. This stage includes the preparation of a sampling plan and determination of the chemical and physical characterizations of the problem. Two main steps are essential for this aim – the preparation of a sampling plan, and the planning of all chemical and physical investigations that will form the framework of data collection.

(c) **Data Quality Control:** Handling of collected soil samples, proper physical, chemical, and biological analysis (in-situ/laboratory) determines the quality of the data. The materials for sampling collection must be naturally free from any contamination to avoid secondary contaminants. In most cases, polythene bag is used to store collected soil samples prior to onward laboratory analysis. Soil parameters must be analyzed in accordance to scientific procedures.

(d) **Interpretation/Reporting:** Obtained data from onsite and laboratory analysis must be collated, sorted, and presented as simple as possible. The interpretation of data can be mathematical/statistical and with comparison to established standard. Maps, graphs, and tables are the appropriate format of presenting soil data. The use of software packages is most appropriate for reporting soil data. This includes, Power Points, Excel, MS Word, Surfa8, etc

3.3.2 Soil Sampling-Planning

In all the types of monitoring mentioned above, sampling forms the principal chain in all processes needed for the delineation and characterizations of the environmental quality parameters of the area under investigation. It helps locate the site(s) of contamination and provides information on time and spatial patterns related to the distribution of pollutants.

(a) Location of Sample Points

Location of sampling points largely depends upon the purpose of monitoring, as well as on the topography and geologic conditions of the area. A detection-monitoring plan, or an assessment-monitoring plan, for example, indicate a large network of sampling stations, which must be systematically distributed over the whole area of investigation, while evaluation monitoring will require a concentration of sampling stations in the neighborhood of the pollution sites. Spatial patterns of sampling follow two fundamental models (Boulding 1995) the simple rectilinear grid type and the traverse type (See figure 7.3a).

Rectilinear grid sampling is taken at equal intervals along evenly spaced lines, while the traverse line sampling, points are selected on a traverse following topographic, geologic, or geophysical data. The environmental and geochemical data of the area is decisive for the direction and density of the sample points. Samples along a traverse may also be taken systematically (at equal intervals) or at random distances. However, rectilinear grid patterns of sampling are more popular because of the ease in laying out the fieldwork and in plotting the data. The reliability of samples, as representatives for the environmental conditions in the investigated area, depends principally on factors like frequency of sampling, technical procedures of sample collection, objective and technical errors of the operator, as well as storing, handling and treatment of samples in the course of their collection and transport to the laboratory (see figure 7.3b)

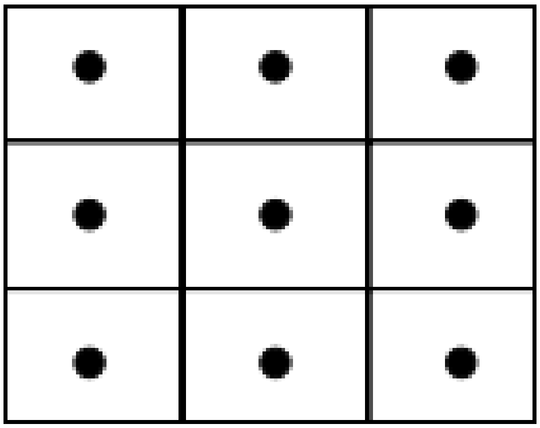


Figure 7.3a: Grid pattern

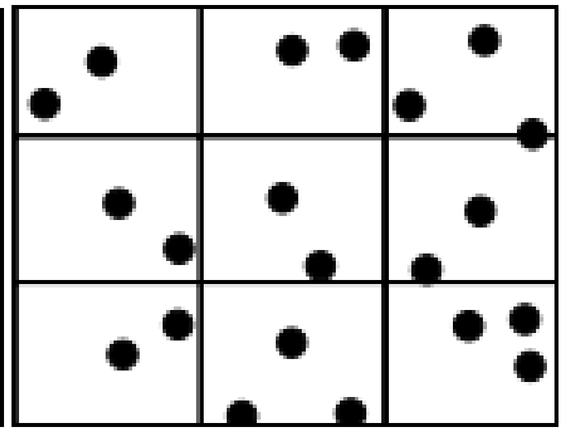


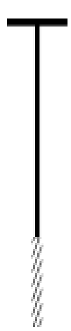
Figure 7.3b: Random block pattern

Generally, sampling points should be concentrated around hot spots, i.e. around spots where contamination is expected, or near areas that are suspected of being contaminated.

3.4 Instruments for Soil quality monitoring

3.4.1 Sampling of Solid Matter:

Soil samples are taken at fixed depths or separately from each pedogenic horizon, if detailed work is intended, the pit profiling examination is conducted. The UN recommends the following depths/ ECE ICP Forests programme (UN/ECE ICP Forests 1994): 0–5 cm, 5–10 cm, 10–20 cm and 40–80 cm. Samples from shallow depths (up to 30 or 60 cm) are collected from small pits. Deeper samples are normally collected using a soil auger. Simple soil augers are found satisfactory in sampling depths from 1 to 2 metres. Simple soil augers are normally used to sample loamy soil. For stony soils, especially if deep samples are to be collected, light power augers are recommended. Peat samples are collected using box-type samplers or by means of special augers, such as the Hillier peat borer. For bulk-density assessment, the core sampler is recommended. The increase of technology has saw the emergence of digital soil nutrient assessment. See figure 7.4a and b below for soil sample equipment.



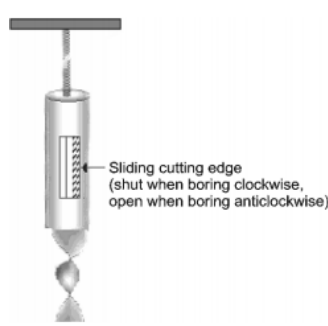


Figure 7.4a A simple soil auger Figure 7.4b Hilliers peat borer

3.4.2 Sampling of Soil Solution

The sampling of soil solution may be carried out using different techniques, depending upon the strategy and aim of the collection. The zero tension or vacuum pumps are used to collect samples at vessels located at or near the ground surface. Collection vessels, generally known as lysimeters, consist of two main types:

1. **Zero-tension lysimeters (ZTL)**

This instrument is used to sample soil water as it moves through saturated soil. A lysimeter of this type consists of a cylinder placed under an undisturbed core of soil, which has been originally removed by a piston sampler. Two flexible connections are attached to tubes at the soil surface. One of the connected tubes serves as an air let tube, while the other may be attached to a pump for collecting the samples. ZTLs may be of different shapes and types, is found useful in monitoring soil water during and after in situ remediation (Derome, 2002).

2. **Suction (tension) lysimeter**:

This is a device used to sample soil water in unsaturated soils. Acting as a continuous vacuum, it draws the water into the lysimeter through a porous membrane. Water samples are brought to the surface by suction through a tube dipping deep into the device. The tension lysimetery is the technique most widely used for sampling solution. See figure 7.5a and b below;

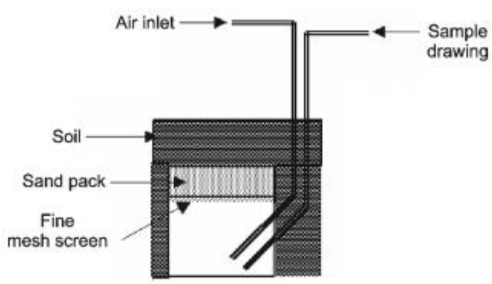


Figure 7.5a Zero-tension lysimeter

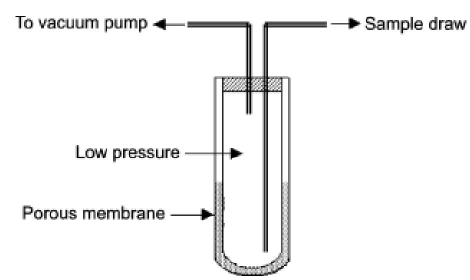


Figure 7.5bSuction lysimeter

3.5 Pollutant Interaction with Vegetation

Plants are particularly exposed to pollutants either directly or indirectly. Plants interact with pollutants indirectly through mineral absorption from contaminated environments. Soils are the bedrock of all terrestrial vegetation –providing physical support, and mineral nutrients to plants. Therefore, polluted soil becomes harmful to plant ecosystem as well. Plants are also exposed to pollutants directly, through trapping and absorbing pollutants from atmospheric air and polluted water. Research shows that major pool sink of air pollutants is vegetation and acts as sink to several air pollutants (Mellios, Aalst & Samaras, 2006). Runoff from polluted field interacts with plants tissue directly from root absorption. This process takes place in the soil medium.

3.5.1 Mechanism of Pollutant Interaction with Vegetation

Pollutants can be introduced into the vegetation/plants system directly from industrial fume emission and effluent discharge. Both the soil and air are the medium through which vegetation interacts with pollutant. Fume from transport system, industries and domestic source pollutes the air with adverse pollutants such as NOx, CO, CO_2, NH_3, H_2S, and VOC. Through the stomata of plant leaves, plants take-up some of this pollutants. In addition, pollutants from the soil are introduce into the plant system through the root hair of plants. This pollutant gets into the soil and air through the following medium:

- Industrial effluent discharge
- Hydro-carbon spills from workshop/petro-chemical industries
- Domestic waste
- Agrochemicals

a. Industrial effluent discharge:

Liquid, gas and solid waste released from industrial processing are very harmful to plant. The liquid and solid effluents are the chief source of soil pollution, which formed the primary source of plants nutrients. This may include; radioactive waste, batteries, cells, etc. The gaseous waste directly affects plants through plant respiration. Example is the release of smokes and fumes from combustion.

b. Hydro-carbon spills:

The major source of oil and petro-chemical substances into the natural environment is from the mining sector. Mining of petroleum products has a considerable effect on the environment (Soil, air, water and vegetation) through the releases of chemicals such as oil spills. The introduction of petroleum product into water and soil system degrades the quality of soil nutrients and water quality. Spills have a secondary effect on plant growth and well-being through soil and plant interaction.

c. **Domestic waste**

Waste generated from domestic source contains elements that can pollutes the entire ecosystem. These wastes must be properly handled to prevent its adverse effect. Domestic waste can also be categorized into solid and liquid waste, such as sewage, food-waste, papers, polythene, etc.

d. Agro-chemicals:

The use of fertilizer and pesticide/herbicide has gain recognizable interest in recent time. The African agricultural sector is over dependent on both pesticide for pest control and fertilizer for soil nutrient replenishment –particularly the Nigeria agricultural sector. Both fertilizer and pesticide contains pollutants with adverse effect on soil mineral and nutrients. These chemicals therefore pollute the soil with heavy metals, and contaminants, which gets into the plants system through osmosis. In some case, these chemicals are washed down stream by runoff. The stream water in-turn, is dependent upon for irrigation agriculture.

3.5.2 Vegetation monitoring techniques

For most ecological restoration projects, direct field investigation provides better understanding of the nature, characteristics, distribution, and overall wellbeing of vegetal resources. Major techniques of vegetation studies can be divided into three. These include;

a. Line Transect Method

A transect is a path along which one counts and records occurrences of the species of study. Plant species can be investigated on a linear or a general curved path. The basic idea of line transect sampling is that an observer moves along a line through a study area observing plant species along the transects (See figure 7.6). Line transects are walked, flown, or otherwise traversed, and the perpendicular distances to all detected items of interest are recorded. Basic Procedures in Line Transect Sampling includes;

- Line is drawn randomly in the area of interest
- Line is divided into equal intervals
- All plant on the transect line are detected.
- Plant are recorded at the point of initial detection.

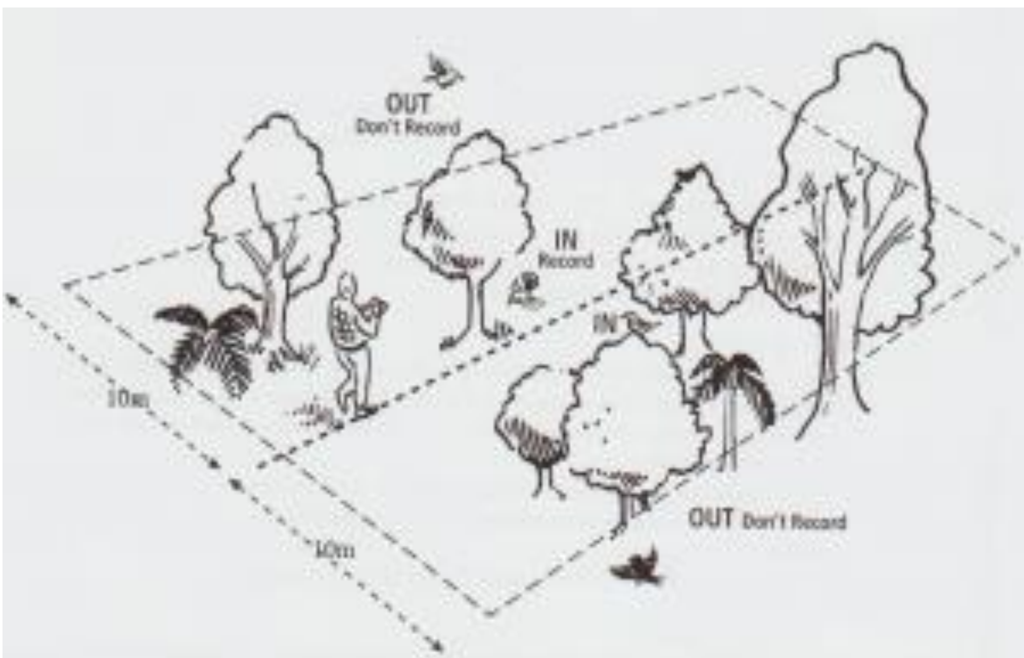


Figure 7.6: Line Transect Method

b. Plot/Quadrat Method

Sampling with quadrats (plots of a standard size) can be used for most plant communities. A quadrat delineates an area in which vegetation cover can be estimated, plants counted, or species listed. The delineation is often in a square shape. For small area study, a box frame can be used, while pigs can be used to form square box for large areas. Quadrats can be established randomly, regularly, or subjectively within a study site.

Since plants often grow in clumps, long, narrow plots often include more species than square or round plots of equal area; especially if the long axis is established parallel to environmental gradients (Cox, 1990) However, accuracy may decline as the plot lengthens because, as the perimeter increases, the observer must make decisions that are more subjective about the placement of plants inside or outside the plot.

The appropriate size for a quadrat depends on the items to be measured. If cover is the only factor being measured, size is relatively unimportant. If plant numbers per unit area are to be measure, then quadrat size is critical. A plot size should be large enough to include significant numbers of individuals, but small enough so that plants can be separated, counted and measured without duplication or omission of individuals (Cox, 1990). Large quadrats with many plants may require two or more people to obtain an accurate census, while one person may be sufficient for smaller plots or those with sparse vegetation.

c. Remote Sensing and Geographic Information System (GIS)

Traditional sampling methods may be too labor intensive to provide accurate information over large areas. Aerial photography using large-scale (1:200) color or infrared photographs are useful for mapping and recording individual plant species in a range of vegetation types (Hacker *et. al.*, 1990) a process referred to as remote sensing and aerial photometry. Acceptable estimates of plant cover can be made, and the condition of the soil surface is clearly recognizable, particularly on color infrared film. Neither film type permits accurate identification of all species and the presence of understory plants may be obscured by foliage or shadow. For best interpretation, photographs need to be taken within four to six weeks of effective rain. Unfortunately, the difficulty and expense of establishing permanently marked flight line, and acquiring and printing the photographs, precludes using the technique for some projects. Other computerized software's are used in recent time to provide base map of vegetation, using the principles of Geographic Information System (GIS). Both methods complement each other's in most cases.

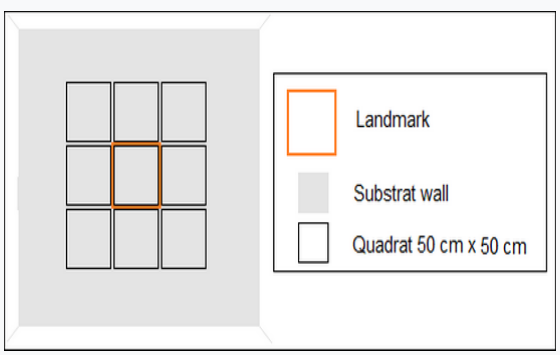


Figure 7.7a: Quadrat

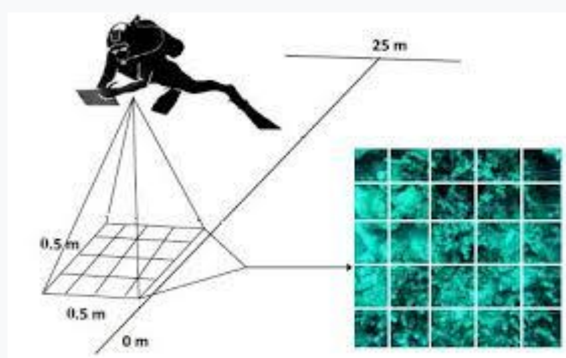


Figure 7.7b Arial Photograph

3.5.3 Instruments for vegetation monitoring

The instrument for vegetation studies includes;

a. Fieldworker

- **b.** Topographical map
- **c.** Aerial Photograph
- **d.** Clipboard
- **e.** Notepad
- **f.** Measuring tape.
- **g.** Wristwatch
- **h.** Hammer
- **i.** Pegs
- **j.** Cutlass
- **k.** Lines
- **l.** GPS
- **m.** Cameras

4.0 Conclusion

Soil and vegetation resources are highly sensitive to pollution. Soil in particular, are affected by pollutants through directly interaction resulting from the introduction of substances containing pollutants into the soil system. This may be due to spills, waste disposal, effluent discharge, which are all humanly induced. Substances penetrate into the soil system through percolation, infiltration, runoff, etc. Both physical, biological and chemical process forms the medium of pollutant interaction with soil. Vegetation on the other hands interacts with pollutants directly from respiration (air) and indirectly through the uptake of mineral salts (Osmosis). To ensure sustainability, both vegetation and soil are monitored on a routine basis, through direct field observation, sampling collection and laboratory analysis for the latter, while the former can be invested directly in the field.

5.0 Summary

In this unit we have leant that:

i. Soil and vegetation are highly sensitive to environmental pollution
ii. Soil interacts with pollutants through retention on, and within the soil body, infiltration, diffusion and transport by soil solutions and alteration, transformation, and initiation of chemical changes within the soil. This process encompasses both physical chemical and biological conditions of the soil.
iii. Vegetation interacts with pollutants directly through trapping and absorbing pollutants from atmospheric air, and indirectly through mineral absorption from contaminated environment.
iv. Effective monitoring of soil and vegetation must be site specific and with detailed field investigation. For soil, in-situ analysis is carried out and complemented with laboratory analysis, while for vegetation, an intense field examination of the characteristics, nature, distribution of vegetation is carried out.

6.0 Tutor-marked questions

1. Highlight and explain the various procedures soil quality assessment?
2. Explain the major techniques of vegetation studies.

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UNIT 8: GENERAL PRINCIPLES OF BIOTESTING /BIOASSAY

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main content
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3.2 Principles of Biotesting/Bioassays

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3.5 Applications of Bioassay
3.6 Environmental toxicity
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4.0 Summary
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1.0 Introduction

Any effects of contaminants on ecosystems must be caused by their direct effects on one or more organisms in the ecosystem. Thus, changes in the function of an organism or organisms will be behind any ecotoxicological effects. Consequently, understanding the normal physiology of organisms is at the center of all biotesting. Effluent discharges and thus the measurements of chemical concentrations are of no toxicological significance if they cause no effects on any organism. It is pointed out that interactions between organisms, and between natural environmental and toxicant-induced changes, occur whenever toxicant responses of organisms in an ecosystem are considered. . In this unit, we shall presenting biotesting/bioassay, the principles of bioassay, and various types of bioassays and explain the applicability's of bioassays. We shall equally consider environmental toxicity and the major types of environmental contaminants.

2.0 Objectives

- state what Biotesting/Bioassay is
- explain the principles of Biotesting/Bioassay
- mention the various types of Bioassays
- identify the advantages and disadvantages of bioassay
- discuss the applicability of bioassays
- discuss environmental toxicity and the major types environmental contaminants.

3.1 What is Biotesting/Bioassay?

Biotesting/Bioassays are methods for the estimation of nature, constitution, or potency of a material by means of the reaction that follows its application to living matter. Bioassay is defined as estimation or determination of concentration or potency of physical, chemical or biological agents by means of measuring and comparing the magnitude of the response of the test with that of standard over a suitable biological system under standard set of conditions (Agatonovic-Kustrin, 2015). An assay is a form of biological experiment; but the interest lies in comparing the potencies of treatments on an agreed scale, instead of in comparing the magnitude of effects of different treatments. Biological assays or biological standardizations or simply bioassays are methods used for estimation of the potency of substances by observing their effects on living organisms which include plants and animals (in vivo) or isolated tissues (in vitro) and comparing the effect of these substances of unknown potency to the effect of a standard.

In bioanalysis the response produced by the test compound is compared with that of standard sample the way similar to other analytical methods but here the biological system is involved in the determination. In other words, bioassays are based upon the use of biological responses as detection system for biologically active substances. In the simplest form it is used to assay the presence (and concentration) of a particular substance by comparison with a known amount of the same substance. It is the procedures by which the potency or the nature of a substance is estimated by studying its effects on living matter (Zainal, 2014; Ado, 2014).

3.2 Principles of Biotesting/Bioassays

The Principles of Bioassays include the following;

i. The active principle of bioassay should be the same measured response in all animal species and plant species (Uddin, 2013).
ii. Bioassay involves the comparison of the environmental contaminated organism with that of the standard (Din, 2013).
iii. The bioassays method selected should be reliable, sensitive, and reproducible and should minimize errors due to biological variation and methodology.
iv. The degree of contaminations response to pollutants produced should be reproducible under identical conditions.
v. Activity assayed should be the activity of interest as such individual variations must be minimized/accounted for (Turaka, 2013).
vi. Bioassay might measure a different aspect of the same substance compared to chemical assay.
vii. The test solution and standard should be compared for their established health effect using a specified environmental/pharmacological technique (Bhandare N and Mendenhall, 2012; Shintani, 2014).
viii. The biotesting/bioassay compares the test sample with a same internationally applicable standard substance.

ix. It determines the quantity of test sample required to produce an equivalent biological response to that of standard substance. Standard samples are accepted by expert committee at international level and they represent fixed units of activity.

3.3 Types of Bioassays

There are several types of bioassays which include;

1. Direct Assay

Under this assay, prescription of standard and test preparations are sufficient to produce a specified response, and can be directly measured.

2. Indirect Assay

In indirect bioassays the relationship between the prescribe standard and response of each preparation is first ascertained. Then the prevention or the cleaning mechanism corresponding to a given response is obtained from the relation for each preparation separately (Huang, 2015).

3. Quantal Assay

This response is in the form of all or none means no response or maximum response. These can be bioassay by end point method. Predetermined response is measured which is produced by threshold effect on pollutant or infection.

4. Graded Assay

It is proportional to the limit and response may lie between no response and maximum response (Huang, 2015). Graded Responses can be any type of measured responses in isolated tissues in particular, but also in whole animals or plants. Such responses are infinitely graded and there are a large number of them.

5. Matching Method

In this type of assay the test substance and the standard are applied and the responses obtained are matched by a trial and error process until they produce equal effects (Lai, 2013). This may also limit to analytical dilution assay, as the assay involves the determination of the factor by which the test substance is diluted or concentrated in order to produce response that is equal to that of known amount of the standard limit of prevention or treatment (Ado, 2014). Its advantage is that it does not depend on the assumption of response relationship. The main disadvantages are that it is purely subjective, and experimental errors cannot be determined from the assay. It gives no indication or the parallelism of the preventive response curves of the standard drug and test substance, and hence the qualitative differences, as the effects are matched at only one dose level (Uddin, 2013). This assay is quick and easy; useful when one is has many samples to test and a semi qualitative answer is sufficient. But the assay inherently lacks precision and no accuracy. The data is not easily statistically analyzed and probably should not be so analyzed due to lack of integrity (Hu, 2013).

6. Bracketing Method

This is highly used on animals, by selecting two standard doses, which will give a close bracket on either side of the response produced by the unknown. The working dose of standard is first determined in the sensitive part of dose-response curve, that is, a dose that will approximately produce 50% of the maximal concentration. The dose of the standard drug is kept constant throughout the experiment, in order to have some idea about the change in the sensitivity of tissue with time (Agatonovic-Kustrin, 2015).

7. Seed Bioassay

Seeds are living organisms that may be harmed by chemicals. The seed bioassay technology has been implied as decisive and lab scale and method to assess the toxicity of any substance on profitable crops (Agatonovic-Kustrin, 2015). The seedling germination and seedling growth impressions under contrasting concentrations of industrial derivation can give some perception about the abolishing or toxicological impact of industrial effluents on plants.

8. Antimicrobial Assay

Standard and clinically isolated microorganism strains were used for antimicrobial assays. A large number of human, animal and plant disease are caused by pathogenic microbes. Infection due to fungi and bacteria has been a major cause of death in higher organisms (Din, 2013). The discovery of antibiotic penicillin by Fleming is therefore considered to be one of most important discoveries in the world. The microbial assay for antibiotics is a method that uses microorganisms to determine the antimicrobial potency of the antibiotics contained in medicine.

Other forms of bioassays include interpolation method, antifungal assay, bioassay for drugs, Antibiotic assay, three point bioassay and four point bioassay which are commonly used in human medical sciences and veterinary medicine.

3.4 Advantages and Disadvantages of Bioassays

Some of the advantages of bioassays are;

i. They not only help to determine the concentration of pollutants but also ascertain the potency in the sample. It is especially used to standardization curative and preventive measures as these are all used over biological system in some or other form.

ii. The concept and principles of bioassay can be very useful when performing structure activity relationship studies as part of the drug invention process when we wish to compare the relative potency and functional effects of different compounds on intact tissue systems.
iii. Testing of infected plants or animal sputum helps determine which curative measure is to be use.
iv. It is Simple and faster method.
v. Improvements in chemistry and biochemistry have increased the precision and accuracy of all physical methods for the measurement of the presence and concentrations toxins in plants and animals and have made many biological-response bio-assays outstanding.
vi. Certain complex compounds which can't be analyzed by simple techniques can be effectively estimated by bioassays.

The critical disadvantage of bioassay is that quantitative difference between standard and test may not be obtain due to some certain biological variations.

3.5 Applications of Bioassay

i. Bioassays are usually use in establishing regulatory requirements for water quality;
ii. Bioassays are usually use in carrying out ecological monitoring of sewages discharge
iii. Bioassays are usually use in ascertaining the state environmental monitoring of water bodies, particularly in the areas of the human exposure;
iv. Bioassays are usually use in environmental impact assessment of new technologies, treatment facilities, reconstruction and modernization of national economic projects; for designing local treatment facilities assessment of aquatic ecosystems.

3.6 Environmental toxicity

Generally, understanding that human actions cause deterioration of the environment identified centuries ago, and even now the environmental aspects of these actions are often forgotten when environmental effects and short-term economic gains are in conflict. The following factors need to be taken seriously when considering the importance of a compound as a pollutant:

i. The amount of the compound released. Naturally, the more a substance is released, the more harmful it is. Comparing the released amounts is highly important, as it is possible that a potentially very toxic compound is environmentally unimportant if it reaches the environment only in very small amounts. Conversely, a compound which is relatively nontoxic may become an important contaminant, if it reaches the environment in large amounts. Examples of relatively nontoxic compounds that have caused serious environmental problems in aquatic bodies are nitrates and phosphates. Their release results in eutrophication and consequent lack of oxygen.

ii. The water solubility of the compound. This affects both the uptake route and the bio-magnification of the compound in the food web as it is closely related to bioavailability.
iii. The tendency of the compound to escape from the material it is currently associated with will affect all aspects of its toxicity.
iv. The transformation of the compound. Several chemicals that enter the environment do not remain in their original form, but are transformed into daughter compounds. The compounds formed may be more or less toxic than the parent compound. Both abiotic and biotic factors may cause the transformation. For example, solar radiation will cause oxidation of many compounds.
v. Complex formation by some compounds. Some chemicals form complexes with other constituents of the aquatic environment or the internal surroundings of the organism. This will affect both the availability of the compound to an organism and the ability of the compound to interact with its toxicity target.

3.6.1 Major Types Contaminants

The major types of pollutants are presented thus;

i. Metals and metalloids: Includes essential metals such as copper, zinc, and iron; nonessential metals such as cadmium, lead, mercury, and silver; and metalloids such as arsenic. Major sources are household effluents, mining, and associated industry.
ii. Organometallic compounds: Contaminants include organic tin compounds and methylmercury. Although methylmercury is partially of anthropogenic origin, natural methylation/demethylation processes also cause its presence in waterways.
iii. Fertilizers: Include especially nitrates, ammonium nitrogen, and phosphates. Their sources are household effluents, agriculture, and aquaculture.
iv. Greenhouse gases: Carbon dioxide production is involved in ocean acidification, and methane can be liberated in natural gas production.
v. Oxides of sulfur and nitrogen: Their deposition in smoke from energy production and traffic causes acid rain.
vi. Radioactive compounds: A natural source of radioactivity is radon gas. In addition, effluent from plants performing military processing of uranium is a major source of radioactivity in water. If nuclear power plants are functioning properly, the radioactivity given out to water is smaller than from power plants using coal. However, abnormal occurrences, such as earthquakes or accidents in the power plants, may result in high environmental radioactivity. Further, leaks from storing radioactive material and uranium mining can be significant sources of radioactivity in the environment.
vii. Oil and its components: Oil spills can take place during oil drilling, as a result of shipwrecks during oil transport, and from effluent discharges from oil refineries. Also, oil tanks of ships are surprisingly often cleaned in open sea, resulting in oil discharges.
viii. Pharmaceuticals and personal care products: Since the intention is to produce drugs with minimal breakdown, these often pass through water cleaning unmodified. In addition, antibiotics may kill bacteria in biological water

purification. Soaps and other detergents dissolve lipid membranes, and sunscreens are often photo-chemically modified to more toxic compounds.

ix. Paper and pulp-mill effluents: Since chlorinated compounds have disappeared from effluents, the major toxic compounds are natural compounds of trees, such as resin acids from coniferous trees and phenolics from deciduous trees.

x. Pesticides: Pesticides contain several different types of compounds, including herbicides, insecticides, and fungicides.

xi. Ultraviolet (UV) radiation: The effects are restricted to surface layers of water bodies, as light penetrates only a short distance in water.

xii. Ionic liquids: These compounds are called “environmentally friendly” solvents, because their vapor pressure is small; however, their aquatic effects are poorly known. Among others.

4.0 Conclusion

This unit unveil that the effects of contaminants to the environment are usually caused by their direct effects on one or more organisms in the environment. The understanding the normal physiology of organisms is at the center of all biotesting. Generally, effluent discharges and the measurements of chemical concentrations are of no toxicological significance if they cause no effects on any organisms. The interactions between organisms, and the interactions between natural environmental and toxicant-induced changes usually occurs whenever toxicant responses of organisms in an environment are considered disturbing. In this unit, we presented biotesting/bioassay, the principles of bioassay, and various types of bioassays and explain the applicability’s of bioassays. We equally consider environmental toxicity and the major types of environmental contaminants.

5.0 Summary

In this unit we have leant that:

i. The effects of contaminants to the environment are usually caused by their direct effects on one or more organisms in the environment.

ii. The understanding the normal physiology of organisms is at the center of all biotesting.

iii. Effluent discharges and the measurements of chemical concentrations are of no toxicological significance if they cause no effects on any organisms.

iv. The interactions between organisms, and the interactions between natural environmental and toxicant-induced changes usually occurs whenever toxicant responses of organisms in an environment are considered disturbing.

v. Biotesting/bioassay is important in toxicological studies and this centres around some certain principles.

vi. There are several applicability’s of bioassays.

6.0 Tutor-Marked Assignments

1. Identify the major principles of bioassays.
2. Discuss the various types of bioassays.

3. Identify the major types of contaminants to the environment.

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