NATIONAL OPEN UNIVERSITY OF NIGERIA

FACULTY OF HEALTH SCIENCES

COURSE CODE: EHS503

COURSE TITLE: WATER/AIR QUALITY MANAGEMENT 2 CREDIT

COURSE GUIDE

EHS 503
WATER/AIR QUALITY MANAGEMENT 2 CREDIT UNIT

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INTRODUCTION

This course, *Water/Air Quality Management* discusses the importance of water and air quality in terms of their ability to meet designated uses and support healthy living. Several natural and anthropogenic activities introduce contaminants and pollutants into the aquatic and atmospheric environments. These must be controlled or prevented in order to keep the water and air in good quality to meet current and further human needs. In this course, you will be introduced to different aspects of water/air quality management.

WHAT YOU WILL LEARN IN THIS COURSE

In this course, you have the course units and a course guide. The course guide will tell you what the course is all about. It is general overview of the course materials you will be using and how to use those materials. It also helps you to allocate the appropriate time to each unit so that you can successfully complete the course within the stipulated time limit.

The course guide also helps you to know how to go about your Tutor-Marked Assignment which will form part of your overall assessment at the end of the course. Also, there will be regular tutorial classes that are related to this course, where you can interact with your facilitator and other students. Please, I encourage you to attend these tutorial classes.

COURSE AIM

The aim of this course is to provide you with the basics of water/air quality management, framework for water/air pollution control and the different methods of assessing water and air quality.

COURSE OBJECTIVES

To achieve the aim set above, there are objectives. Each unit has a set of objectives presented at the beginning of the unit. These objectives will guide you on what to concentrate / focus on while studying the unit. Please read the objective before studying the unit and during your study to check your progress.

The Comprehensive Objectives of the Course are given below. By the end of the course/after going through this course, it is expected that at the end of this course, students should be able to:

- Define and explain the concept of water/air quality
- Understand the principles and objectives of water and air quality management
- Know the international conventions and treaties on water quality management
- Understand the roles of the World Health Organization in water and air quality management
- Explain the procedures for water quality monitoring and surveillance
- Explain how to protect water sources and treatment of wastewater
- Explain how water/air pollution impact on the quality of life and the environment
- Explain the different air quality assessment technologies and air quality modeling

WORKING THROUGH THIS COURSE

To successfully complete this course, you are required to read each study unit, read the textbooks materials provided by the National Open University.

Reading the referenced materials can also be of great assistance.
Each unit has self-assessment exercises which you are advised to do and at certain periods during the course you will be required to submit your assignment for the purpose of assessment.

There will be a final examination at the end of the course. The course should take you about 17 weeks to complete.

This course guide will provide you with all the components of the course how to go about studying and hour you should allocate your time to each unit so as to finish on time and successfully.

THE COURSE MATERIALS

The main components of the course are:

- The Study Guide
- Study Units
- Reference / Further Readings
- Assignments
- Presentation Schedule

STUDY UNIT

The study units in this course are given below:

Module 1 An Overview of Water Quality Management

Unit 1 Definitions, Concepts, Principles and Objectives
Unit 2 Water Quality Standards
Unit 3 International Conventions and Treaties

Module 2 Water Quality Monitoring and Survellance

Unit 1 Procedures for Water Quality Monitoring and Surveillance
Unit 2 Protection of Water Sources
Unit 3 Wastewater Management

Module 3 An Overview of Air Quality Management

Unit 1 Concept of Air Quality
Unit 2 Composition of Air
Unit 3 Air Pollution
Unit 4 Measurement of Air Quality

Module 4 Assessment of Air Quality

Unit 1 Air Quality Assessment Technologies
Unit 2 Source Apportionment, Mobile Monitoring and Land Use Regression
Unit 3 Air Quality Modelling

There are activities related to the lecture in each unit which will help your progress and comprehension of the unit. You are required to work on these exercises which together with the TMAs will enable you to achieve the objectives of each unit.

ASSIGNMENT FILE

There are two types of assessments in this course. First are the Tutor-Marked Assessments (TMAs); second is the written examination. In solving the questions in the assignments, you are expected to apply the information, knowledge and experience acquired during the course. The assignments must be submitted to your facilitator for formal assessment in accordance with prescribed deadlines stated in the assignment file.

The work you submit to your facilitator for assessment accounts for 30 percent of your total course mark. At the end of the course, you will be required to sit for a final examination of 1½ hours duration at your study center. This final examination will account for 70 % of your total course mark.

PRESENTATION SCHEDULE

There is a time-table prepared for the early and timely completion and submissions of your TMAs as well as attending the tutorial classes. You are required to submit all your assignments by the stipulated time and date. Avoid falling behind the schedule time.

ASSESSMENT

There are three aspects to the assessment of this course.
The first one is the self-assessment exercises. The second is the tutor marked assignments and the third is the written examination or the examination to be taken at the end of the course.

Do the exercises or activities in the unit by applying the information and knowledge you acquired during the course. The tutor-marked assignments must be submitted to your facilitator for formal assessment in accordance with the deadlines stated in the presentation schedule and the assignment file.

The work submitted to your tutor for assessment will count for 30% of your total course work.

At the end of this course, you have to sit for a final or end of course examination of about a three-hour duration which will count for 70% of your total course mark.

TUTOR-MARKED ASSIGNMENT

This is the continuous assessment component of this course and it accounts for 30% of the total score. You will be given four (4) TMAs by your facilitator to answer. Three of which must be answered before you are allowed to sit for the end of course examination.

These answered assignments are to be returned to your facilitator.
You're expected to complete the assignments by using the information and material in your readings references and study units.

Reading and researching into you references will give you a wider via point and give you a deeper understanding of the subject.

1. Make sure that each assignment reaches your facilitator on or before the deadline given in the presentation schedule and assignment file. If for any reason you are not able to complete your assignment, make sure you contact your facilitator before the assignment is due to discuss the possibility of an extension. Request for extension will not be granted after the due date unless there in exceptional circumstances.

2. Make sure you revise the whole course content before sitting or the examination. The self-assessment activities and TMAs will be useful for this purposes and if you have any comment please do before the examination. The end of course examination covers information from all parts of the course.

COURSE MARKING SCHEME

Assignment	Marks
Assignments 1 – 4	best three marks of the each–30% of course
End of course examination	70% of overall course marks
Total	100% of course materials.

Table 2: Course Organization

Unit	**Title of Work**	**Weeks activity**	**Assessment (End of Unit)**
1	Definitions, Concepts, Principles and Objectives	Week 1	Assignment 1
2	Water Quality Standards	Week 2	Assignment 2
3	International Conventions and Treaties	Week 3	Assignment 3
4	Procedures for Water Quality Monitoring and Surveillance	Week 4	Assignment 4
5	Protection of Water Sources	Week 5	Assignment 5
6	Wastewater Management	Week 6	Assignment 6
7	Definition of terms in air quality	Week 7	Assignment 7
8	Air Pollution	Week 8	Assignment 8
9	Measurement of Air Quality	Week 9	Assignment 9
10	Air Quality Assessment Technologies	Week10	Assignment10
11	Source Apportionment, Mobile Monitoring and Land Use Regression	Week11	Assignment 11
12	Air Quality Modelling	Week12	Assignment 12

HOW TO GET THE MOST OUT OF THIS COURSE

In distance learning, the study units replace the university lecturer. This is one of the huge advantages of distance learning mode; you can read and work through specially designed study materials at your own pace and at a time and place that suit you best. Think of it as reading from the teacher, the study guide tells you what to read, when to read and the relevant texts to consult. You are provided exercises at appropriate points, just as a lecturer might give you an in-class exercise. Each of the study units follows a common format. The first item is an introduction to the subject matter of the unit and how a particular unit is integrated with the other units and the course as a whole. Next to this is a set of learning objectives. These learning objectives are meant to guide your studies. The moment a unit is finished, you must go back and check whether you have achieved the objectives. If this is made a habit, then you will significantly improve your chances of passing the course. The main body of the units also guides you through the required readings from other sources. This will usually be either from a set book or from other sources.

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

The following are practical strategies for working through this course

1. Read the Course Guide thoroughly.
2. Organize a study schedule. Refer to the course overview for more details. Note the time you are expected to spend on each unit and how the assignment relates to the units. Important details, e.g. details of your tutorials and the date of the first day of the semester are available. You need to gather together all these information in one place such as a diary, a wall chart calendar or an organizer. Whatever method you choose, you should decide on and write in your own dates for working on each unit.
3. Once you have created your own study schedule, do everything you can to stick to it. The major reason that students fail is that they get behind with their course works. If you get into difficulties with your schedule, please let your tutor know before it is too late for help.
4. Turn to Unit 1 and read the introduction and the objectives for the unit.
5. Assemble the study materials. Information about what you need `for a unit is given in the table of contents at the beginning of each unit. You will almost always need both the study unit you are working on and one of the materials recommended for further readings, on your desk at the same time.
6. Work through the unit, the content of the unit itself has been arranged to provide a sequence for you to follow. As you work through the unit, you will be encouraged to read from your set books.
7. Keep in mind that you will learn a lot by doing all your assignments carefully. They have been designed to help you meet the objectives of the course and will help you pass the examination.
8. Review the objectives of each study unit to confirm that you have achieved them. If you are not certain about any of the objectives, review the study material and consult your tutor.

9. When you are confident that you have achieved a unit's objectives, you can start on the next unit. Proceed unit by unit through the course and try to pace your study so that you can keep yourself on schedule.
10. When you have submitted an assignment to your tutor for marking, do not wait for its return before starting on the next unit. Keep to your schedule. When the assignment is returned, pay particular attention to your tutor's comments, both on the tutor-marked assignment form and also that written on the assignment. Consult you tutor as soon as possible if you have any questions or problems.
11. After completing the last unit, review the course and prepare yourself for the final examination. Check that you have achieved the unit objectives (listed at the beginning of each unit) and the course objectives (listed in this course guide).

FACILITATORS/TUTORS AND TUTORIALS

Sixteen (16) hours are provided for tutorials for this course. You will be notified of the dates, times and location for these tutorial classes. As soon as you are allocated a tutorial group, the name and phone number of your facilitator will be given to you.

These are the duties of your facilitator: He or she will mark and comment on your assignment. He will monitor your progress and provide any necessary assistance you need. He or she will mark your TMAs and return to you as soon as possible. You are expected to mail your tutored assignment to your facilitator at least two days before the schedule date.
Do not delay to contact your facilitator by telephone or e-mail for necessary assistance if you do not understand any part of the study in the course material. You have difficulty with the self-assessment activities. You have a problem or question with an assignment or with the grading of the assignment.

It is important and necessary you acted the tutorial classes because this is the only chance to have face to face content with your facilitator and to ask questions which will be answered instantly. It is also period where you can say any problem encountered in the course of your study.

FINAL EXAMINATION AND GRADING

The final examination for EHS 503: Water/Air Quality Management will be of 1½ hours duration. This accounts for 70 % of the total course grade. The examination will consist of questions which reflect the practice, exercises and the tutor-marked assignments you have already attempted in the past. Note that all areas of the course will be assessed. To revise the entire course, you must start from the first unit to the twelfth unit in order to get prepared for the examination. It may be useful to go over your TMAs and probably discuss with your course mates or group if need be. This will make you to be more prepared, since the examination covers information from all aspects of the course.

SUMMARY

This course, water/air quality management contains relevant information on water/air quality management. The knowledge gained from the course is to enable you as an environmental scientist to take up any role involving water/air quality management.

I wish you success in this course.

MAIN COURSE

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MODULE 1 AN OVERVIEW OF WATER QUALITY MANAGEMENT

UNIT 1 DEFINITIONS, CONCEPTS, PRINCIPLES AND OBJECTIVES

CONTENTS

1.0 INTRODUCTION

The global importance and vulnerability of our water supply, both in terms of quantity and quality has been well documented and, although water is a renewable resource, it is also a finite resource. Water, vital to both human health and ecosystem sustainability, is under increasing pressure as urbanization and agricultural intensification increase and, as such, it is essential that we improve our understanding of the types, and complexity and potential impacts of chemicals that are increasingly being released into the environment, especially the water bodies, and how they affect the quality of our lives.

2.0 OBJECTIVES

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

- explain the concept of water quality management
- explain the principles and objectives of water quality management
- understand water quality standards including standards for drinking water quality
- know the international conventions and treaties on water quality management

3.0 MAIN CONTENT

3.1 Definitions

Community Managed Water Systems: on-site or centralized drinking water systems protected, operated and maintained (small maintenance only) by community water committee.

Contaminant: any chemical or substance present or released or added into drinking water which is capable of being hazardous to health.

Drinking Water: all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a drinking water system, or a tanker, or taken from a private well.

All water used in any food production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption.

Drinking Water Quality Control: water tests conducted on routine basis by the water utility to ensure that water supplied to the consumers meet the standard.

Drinking Water Quality Surveillance: water tests, sanitary inspections and spot checks conducted by an independent agency to ensure that water utilities and others suppliers meet the Standard.

Drinking Water Service Level: measure of quality, quantity, accessibility, coverage, affordability and continuity of drinking water supplied to the population. Water service levels are defined in the National Water Supply Policy and sanitation Policy.

Drinking Water Service Provider: the whole set of organization, processes, activities, means and resources necessary for abstracting, treating, distributing or supplying drinking water and for providing the associated services. Drinking water service providers are essentially states water agencies. The States Water Agencies are:

State Water Boards/Corporations, which mostly serve urban areas greater than 20,000 inhabitants
Small Water Town Agencies, which mostly serve semi-urban areas with population between 5,000 to 20,000 inhabitants.

Rural Water Supply and Sanitation Agencies operate in rural areas and usually serve communities of 500 to 5,000 inhabitants..

Drinking Water System: tangible assets necessary for abstracting, treating, distributing or supplying drinking water. Drinking water systems include centralized and on-site systems:

Protected on-site drinking water systems:
i. Protected hand dug wells equipped with hand pump
ii. Protected spring catchments
iii. Borehole equipped with hand pump

Protected centralized drinking water systems:
i. Mechanized borehole with distribution system
ii. Surface water intake, treatment and distribution system

Laboratory Quality Assurance: minimum requirements regarding staff qualification, analytical method, sampling procedures, calibration procedures, quality control, preventive maintenance and record keeping procedures that a laboratory has to comply with to ensure reliable and accurate results

Maximum Permitted or Allowable Limits: maximum concentration of microbiological, chemical and organic constituents / contamination allowed in drinking water. These concentrations are based on WHO guideline value for which no adverse health effect is noticed.

Mineral Water: water packaged in suitable container that meets the Nigerian Industrial Standards for Natural Mineral Water (NIS 345: 2003).

Packaged Water: water packaged in suitable container that meets The Nigerian Industrial Standards for Potable Water.

Point of Delivery: physical fixed interface beyond which the water service provider is not legally responsible for the service.

Point of compliance: points where the surveillance agency collects water samples in order to measure compliance with maximum allowable limits.

Private Drinking Water System: drinking water systems owned by a private person(s) and use solely for the family residence.
Protection Zone: defined area surrounding a water source where activities that may affect water quality are restricted or prohibited
Public or Privately Owned Establishment: establishment where water is supplied to the public, such as secondary schools, university, hospitals, restaurants.

Sanitary Inspections: inspections used to evaluate the likelihood of contamination of water

Sanitary Surveys: the evaluation of the water source and intake structure, the treatment and conditioning process, the facilities and components and also an evaluation of the distribution system

Sources of Contamination: release into the environment of man-made chemical and bacteriological contaminants. Major contamination sources are animal and human wastes, industry and mining activities, agriculture and accidents and leaks such as oil spillage.

State Urban Water Supply Regulators: independent regulatory bodies that monitor the performance of water utilities or any other water supply operators and ensure that the water supply complies with quality standard and service levels

Toxic element: organic or inorganic constituents that may adversely affect human health when its concentration in water reaches a specific threshold.

Water quality: the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose.

Water Source (groundwater or surface water):
Surface water includes streams, rivers, lakes or reservoirs.
Ground water includes springs, wells or boreholes

Water Safety Plan: essential actions that are the responsibility of the drinking water provider in order to ensure that drinking water is safe. These are:

1. a system assessment;
2. effective operational monitoring; and
3. management

Water Vendors: these are persons or organizations selling water to households or at collection points. Vendors may carry drinking water for sale directly to the consumer by tanker trucks, wheelbarrows /trolleys or donkey carts

3.2 Concept of Water Quality

Pollution influences living organisms, humans included, both directly (by affecting their health) and indirectly (via contamination of food and abiotic compartments). Heavy metals and organic compounds, such as polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs) and pesticides, have been the center of attention for a long time. It is necessary to understand the nature of these pollutants and their effects on water quality for the development of better management practices.

The importance of water quality as a factor constraining water use has often gone unacknowledged in the analyses of water scarcity. Water scarcity is a function not only of volumetric supply, but also of quality sufficient to meet the demand. The UN World Water Development Report from the World Water Assessment Program indicates that, in the next 20 years, the quantity of water available to everyone is predicted to decrease by 30%.More than 2.2 million people died in 2000 from waterborne diseases (related to the consumption of contaminated water) or drought. In 2004, the UK charity WaterAid reported that a child dies every 15 seconds from easily preventable water-related diseases. Some observers have estimated that by 2025 more than half of the world population will be facing water-based vulnerability (Kulshreshtha, 1998). A report, issued in November 2009, suggests that by 2030, in some developing regions of the world, water demand will exceed supply by 50%.

Water plays an important role in the world economy. Water quality management is important because safe drinking water is essential to humans and other lifeforms. The drinking water demand is perhaps the largest demand for high quality water apart from many industrial uses which also require high quality water. Water is an excellent solvent for a wide variety of chemical substances; as such it is widely used in industrial processes, and in cooking and washing. Agriculture, by far the largest consumer of water, also suffers when water supplies is affected. Other anthropogenic activities that use water include fishing, transport, cooling and heating in industries and homes etc.

3.3 Water Quality Principles

The following guiding principles provide a suitable basis for water quality management:

1. **Prevent pollution rather than treating symptoms of pollution**.
   Remedial actions to clean up polluted sites and water bodies are generally much more expensive than applying measures to prevent pollution from occurring. This principle seeks to prevent the production of wastes that require treatment. Water pollution control that focus on wastewater minimization, in-plant refinement of raw materials and production processes, recycling of waste products, etc., are given priority over traditional end-of-pipe treatments. Where water pollution originates from diffuse sources, such as agricultural use of fertilizers, which cannot be controlled by this approach the principle of **"best environmental practice"** should be applied to minimize non-point source pollution e.g. codes of good agricultural practice that address the causes of water pollution from agriculture, such as type, amount and time of application of fertilizers, manure and pesticides, can give guidance to farmers on how to prevent or reduce pollution of water bodies. (UNECE,1993).
2. **Precautionary principle**.
   There are many examples of the application and discharge of hazardous substances into the aquatic environment, even when such substances are suspected of having detrimental effects on the environment. Until now the use of any substance and its release to the environment has been widely accepted, unless scientific research has proved unambiguously a causal link between the substance and a well-defined environmental impact. Actions to avoid potential environmental damage by hazardous substances should not be postponed on the grounds that scientific research has not proved fully a causal link between the substance and the potential damage (UNECE, 1994).
3. **Polluter-pays-principle.**
   The costs of pollution prevention, control and reduction measures are borne by the polluter. This principle is an economic instrument that is aimed at affecting behaviour, i.e. by encouraging and inducing behaviour that puts less strain on the environment. Examples of attempts to apply this principle include financial charges for industrial waste-water discharges and special taxes on pesticides (Warford, 1994).
4. **Realistic standards and regulations**
   An important element in a water pollution control strategy is the formulation of realistic standards and regulations. However, the standards must be achievable and the regulations enforceable. Unrealistic standards and non-enforceable regulations may do more harm than having no standards and regulations, because they create an attitude of indifference towards rules and regulations in general, both among polluters and administrators. Standards and regulations should be tailored to match the level of economic and administrative capacity and capability. Standards should be gradually tightened as progress is achieved in general development and in the economic capability of the private sector. Thus, the setting of standards and regulations should be an iterative and on-going process.
5. **Balance economic and regulatory instruments**
   Regulatory management instruments are heavily relied upon by governments in most countries for controlling water pollution. Economic instruments, typically in the form of wastewater discharge fees and fines, have been introduced to a lesser extent and mainly by industrialized countries. The setting of prices and charges are crucial to the success of economic instruments. If charges are too low, polluters may opt to pollute and to pay,

whereas if charges are too high they may inhibit economic development. In developing countries, where financial resources and institutional capacity are very limited, the most important criteria for balancing economic and regulatory instruments should be cost-effectiveness (those that achieve the objectives at the least cost) and administrative feasibility.

6. **Water pollution control at the lowest appropriate level**

The appropriate level may be defined as the level at which significant impacts are experienced. If, for example, a specific water quality issue only has a possible impact within a local community, then the community level is the proper management level. If environmental impacts affect a neighboring community, then the appropriate management level is one level higher than the community level, for example the river basin level. The important point is that decisions or actions concerning water pollution control should be taken as close as possible to those affected, and that higher administrative levels should enable lower levels to carry out decentralized management.

7. **Establishment of mechanisms for cross-sectoral integration**

In order to ensure the co-ordination of water pollution control efforts within water-related sectors, such as health and agriculture, formal mechanisms and means of co-operation and information exchange need to be established. Such mechanisms should:

- Allow decision makers from different sectors to influence water pollution policy.
- Urge them to put forward ideas and plans from their own sector with impacts on water quality.
- Allow them to comment on ideas and plans put forward by other sectors.

For example, a permanent committee with representatives from the involved sectors could be established. The functions and responsibilities of the cross-sectoral body would typically include at least the following:

- Co-ordination of policy formulation on water pollution control.
- Setting of national water quality criteria and standards, and their supporting regulations.
- Review and co-ordination of development plans that affect water quality.
- Resolution of conflicts between governments bodies regarding water pollution issues that cannot be resolved at a lower level.

8. **Participatory approach with involvement of all relevant stakeholders**

The participatory approach involves raising awareness of the importance of water pollution control among policy-makers and the general public. Decisions should be taken with full public consultation and with the involvement of groups affected by the planning and implementation of water pollution control activities. This means, for example, that the public should be kept continuously informed, be given opportunities to express their views, knowledge and priorities, and it should be apparent that their views have been taken into account.

9. **Open access to information on water pollution**

This principle is directly related to the principle of involvement of the general public in the decision-making process, because a precondition for participation is free access to information held by public authorities. Open access to information helps to stimulate understanding, discussions and suggestions for solutions of water quality problems.

10. **International co-operation on water pollution control**

Trans-boundary water pollution, typically encountered in large rivers, requires international co-operation and co-ordination of efforts in order to be effective. In a number of cases (e.g. the Danube, Zambezi and Mekong rivers), permanent international bodies with representatives from riparian states have been successfully established, with the objective of strengthening international co-operation on the pollution control of the shared water resources. A framework for international co-operation on water pollution control that has been widely agreed is the Convention on the Protection and Use of Trans-boundary Watercourses and International Lakes (UNECE, 1994).

3.4 Water Quality Criteria and Objectives

Water quality criterion (or water quality guideline) refers to numerical concentration or narrative statement recommended to support and maintain a designated water use. Water quality objective (water quality goal or target) on the other hand refers to numerical concentration or narrative statement which has been established to support and to protect the designated uses of water at a specific site, river basin or part(s) thereof.

Water Quality Criteria

Water quality criteria are developed to provide basic scientific information about the effects of water pollutants on a specific water use. They also describe water quality requirements for protecting and maintaining an individual use. Many water quality criteria set a maximum level for the concentration of a substance in a particular medium (i.e. water, sediment or biota) which will not be harmful when the specific medium is used continuously for a single, specific purpose. For some other water quality variables, such as dissolved oxygen, water quality criteria are set at the minimum acceptable concentration to ensure the maintenance of biological functions.

Water quality criteria for individual use categories

Water quality criteria have been widely established for a number of traditional water quality variables such as pH, dissolved oxygen, biochemical oxygen demand for periods of five or seven days (BOD_5 and BOD_7), chemical oxygen demand (COD) and nutrients.

In setting criteria for water quality water-management authorities in consultation with industries, municipalities, farmers' associations, the general public and others agree on the designated water uses in a catchment area that are to be protected. Such uses include categories such as drinking-water supply, irrigation, livestock watering, fisheries, leisure activities, amenities, maintenance of aquatic life and the protection of the integrity of aquatic ecosystems etc. Each of these uses have different requirements that will therefore inform the water quality goal or target (objectives).

Water Quality Objectives

The establishment of water quality objectives is not a scientific task but rather a political process that requires a critical assessment of national priorities. Such an assessment is based on economic considerations, present and future water uses, forecasts for industrial progress and for the development of agriculture, and many other socio-economic factors (UNESCO/WHO, 1978; UNECE, 1993, 1995). General guidance for developing water quality objectives is given in the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (UNECE, 1992).

Water quality objectives provide the basis for pollution control regulations and for carrying out specific measures for the prevention, control or reduction of water pollution and other adverse impacts on aquatic ecosystems. In some countries, water quality objectives play the role of a regulatory instrument or even become legally binding. Their application may require, for example, the appropriate strengthening of emission standards and other measures for tightening control over point and diffuse pollution sources. In some cases, water quality objectives serve as planning instruments and/or as the basis for the establishment of priorities in reducing pollution levels by substances and/or by sources.

The establishment of a time schedule for attaining water quality objectives is mainly influenced by the existing water quality, the urgency of control measures and the prevailing economic and social conditions. It is of the utmost importance that the objectives are understandable to all parties involved in pollution control and are convertible into operational and cost-effective measures which can be addressed through targets to reduce pollution. It should also be possible to monitor, with existing networks and equipment, compliance with such objectives. Objectives that are either vague or too sophisticated should be avoided. The objectives should also have realistic time schedules.

4.0 CONCLUSION

Water quality objectives should be revised regularly in order to adjust them, among other things, to the potential of pollution reduction offered by new technologies, to new scientific knowledge on water quality criteria, and to changes in water use.

5.0 SUMMARY

So far we have looked at some common definitions in water quality management, and the concept, principles and objectives of water quality.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the concept of water quality.
2. List and discuss five principles of water quality management.
3. Distinguish between water quality criteria and objectives.

7.0 REFERENCES/FURTHER READING

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UNIT 2 WATER QUALITY STANDARDS

CONTENTS

1.0 INTRODUCTION

Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. Water quality standards are numeric values or narrative descriptions of water quality parameters that are meant to sustain the designated uses of a water body. It is most frequently used by reference to a set of standards against which compliance, generally achieved through treatment of the water, can be assessed. Water quality standards consist of two different elements namely designated use and water quality criteria. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact, and drinking water. The parameters for water quality are determined by the intended use.

Water quality standards are part of regulations. There are several sets of water quality standards, or guidelines for water quality standards issued by various agencies and authorities (e.g. United States Environmental Protection Agency (EPA), World Health Organization (WHO), and European Union (EU). Federal Environmental Protection Agency in 1988 (now under Federal Ministry of Environment) intended to define the maximum acceptable limit of water pollution by various pollutants. Standards for ambient water quality (quality objectives) are designated depending on the intended use of the water resource (e.g. drinking water, fishing water, spawning grounds).

To establish water quality standards, it is important to identify and describe how surface waters are used and what water quality parameters should be managed.

2.0 OBJECTIVES

By the end of this unit, the student will understand the concept of water quality standards.

3.0 MAIN CONTENT

3.1 Categories of Water Uses

The parameters for water quality are determined by the intended use. The "designated uses" of a water body are grouped into four categories:

1. Agricultural and industrial water supply
2. Recreation water
3. Public water supply
4. Aquatic life

3.2 Standards for Drinking Water Quality

Drinking water quality standards describes the quality parameters set for drinking water. In 2011, the World Health Organization (WHO) published guidelines for drinking-water quality (GDWQ) which include recommended limits on naturally occurring constituents that may have direct adverse health impact (WHO, 2011).The International Organization for Standardization (ISO) published regulation of water quality in the section of ICS 13.060, ranging from water sampling, drinking water, industrial class water, sewage, and examination of water for chemical, physical or biological properties. ICS 91.140.60 covers the standards of water supply systems.

Although drinking water standards frequently are referred to as if they are simple lists of parametric values, standards documents also specify the sampling location, sampling methods, sampling frequency, analytical methods, and laboratory accreditation Analytical Quality Control (AQC).

Water quality standards usually contain parametric values which may be the concentration of a substance that may cause adverse effects on health, e.g.30 mg/l of Iron. It may also be a count such as 500 *E. coli* per litre or a statistical value such as the average concentration of copper is 2 mg/L. Parametric values may also include a range of constituents that by themselves are unlikely to have any impact on health. These include colour, turbidity, pH, and the organoleptic (aesthetic) parameters (taste and odour).

3.3 Nigerian Water Quality Standard

The National Water Quality Guidelines and Standards for Nigeria address drinking water, recreational use of water, freshwater aquatic life, agricultural (irrigation and livestock watering) and industrial water uses.

Nigerian Standard for Drinking Water Quality (NSDQW)
The Nigerian Standard for Drinking Water Quality covers all drinking water except mineral water and packaged water. Mineral water and packaged water are covered under the Nigerian Industrial Standards for Natural Mineral Water (NIS 345:2003) and Potable Water (NIS 306:2004). These standards are used for regulation and certification by the National Agency for Food and Drug administration and Control (NAFDAC) and Standard Organization of Nigeria (SON) respectively.
Nigerian Standard for Drinking Water Quality contains mandatory limits concerning constituents and contaminants of water that are known to be hazardous to health and/or give rise to complaints

from consumers. The standard includes a set of procedures and good practices required to meet the mandatory limits.

3.4 Roles of National Council on Water Resources (NCWR) in NSDQW

In 2005, the National Council on Water Resources (NCWR) recognized the need to urgently establish acceptable Nigerian Standard for Drinking Water Quality because it was observed that the "Nigerian Industrial Standard for Potable Water" developed by Standards Organization of Nigeria and the "National Guidelines and Standards for Water Quality in Nigeria" developed by Federal Ministry of Environment did not receive a wide acceptance by all stakeholders in the country.

Since water quality issues are health related issues, the Federal Ministry of Health, collaborating with the Standards Organization of Nigeria and working through a technical committee of key stakeholders developed the Nigerian Standard for Drinking Water Quality. The standard was to be reviewed every three years and/or as when necessary.

4.0 CONCLUSION

Drinking Water Quality Standard is important in water quality management and protection of public health. Standard for Drinking Water quality stipulates allowable limits of substances which may be present in the water that may adversely affect public health.

5.0 SUMMARY

Water quality standards are based on designated use of water. In this unit, we have discussed the standards for drinking water quality.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain Standards for Drinking Water Quality.
2. Discuss the roles of the agencies involved in setting Standards for Drinking Water Quality in Nigeria.

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UNIT 3 INTERNATIONAL CONVENTIONS AND TREATIES

CONTENTS

1.0 INTRODUCTION

The United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (UN Watercourses Convention) holds an important position in the development of International Water Law (IWL) and has influenced many river basins of the world. The Convention became effective on 17th August 2014, seventeen years after its adoption by the UN General Assembly in 1997.

2.0 OBJECTIVES

By the end of this unit, the student will understand International Conventions and Treaties

3.0 MAIN CONTENT

3.1 The UN Watercourses Convention (UNWC)

The UNWC was proposed as a response to the acknowledgment that a global legal instrument was needed to bolster cooperation between states over their shared water resources and mitigate the potential for conflict. The UNWC was also meant to serve as a global treaty whose role was to *support* other watercourse treaties by acting as a template and filling the gaps where coverage was lacking (McCaffrey, 1998).

Along with the UNECE Helsinki Convention, the UNWC is the only global treaty governing transboundary watercourses. It provides rules that can be tailored to the distinct circumstances of each international watercourse and gives liberty to watercourse states to take the actions that suit their needs and interests as required by the singularity of the situation (McCaffrey. 1998).

The UNWC, which is now widely recognized as the most authoritative source of international water law, is a pivotal document of IWL in a number of ways: it creates a strong framework for water governance arrangements and a basic common ground that enhances predictability and encourages reciprocity (Rieu-Clarke *et al.,* 2013). It codifies and clarifies existing norms and develops emerging principles of customary IWL; it constitutes a model that can guide the interpretation of other treaties and the negotiation and drafting of future ones (Rocha Loures et al., 2013); and, it has informed the judgments of international and regional courts (McCaffrey. 1998).

3.2 The UNECE Water Convention

The UNECE Water Convention aims to ensure the sustainable use of transboundary water resources by facilitating cooperation on transboundary surface and ground waters and strengthens their protection and sustainable management. Initially negotiated as a regional instrument, it has been amended to become universally available.

The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) was adopted in Helsinki in 1992 and entered into force in 1996. Almost all countries sharing transboundary waters in the region of the United Nations Economic Commission for Europe (UNECE) are Parties to the Convention. The Convention obliges Riparian Parties to prevent, control and reduce transboundary impact, use transboundary waters in a reasonable and equitable way and ensure their sustainable management.

4.0 CONCLUSION

The UN Watercourses and the UNECE Conventions hold important positions in the development of International Water Law (IWL) and water laws in many countries and regions of the world.

5.0 SUMMARY

In this unit, we discussed the UN Watercourses Convention and the UNECE convention and how they influenced the International Water Law and water policies in countries that are parties to the convention.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is the focus of the UN Watercourses Convention and the UNECE Convention?
2. How can the water convention be adopted Nigeria to improve water quality?

7.0 REFERENCES/FURTHER READING

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MODULE 2 WATER QUALITY MONITORING AND SURVELLANCE

UNIT 1 PROCEDURES FOR WATER QUALITY MONITORING AND SURVEILLANCE

CONTENTS

1.0 INTRODUCTION

Water quality monitoring is of little use without a clear and unambiguous definition of the reasons for the monitoring and the objectives that it will satisfy. Almost all monitoring (except perhaps remote sensing) is in some part invasive of the environment under study and extensive and poorly planned monitoring carries a risk of damage to the environment. Parameters monitored in water quality include: chemical, biological, radiological, and microbiological.

2.0 OBJECTIVES

By the end of this unit, the student should be able to explain the procedures for water quality monitoring and surveillance.

3.0 MAIN CONTENT

3.1 Water Quality Monitoring

In some nations, most of the portable water used for both domestic and industrial purposes are channeled from rivers and groundwater. The present water quality monitoring status in Nigeria involves monitoring only groundwater once every year by each states' water board using FEPA standards.

The United States Environmental Protection Agency (EPA) sets standards that, when combined with protecting ground water and surface water, are critical to ensuring safe drinking water. The EPA also regulates about 90 contaminants and so does FEPA (Federal Environmental Protection Agency) but the EPA works with its regional offices, states, tribes and its many partners to protect public health through implementing the Safe Drinking Water Act.

Routine Monitoring

Inspectors in charge of Drinking Water Quality Surveillance conduct regular verification, water quality tests and sanitary inspections to determine whether water utilities, community water committees, food processing industries, private or public establishment and private water system owners meet standard for drinking water quality. The frequencies of monitoring are as follows:

a) On-site drinking water systems are checked at least once every 3 years
Drinking Water Quality Surveillance agency increases the frequency of sampling for drinking water facilities in the following areas:
- areas located in high risk for faecal contamination or chemical contamination
- highly populated areas,
- areas prone to floods

b) Centralized drinking water system: For a population of < 5000, one sample is collected per 2000 population per month; for population of 5000 – 100000, one sample is collected per 5000 population per month; for population of > 100000, one sample is collected per 10000 population per month.
Inspectors for Drinking Water Quality conducts sanitary inspection each time a water sample is collected in accordance with the procedures developed by the Federal Ministry of Health.

3.2 Sampling and Analytical Methods

Sampling and testing are conducted according to the following minimum requirements:

1. Point of compliance

Locations where samples are collected must be representative of the water source, treatment plant, storage facilities, and distribution network, points at which water is delivered to consumers.

1. For centralized drinking water system, samples are taken in the distribution system
2. In case of water supplied from an on-site water system, samples are taken at the hand pump outlet or from the bucket used to fetch water; and in household water storage
3. In case of water supplied from a tanker, samples are taken at the point at which it emerges from the tankers,
4. In the case of water used in a food-production undertaking, samples are taken at the point where the water is used in the undertaking

2. Sampling Method

All precautions must be taken to prevent contamination of the sample and to ensure the concentration of the substance being determined do not change between sampling and analysis. This is ensured by using trained personnel (inspectors for drinking water quality surveillance) in the process of sample collection. Sampling methods must comply with ISO or WHO guideline.

3. Analytical Method

Analytical methods must comply with ISO or WHO guideline. Field test kits may be used by the surveillance agency to conduct routine tests.

4. Laboratory Quality Assurance

Laboratories contracted by the Drinking Water Quality Surveillance agency to conduct water testing must comply with NIS ISO 17025: 2005

4.0 CONCLUSION

Water quality monitoring and surveillance is used by regulatory bodies to ensure that water supplied meet their designated uses. Monitoring and surveillance involves collection and analyses of water samples.

5.0 SUMMARY

In this unit, we discussed the procedure for water quality monitoring and surveillance including some parameters measured to ascertain water quality.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is water quality monitoring?
2. What are the minimum requirements for sampling and testing of water

7.0 REFERENCES / FURTHER READING

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UNIT 2 PROTECTION OF WATER SOURCES

CONTENTS

1.0 INTRODUCTION

Contamination of water sources may arise from microbiological pathogens from human and animal excreta or accidental or deliberate pollution by industries or the agricultural community. Sources of water that are practicable for public and domestic purposes e.g. rain water, surface water such as lakes, rivers and ponds**,** groundwater from springs, wells and boreholes should be protected from possible contamination.

2.0 OBJECTIVES

By the end of this unit, the student should be able to know how to identify water sources and protect them.

3.0 MAIN CONTENT

3.1 Protection and Development of Water Resources

Several issues need to be taken into consideration when planning the protection and development of water sources:

i. **Assessing needs**
Water source protection should be based on needs identified by the community themselves. The community should identify its own water and sanitation needs through a process of internal discussion and external negotiation. The internal discussion would involve health experts, community leaders and other members of the community. The external negotiations may involve local government offices, NGOs and other partners who can assist with the assessment of the communities' needs with information and technical guidance.

ii. **Water source identification**
All potential water sources should be considered and checked. Issues to consider are the sources of possible contaminants, the amount of water available to users annually and the consistency of the supply. Other important issues are social acceptance, cost effectiveness

and community health. All potential water sources need to be assessed in order to identify the best solution.

iii. Water quantity

Whenever a new protected water source is proposed it should have the capability of supplying at least 20 litres of water per person per day to the target population. The protected water source should provide sufficient quantities of water to meet essential health-related household and personal needs, including drinking, cooking, personal hygiene, clothes washing and cleaning for all community members.

iv. Sanitary surveys

A sanitary survey is an evaluation of the physical environment to identify possible health hazards and sources of environmental contamination. The sanitary survey should include the nature of the water-bearing layer, the hydraulic gradient (i.e. the variations in underground water pressure that affect the natural flow of water), topography, vegetation, potential sources of contamination, and the adequacy of the yield particularly for dry seasons.

Health and hygiene education

Before developing any water protection, the health benefits of an improved water supply and sanitation need to be accepted by the local community. Providing hygiene education for the people promotes their behavioural change.

Water quality

Water quality is a description of the chemical, physical and biological characteristics of water, usually with respect to its suitability for drinking. Water source development projects should draw water from the best available sources.

3.2 Protection Zones

For on-site drinking water system, a minimum distance of 15 meters is to be kept between the water system and potential source of contamination. Communities must keep clean the protected area surrounding on-site drinking water systems.

Construction Requirements and Best Practices

All drinking water systems must comply with construction specifications as stipulated by Federal Ministry of Water Resources. All materials and equipment in contact with drinking water must comply with relevant Nigerian Industrial Standard (NIS) (such as casing, drilling additive, hand pumps, fitting, distribution pipe, and reservoir paint). Water containers must be stored away from poisonous materials and contamination sources.

Protection of well water

The different types of wells include: dug wells, bored wells (also known as boreholes), and driven and jetted wells. During heavy rain, dug wells are susceptible to contamination by pathogens which may be deposited on the surface or naturally present in the soil and are washed in to the well, particularly if it is improperly constructed.

Contamination of wells can arise from:

- Lack of, or improper, disinfection of a well following repair or construction.
- Failure to seal the space between the drill hole and the outside of the casing.
- Failure to provide a tight sanitary seal at the place where the pump line(s) passes through the casing.
- Wastewater pollution caused by contaminated water percolating through surrounding soil and rocks into the well.

At the time when a new well is constructed or repairs are made to a well, pump or piping, contamination from the work is possible. Therefore, it is important that the well, pump, piping and associated structures should be regularly disinfected using chlorine solution.

Wells can be protected by installing a pump over them, but if a pump is not available then a sanitary bucket and rope system may be used. The surrounding ground of a well should be covered and protected and the immediate area fenced to keep animals away. Grading off the area surrounding a well can be done to create a slope away from the well, in order to prevent the flow of storm water into the well. Any pipework associated with pumps that enters the well needs to have watertight connections so there can be no contamination from surrounding soil.

Wells should be located on a higher level than possible sources of contaminants such as latrines and cesspits (a pit for collection of waste matter and water especially sewage). This is because the liquid from the pit may seep into the surrounding ground and into the groundwater. If the latrine is higher up a slope than the well then the contaminated groundwater is likely to flow downwards and into the well. The natural flow of the groundwater (the hydraulic gradient) should be away from the well and towards the sources of contaminants, and not the other way round. In normal soils, the minimum distance between the well and the source of contaminants should never be less than 15 metres and a distance of 30–50 m is recommended. However for limestone and some other soil formations this distance need to be greater because groundwater can pass very easily through some rocks and soils.

The inside wall of the well should be made waterproof by constructing a well casing. In small diameter bored wells the casing can be a pipe, but in larger wells the casing needs to be constructed by cementing from the top of the well down to a minimum depth of 3 metres. The casing of the well should also be extended for a minimum of 60 cm above the surrounding ground level to prevent the entrance of surface runoff. A concrete cover should be fitted over the casing to prevent dust, insects, small animals and any other contaminants from falling in (Figure 1).

Figure 1: Two wells with concrete protection. Note the removable covers. (Photos: Pam Furniss, 2014)

Spring source protection

Before using a spring a thorough sanitary survey needs to be carried out at the site to assess the quantity and quality of water, and the possible contamination. If the results of the sanitary survey are satisfactory, the eye of the spring (the point where the water emerges from the ground) should be located by digging out the area around the spring down to the impermeable layer.

Different types of spring protection can be constructed but in general they are as follows:

- A concrete waterproof protection box, also known as a spring box, should be constructed over the spring to prevent all actual and potential sources of contamination.
- A retention wall in the front part of the protection box should be constructed to keep water flowing to the delivery pipe(Figure 2)
- In some situations, if the flow is not constant, a collection box may also be constructed in order to ensure adequate water storage.

- The intake and overflow pipes should be screened to prevent the entrance of small animals. The spring and collection box, if there is one, should have a watertight top, preferably concrete. Water will move by gravity flow or by means of a properly-installed mechanical pump. An inspection hole should be tightly covered and kept locked.

Springs should be protected from flooding and surface water pollution by constructing a deep diversion ditch above and around the spring. The ditch should be constructed so it collects surface water running towards the spring and carries, or diverts, it away. It needs to be deep enough to carry all surface water away, even in a heavy rainstorm. The surrounding area should be fenced to protect it from animals.

Figure 2: A protected spring (Photo: WaterAid, Ethiopia)

Rainwater source protection

Rainwater used for water supply may be contaminated by the air, dust, dirt, paint and other material on the roof the water is collected from or improper methods of storage.

To protect rainwater, precaution must be taken to use a storage tank that is completely covered and well maintained. The roof and gutters should be cleaned regularly, especially before the start of the wet season. It may be necessary to divert the first rainwater away from the tank so the dust and dirt is washed away. Leaves and other larger debris can be prevented from entering the tank by placing a mesh screen between the guttering and the pipe that leads to the tank; the mesh screen will need to be cleaned regularly.

3.3 Surface water sources

All surface water sources are subject to continuous or intermittent pollution and must be treated to make them safe to drink. The extent of the treatment required will depend on the results of a sanitary survey made by an experienced professional, including physical, chemical and microbiological analyses. Surface waters are, by definition, unprotected sources.

4.0 CONCLUSION

Water sources must be protected from contaminants to forestall pollution and water borne diseases. Designated use of a water source will inform the methods required for its protection.

5.0 SUMMARY

In this study unit, we discussed the different sources of water and how to protect them.

6.0 TUTOR-MARKED ASSIGNMENT

1. Highlight the issues that must be considered in planning and protection and development of a water source
2. What are protection zones?
3. List the different sources of water and briefly discuss how they can be protected.

7.0 REFERENCES / FURTHER READING

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UNIT 3 EFFLUENT AND PARTIALLY TREATED WATER DISCHARGE

CONTENTS

1.0 INTRODUCTION

Wastewater is produced by human activities and has a direct impact on the environment into which it is discharged. Production of more and more wastewater by anthropogenic activities is a genuine issue for public health and for the environment. Wastewater management is a genuine sanitary and environmental challenge for all the players involved in environmental management all over the world. It is important to treat wastewater and encourage its reuse in order to protect public health and water resources.

2.0 OBJECTIVES

By the end of this unit, the student should be able to discuss the different ways of wastewater management and partially treated effluent.

3.0 MAIN CONTENT

3.1 Waste water Treatment Processes

Wastewater treatment usually consists of two major steps – primary treatment and secondary treatment along with a process to dispose of solids (sludge) removed during the two steps. In some areas where receiving waters are more sensitive to pollution or where specific pollutants have not been removed by secondary treatment, a third step called advanced waste treatment (also called tertiary treatment) may be required. Some plants use pre-chlorination for hydrogen sulfide and odor control prior to beginning any treatment processes.

Preliminary treatment

Preliminary treatment is required to remove the coarse solids and other large materials from raw wastewater. The operations include use of screens and grates for removal of large materials, comminutors for grinding of coarse solids, pre-aeration for odour control. Sometimes pH correction and removal of oil & grease is also done.

3.2 Primary Treatment

Primary wastewater treatment, at times, is the first step in the wastewater treatment process or it may be the second step after the preliminary treatment. It involves physical separation of suspended solids (total suspended solids) from the wastewater using primary clarifiers. The objective of primary treatment is to remove of settle-able organic and inorganic solids by sedimentation and removal of materials that float (scum) by skimming. Some organic nitrogen, organic phosphorus, and heavy metals associated with solids are removed during primary sedimentation but colloidal and dissolved constituents are not affected. The effluent from primary sedimentation units is referred to as primary effluent.

Sedimentation chambers are the main units involved in primary treatment but various auxiliary processes such as fine screening, flocculation and floatation may also be used. The second step may be chemical treatment (generally with lime and alum) which is sometimes preceded by flocculation. The purpose is to remove metals by precipitation but it also removes some associated colloidal BOD. The process generates chemical sludge.

Primary treatment involves various physical-chemical processes:

- Flocculation - a physico-chemical process for the aggregation of coagulated colloidal and finely divided suspended matter by physical mixing or chemical coagulant aids. The process involves mixing of wastewater stream with coagulants in a rapid mix tank, which is then passed on to the flocculation basin.
- Sedimentation - this process is aimed to remove easy to settle solids. Sedimentation chambers may also include baffles and oil skimmers to remove grease and floatable solids and may include mechanical scrapers for removal of sludge at the bottom of the chamber.
- Dissolved Air Floatation - air-bubbles are introduced into the waste water, they attach themselves to the particles, thus causing them to float. This process of diffused air flotation can be used to remove suspended solids and dispersed oil and grease from oily wastewater.
- Clarification- in a clarifier, wastewater is allowed to flow slowly and uniformly, permitting the solids to settle down. The clarified water flows from the top of the clarifier over the weir. Solids get collected at the bottom and sludge are periodically removed, dewatered and safely disposed.

Chemical treatment processes

Chemical treatment may be used at any stage in the treatment process as and when required (preferably before biological treatment as it removes toxic chemicals which may kill the microbes). Mainly used methods are:

- Neutralization- incoming untreated wastewater has a wide range of pH. Neutralization is the process used for adjusting pH to optimize treatment efficiency. Acids such as sulphuric or hydrochloric may be added to reduce pH or alkalis such as dehydrated lime or sodium hydroxide may be added to raise pH values.
- Precipitation - precipitation is carried out in two steps: in the first step, precipitants are mixed with wastewater allowing the formation of insoluble metal precipitants; in the second step, precipitated metals are removed from wastewater through clarification and/or filtration and the resulting sludge are properly treated, recycled or disposed.

3.3 Secondary Treatment

This process involves decomposition of suspended and dissolved organic matter in waste water using microbes. The mainly used biological treatment processes are activated sludge process or the biological filtration methods. Biological treatment can be aerobic, anaerobic or facultative.

Activated sludge process –a continuous flow, aerobic biological treatment process that involves suspended growth of aerobic micro-organisms to biodegrade organic contaminants. Influent is introduced in the aeration basin and allowed to mix with the contents. A suspension of aerobic microbes is maintained in the aeration tank. A series of biochemical reactions in the basin degrade the organics and generate new bio mass. Microorganisms oxidize the matter into carbon dioxide and water using the supplied oxygen.

These organisms agglomerate colloidal and particulate solids. The mixture is passed to a settling tank or a clarifier where micro-organisms are separated from the treated water. The settled solids are recycled back to the aeration tank to maintain a desired concentration of micro-organisms in the reactor and some of the excess solids are sent to sludge handling facilities.

Biological filters - These filters are biological reactors filled with media which provide a surface that is repeatedly exposed to wastewater and air and on which a microbial layer can grow. The two most common types of biological filters are;

a) Trickling Filters: in trickling filters treatment is provide by a fixed film of microbes that forms on the surface which adsorbs organic particles and degrades them aerobically. Wastewater is distributed over a bed made of rock or plastic and flows over the media by gravity.
b) Rotating Biological Contractor (RBC): the setup consists of a series of discs; about 40% of the area is immersed in wastewater. The RBC provides a surface for microbial slime layer. The alternating immersion and aeration of a given portion of the disc enhances growth of the attached micro-organisms and facilitates oxidation of organic matter in a relatively short time and provides a high degree of treatment.

3.4 Tertiary treatment

Tertiary treatment is the final cleaning process that improves wastewater quality before it is reused, recycled or discharged to the environment. Tertiary treatment can involve physical-chemical separation techniques such as activated carbon adsorption, flocculation/precipitation, membranes filtration, ion exchange, de-chlorination and reverse osmosis. Advanced treatment processes which generally constitute of or are part of the tertiary treatment may also sometimes be used in primary or secondary treatment or used in place of secondary treatment.

Some of the common tertiary treatment processes are described below:

- Granular Media Filtration- Many processes fall under this category and the common element being the use of mineral particles as the filtration medium. It removes suspended solids mainly by physical filtration. Two common types of these granular media filers are:

a) Sand filters: the most common type which consists of either a fixed or moving bed of media that traps and removes suspended solids from water passing through media.

b) Dual or multimedia filtration: consists of two or more media and it operates with the finer, denser media at the bottom and coarser, less dense media at the top. Common arrangement is granite base at the bottom, sand in the middle and anthracite coal at the top. Flow pattern of multimedia filters is usually from top to bottom with gravity flow. These filters require periodic back washing to maintain their efficiency.

These processes are most commonly used for supplemental removal of residual suspended solids from the effluents of chemical treatment processes.

- Membrane Filtration: In membrane filtration, a solvent is passed through a semipermeable membrane. The membrane's permeability is determined by the size of the pores in the membrane. Microfiltration, ultrafiltration and Nano-filtration are examples of membrane filtration techniques.
- Reverse Osmosis Systems– This is also a membrane separation method that is used to remove several types of large molecules and ions from solutions through application of pressure to the wastewater on one side of a selective membrane. The result is that the contaminant is retained on the pressurized side of the membrane and the treated waste water is allowed to pass to the other side.
- Ion Exchange –Ion Exchange can be used in wastewater treatment plants to swap one ion for another for the purpose of demineralization. There are basically two types of ion exchange systems, the anion exchange resins and the cation exchange resins. It can be used for softening, purification, decontamination, recycling, removal of heavy metals from electroplating wastewaters and other industrial processes, polish wastewater before discharging, removal of ammonium ion from wastewaters, salt removal, purify acids and bases for reuse, removal of radioactive contaminants in the nuclear industry, etc.
- Activated carbon, Powdered as well as granular activated carbons are used for the purpose of de-chlorination of organic compounds. Organic compounds in waste water are adsorbed on to the surface of the activated carbon. A number of factors affect the effectiveness of the activated carbon. These include pore size, composition and concentration of the contaminant, temperature and pH of the water and the flow rate or contact time of exposure. Activated carbon can be applied on a broad spectrum of organic pollutants and is typically used to remove contaminants from water such as pesticides, aromatic compounds such as phenol, absorbable organic halogens, non-biodegradable organic compounds, colour compounds and dyes, chlorinated/halogenated organic compounds, toxic compounds, compounds that normally inhibits biological treatments, oil removal in process condensates, halogens, especially chlorine that oxidizes downstream processes and organics that have the potential to foul ion exchange resins or reverse osmosis membranes.
- Ultraviolet (UV) Disinfection – This technique is primarily employed as a disinfection process that inactivates waterborne pathogens without use of chemicals. Additionally, UV is also effective for residual TOC removal, destruction of chloramines and ozone.

3.5 Treatment of Sludge

The solid material that is removed from wastewater, called sludge, requires proper treatment and disposal and can often be reused. The ultimate disposal of this material is one of the most difficult and expensive problems of wastewater treatment.

The goal of sludge treatment is to destroy harmful organisms and remove water. The end product of the sludge handling process is a relatively dry material known as “cake.” It can be applied to agricultural land as a soil conditioner, placed in landfills, or cleanly burned. At some plants, sludge serves as a fuel to produce energy. For land application, sludge is often kept in a liquid slurry form for ease of handling and for subsurface injection into soils with special equipment.

4.0 CONCLUSION

Waste water is generated by both industrial and domestic processes. Waste water treatment technologies allow the reuse of wastewater thereby protecting the public health and water resources.

5.0 SUMMARY

In this unit, we discussed the different methods of wastewater management.

6.0 TUTOR-MARKED ASSIGNMENT

1. Briefly discuss the physico-chemical processes involved in the primary treatment of wastewater.
2. Explain secondary wastewater treatment process.
3. Discuss three processes involved in tertiary treatment of wastewater?

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MODULE 3 AN OVERVIEW OF AIR QUALITY

UNIT 1 DEFINITION OF TERMS

CONTENTS

1.0 INTRODUCTION

Air pollution is perceived as a serious problem. The emission of certain pollutants into our atmosphere has gradually increased over the years. The quality of our ambient air impacts on both humans and animals health and the environment. Air quality management aims to limit negative impacts through a variety of activities, including legislation, policies, and plans to manage emissions and monitor ambient air quality. This unit contains an overview of the definitions that may be encountered in studying the concept of air quality, air pollution and measurement of air quality.

2.0 OBJECTIVES

By the end of this unit, the student should be able to explain the concept of air quality.

3.0 MAIN CONTENT

3.1 Definition of Terms

Air pollutants: Solids, liquids, or gases which, if discharged into the air, may result in statutory air pollution.

Aerosols: Liquid or solid particles that are suspended in air or a gas. It is also referred to as particulate matter.

Ambient air: Generally, the atmosphere; outdoors.

AQI: Air Quality Index.

Attainment: EPA designation that an area meets the National Ambient Air Quality Standards.

Criteria pollutant: An air pollutant for which certain levels of exposure have been determined to injure health, harm the environment and cause property damage. The EPA-developed the standards known as the National Ambient Air Quality Standards, using science-based guidelines as the basis for setting acceptable levels.

Emissions: Air pollutants exhausted from a unit or source into the atmosphere.

EPA or U.S. EPA: Environmental Protection Agency, federal agency that oversees the protection of the environment.

Exceedance: An incident occurring when the concentration of a pollutant in the ambient air is higher than the National Ambient Air Quality Standards.

HAPS: Hazardous Air Pollutants.

Montreal Protocol on Substances That Deplete the Ozone Layer: A 1987 international agreement subsequently amended in 1990, 1992, 1995, and 1997 that establishes in participating countries a schedule for the phase out of chloroflourocarbons and other substances with an excessive ozone depleting potential.

National Ambient Air Quality Standards: Standards established by the EPA and required by The Clean Air Act (last amended in 1990) for pollutants considered harmful to public health and the environment.

Nitrogen oxides: A group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO_2), along with particles in the air, can often be seen as a reddish-brown layer over many urban areas.

Nonattainment areas: Defined by The Clean Air Act as a locality where air pollution levels persistently exceed National Ambient Air Quality Standards or that contributes to ambient air quality in a nearby area that fails to meet standards.

Nonattainment: EPA designation that an area does not meet the National Ambient Air Quality Standards.

NO_X: Nitrogen oxides.

Ozone: A triatomic molecule consisting of three oxygen atoms. Ground-level ozone is an air pollutant with harmful effects on the respiratory systems of animals. On the other hand, ozone in the upper atmosphere protects living organisms by preventing damaging ultraviolet light from reaching the Earth's surface.

Particulate matter (PM): The sum of all solid and liquid particles suspended in air, many of which are hazardous.

Photolysis: A chemical process by which molecules are broken down into smaller units through the absorption of light.

PM_{10}: Particulate Matter less than 10 micrometers (or microns) in diameter.

$PM_{2.5}$: Particulate Matter less than 2.5 micrometers (or microns) in diameter.

Ppb: Parts per billion by volume.

Ppm: Parts per million by volume.

Primary air pollutants: Pollutants that are pumped into our atmosphere and directly pollute the air. Examples include carbon monoxide from car exhausts and sulfur dioxide from the combustion of coal as well as nitrogen oxides, hydrocarbons, and particulate matter (both solid and liquid).

Radical: Atomic or molecular species with unpaired electrons on an otherwise open shell configuration. These unpaired electrons are usually highly reactive, so radicals are likely to take part in chemical reactions.

Secondary air pollutants: Pollutant not directly emitted but forms when other pollutants (primary pollutants) react in the atmosphere. Examples include ozone, formed when hydrocarbons (HC) and nitrogen oxides (NOx) combine in the presence of sunlight; NO2, formed as NO combines with oxygen in the air; and acid rain, formed when sulfur dioxide or nitrogen oxides react with water.

Smog: A kind of air pollution; the word "smog" is a combination of smoke and fog. Classic smog results from large amounts of coal burning in an area and is caused by a mixture of smoke and Sulphur dioxide.

Source or stationary source: Any governmental, institutional, commercial or industrial structure, installation, plant, building or facility that emits or has the potential to emit any regulated air pollutant under the Clean Air Act.

Statutory Air Pollution: The discharge into the air by the act of man of substances (liquid, solid, gaseous, organic or inorganic) in a locality, manner and amount as to be injurious to human health or welfare, animal or plant life, or property, or which would interfere with the enjoyment of life or property.

Volatile organic compounds (VOCs): Organic chemical compounds that have high enough vapour pressures under normal conditions to significantly vaporize and enter the atmosphere.

3.2 Concept of Air Quality

Basic principles guide international and national policies for the management of all forms of air pollution. An important global initiative occurred in 1983 when the UN General Assembly established the World Commission on Environment and Development. The report produced by the Commission, Our Common Future, was endorsed by the UN General Assembly in 1987. It has been influential in bringing environmental issues into the global arena, and in expressing influential concepts in air quality management (WCED 1987).

The Brundtland Commission suggested that sustainable development would be required to meet the legitimate aspirations of the world population without destroying the environment. It defined ***sustainable development*** as: "***development that meets the needs of the present without compromising the ability of future generations to meet their own needs***. This concept has been embraced as an apparent means of integrating environmental policy and economic development. A number of environmental management principles on which some government policies are based, including air quality management include:

- The **precautionary principle** – where it is clear that a proposal will damage the environment, action should be taken to protect the environment without awaiting scientific proof of damage.
- The **polluter pays principle** – the full costs associated with pollution (including monitoring, management, clean-up and supervision) should be met by the organization or person responsible for the source of the pollution. h
- In addition, many countries have adopted the principle of **pollution prevention**; which aims to reduce air pollution at sources.

3.3 Strategy for Air Quality Management

Air quality management encompasses all the activities a regulatory authority undertakes to help protect human health and the environment from all the harmful effects of air pollution. The goal of air quality management is to maintain a quality of air that protects human health and welfare. This goal also includes protection of animals, plants (crops, forests and natural vegetation), ecosystems, materials and aesthetics, such as natural levels of visibility (Murray 1997). And to achieve this air quality goal, it is necessary to develop appropriate air quality policies and strategies.

A government institution typically establishes goals related to air quality. An example is an acceptable level of pollutant in the air that will protect public health, including people who are more vulnerable to air pollution. Government policy is the foundation for air quality management. Without a suitable policy framework and adequate legislation it is difficult to maintain an active or successful air quality management program.

3.4 Policy Framework in Air Quality Management

A policy framework refers to policies in several areas, including transport, energy, planning, development and the environment. Air quality objectives are more readily achieved if these interconnected government policies are compatible, and if mechanisms exist for coordinating responses to issues which cross different areas of government policy. Measures adopted in many developed countries for integrating air quality policy with health, energy, transport and other areas are summarized in a report of the United Nations Economic Commission for Europe (UNECE 1999).

3.5 Goals of air quality management

The complete scheme of relevant interrelationships in air quality management is depicted in Figure 1 below. Air quality management has the ultimate goal of avoiding health and environmental impacts of air pollution. If man-made air pollution had no effects whatsoever, people would not care. Thus all the instruments developed for air quality management such as emissions inventories, dispersion modelling, or concentrations inventories, only serve to enable decision makers to develop legislation and regulations needed to avoid detrimental effects on public health and the environment. The instruments mentioned are, therefore, tactical tools in air quality management, while health and environmental preservation are to be grounded in goals and objectives of air quality management. Emissions inventories, concentration measurements, dispersion models and other tools of air quality management are, therefore, never end in themselves; the ends are human health and a healthy environment.

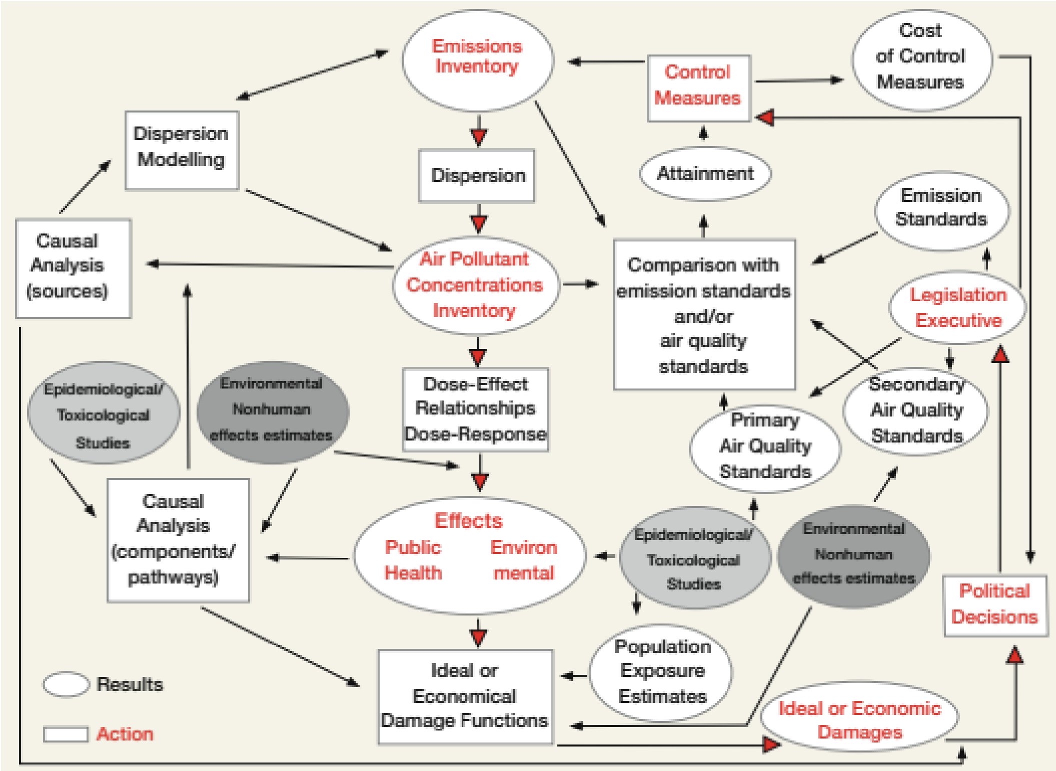

Figure 1. Scope of air quality management

Data of known quality obtained from the tactical tools of monitoring and assessment in air quality management are used to generate information for decision makers and the public, which leads to political decisions and the formulation of policies appropriate to prevent adverse impacts of air pollution on human health and the environment. Also under this aspect of policy formation, health and environment have the prominent role of defining the objectives of policies and regulations. (It should be noted that the information necessary for politicians is created from "data of known quality" and not necessarily from data of high quality, which although most desirable cannot always be obtained under the conditions of many developing countries).

4.0 CONCLUSION

The overall aim of air quality management is to maintain a quality of air that supports public health. This is achieved by developing legislation and regulations from data of known quality that will forestall air pollution that can cause detrimental effects on public health and the environment.

5.0 SUMMARY

In this Unit, we have discussed the definitions, concept of air quality and the goals of air quality management.

6.0 TUTOR-MARKED ASSIGNMENT

1. Highlight the principles of air quality management.
2. What is a policy framework?

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UNIT 2 AIR POLLUTION

CONTENTS

1.0 INTRODUCTION

Air is a mixture of gases that covers the earth atmosphere. Gases that make up air are nitrogen, oxygen, argon, carbon (IV) oxide, neon, helium, methane, krypton, oxides of nitrogen and Sulphur, ammonia etc. (Vanloon, 2004). Air is essential to living on earth, for example, man and animals uses oxygen for breathing while they release carbon dioxide, which is used by plants for the manufacture of food through a process called photosynthesis.

2.0 OBJECTIVES

By the end of this unit, the students should be able to explain what air pollutions means.

3.0 MAIN CONTENT

3.1 Air Quality

The quality of air can be affected by air pollution. Air pollution occurs when certain gases and particles build up in the atmosphere to such levels that they can cause harm to our health, causing breathing and respiratory problems, and even resulting in premature death, as well as damaging the environment around us. These gases and particles (known as pollutants) tend to come from man-made sources, including the burning of fossil fuels such as coal, oil, petrol or diesel, but can also come from natural sources such as volcanic eruptions and forest fires. Pollutants can be in the form of solid particles, liquid droplets or gases.
The science of air pollution centers on measuring, tracking, and predicting concentrations of key chemicals in the atmosphere. Four types of processes affect air pollution levels:

- **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.

- **Chemistry.** Many types of chemical reactions in the atmosphere create chemical pollutants in the atmosphere.
- **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.
- **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.

3.2 Composition of Air

Air is a non-homogeneous mixture of different gases that surround the planet. Clean air is very important as it provides oxygen and other gases that are essential to life on earth.

There are two ways by which we can represent the composition of air:

i. Percentage of gas by volume
ii. Percentage of the gas by mass

The composition of dry air at sea level is given in Table 1

Table 1: General composition of air (Bolz & Tuve, 1973)

S/N	Gas	Volume (%)	Mass (%)	Molecular weight (kg/kmol)	Molecular weight in air
1.	Nitrogen	78.03	75.46	28.015	21.88
2.	Oxygen	20.99	23.19	32.00	6.704
3.	Carbon dioxide	0.03	0.05	44.003	0.013
4.	Hydrogen	0.01	0.0007	2.016	0
5.	Monatomic gases (Ar, Rn, He,Kr, Ne)	0.94	1.30	39.943	0.373
Total		100.00	100.0		

It is important to note that, the composition of different gases (in dry air) by mass is a fixed one whereas the percentage composition of the gases by volume or mass in wet air i.e., air containing moisture is dependent on humidity or the moisture in the air. This is because of the fact that with change in the humidity, the volume and the density of air changes, which results in the change in volume percentage.

3.3 Air Pollutants

Air pollutants are found in the form of solid particles, liquid droplets or gases, and many of them are created by human activity and natural processes. Man plays a key factor in air pollution. Some of the ways through which the ambient air is polluted by man include; industries, automobiles, and power generation. In indoor environments, tobacco smoke and combustion of fuels are the most significant sources. Also, construction material, furniture, carpeting, air conditioning, home cleaning agents and insecticides are other significant sources of chemical and biological pollutants.

Air pollutants can have serious effects which could be acute or chronic. The health effects of air pollution range from minor irritation of eyes, allergies, upper respiratory system to chronic respiratory diseases, heart disease, lung cancer, and even death. Air pollution may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment.

Health impact of air pollution depends on the pollutant type, its concentration in the air, length of exposure, other pollutants in the air, and individual susceptibility. For example, carbon monoxide combines with hemoglobin to form carboxyl-hemoglobin, which reduces the oxygen carrying capacity of the blood and can contribute to anemia and adverse pregnancy outcomes, including miscarriage, stillbirth, low birth weight, and early infant mortality. Some other problems associated with pollution of the atmospheric air include shortage of oxygen for animal respiration, poor visibility, irritation of the eyes and unpleasant odours (Vinod, 2003).

The presence of the oxides of nitrogen (N_2O, NO_2, NO), carbon (CO, CO_2,) Sulphur (SO_2, SO_3) and other gases like methane (CH_4), chlorofluorocarbons (CFCS), hydrocarbons, fumes, dust and sprays in the air makes the air to be polluted (Dara, 2006). Generally, any substance introduced into the atmosphere that has damaging effects on living things and the environment is considered as an air pollutant.

Air pollutants can be classified as:

i. Primary pollutant
ii. secondary pollutant

Primary Air Pollutants
Primary air pollutants are emitted directly into the air from identifiable sources. Primary pollutants are produced by processes such as ash from a volcanic eruption, carbon monoxide gas from motor vehicle exhausts or Sulphur dioxide released from the factories. These pollutants can have dangerous effects on health when released into the atmosphere both directly and as precursors of secondary air pollutants.

Secondary Air Pollutants
Secondary pollutants are produced when primary pollutants interacts with one another in the atmosphere, this reaction forms a harmful product. Secondary air pollutants include ground level ozone, PAN (Peroxyl acetyl nitrate), photochemical smog and aerosols. Some pollutants may be both primary and secondary: they are both emitted directly and formed from other primary pollutants.

3.4 Common Air Pollutants

The U.S. Environmental Protection Agency (EPA) has named the six most common air pollutants. These pollutants are called criteria pollutants because they are regulated by developing limits that are based on human and/or environmental criteria:

1. **Ground-level ozone (O_3)**
   Ozone is comprised of three oxygen atoms. Depending on its location in the atmosphere, ozone can be 'good' or 'bad'. Ground level ozone is a pernicious secondary air pollutant, toxic to both humans and vegetation. It is formed in surface air (and more generally in the troposphere) by oxidation of VOCs (volatile organic compounds) and carbon monoxide in the presence of NOx. The mechanism involves hundreds of chemically interactive species:
   $VOC + OH \rightarrow HO_2$ + other products =>$HO_2 + NO \rightarrow OH + NO_2$ =>$NO_2 + h\nu \rightarrow + O$ => $O + O_2 + M \rightarrow O_3 + M$

   An important aspect of this mechanism is that NO_x and OH act as catalysts - that is, they speed up the rate of ozone generation without being consumed themselves. Instead they cycle rapidly between NO and NO_2, and between OH and HO_2.

   This formation mechanism for ozone at ground level is totally different from that for ozone formation in the stratosphere. In the stratosphere ozone is produced from photolysis of oxygen:

   $O_2 + h\nu \rightarrow O + O$ => $O + O_2 + M \rightarrow O_3 + M$.
   This process does not take place in the troposphere because the strong (< 240 nm) UV photons needed to dissociate molecular oxygen are depleted by the ozone overhead.

2. **Particulate Matter (Aerosols)**

Solid and liquid particles that are suspended in the air are referred to as aerosols or particulate matter (PM). These typically measure between 0.01 and 10 µm in diameter. Most aerosols are found in the lower troposphere, where they have a residence time of a few days. Large aerosol particles (usually 1 to 10 µm) are generated when winds blow sea salt, dust, and other debris into the atmosphere. Fine aerosol particles with diameters less than 1 µm are mainly produced when precursor gases condense in the atmosphere. Major components of fine aerosols are sulfate, nitrate, organic carbon, and elemental carbon. Elemental carbon particles are emitted by combustion, which is also a major source of organic carbon particles. Light-absorbing carbon particles emitted by combustion are called black carbon or soot; they are important agents for climate change and are also suspected to be particularly hazardous for human health.

High concentrations of aerosols are a major cause of cardiovascular disease and are also suspected to cause cancer. Fine particles are especially serious threats because they are small enough to be absorbed deeply into the lungs, and sometimes even into the bloodstream.

Aerosols also have important radiative effects in the atmosphere. Particles are said to scatter light when they alter the direction of radiation beams without absorbing radiation. This is the principal mechanism limiting visibility in the atmosphere. When relative humidity is high, aerosols absorb water, which causes them to swell and increases their cross-sectional area for scattering, creating haze. Without aerosol pollution our visual range would typically be about 200 miles, but haze can reduce visibility significantly.

Aerosols have a cooling effect on Earth's climate when they scatter solar radiation because some of the scattered light is reflected back into space. In contrast, some aerosol particles such as soot absorb radiation and have a warming effect. Aerosol particles can influence Earth's climate indirectly.

3. **Carbon monoxide (CO)**

CO is an odorless, colorless gas formed by incomplete combustion of carbon in fuel. The main source is motor vehicle exhaust, along with industrial processes and biomass burning. Carbon monoxide binds to hemoglobin in red blood cells, reducing their ability to transport and release oxygen throughout the body. Low exposures can aggravate cardiac ailments, while high exposures cause central nervous system impairment or death.

4. **Nitrogen oxides (NO and NO_2, referred together as NOx)**

Nitrogen oxides are highly reactive gases formed when oxygen and nitrogen react at high temperatures during combustion or lightning strikes. Nitrogen present in fuel can also be emitted as NOx during combustion. In the atmosphere NOx reacts with volatile organic compounds (VOCs) and carbon monoxide to produce ground-level ozone through a complicated chain reaction mechanism. It is eventually oxidized to nitric acid (HNO_3). Like sulfuric acid, nitric acid contributes to acid deposition and to aerosol formation.

5. **Sulfur dioxide (SO_2)**

SO_2 is produced by volcanic eruptions and industrial processes. SO_2 is a gas formed when sulfur is exposed to oxygen at high temperatures during fossil fuel combustion, oil refining, or metal smelting. SO_2 is toxic at high concentrations, but its principal air pollution effects are associated with the formation of acid rain and aerosols. SO_2 dissolves in cloud droplets and oxidizes to form sulfuric acid (H_2SO_4), which can fall to Earth as acid rain or snow or form sulfate aerosol particles in the atmosphere. Pollution from SO_2 has been linked to many adverse health effects on the respiratory system.

6. Lead

Lead is a toxic heavy metal, found naturally in the environment. It is a common pollutant in manufactured products. Motor vehicles and industries are the largest source of lead emissions. Lead can affect the nervous system, kidney function, immune system, reproductive and development systems and the cardiovascular system.

3.5 Hazardous Air Pollutants

Toxic air pollutants, also known as hazardous air pollutants (HAPs), are those pollutants that are known or suspected to cause cancer, other serious health effects (including reproductive effects or birth defects), or adverse environmental effects. Regulatory bodies work together with government at all levels to reduce air emissions of HAPs to the environment.

Example of HAPs includes benzene, which is found in gasoline; perchloroethylene, which is emitted from some dry cleaning facilities; and methylene chloride, which is used as a solvent and paint stripper by a number of industries. Other examples are dioxins, asbestos, toluene, and metals such as cadmium, mercury, chromium, and lead compounds.

4.0 CONCLUSION

Pollutants in the atmosphere cause harmful effects to both humans and animals, they also affect the environment. Pollutants in the ambient air must be monitored to see that their levels do not exceed the permitted limits.

5.0 SUMMARY

So far in this unit we have discussed air pollution and also distinguished between criteria and hazardous pollutants.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is air pollution?
2. What are the classes of air pollutants giving relevant examples?
3. Distinguish between criteria and hazardous pollutants

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UNIT 3 MEASUREMENT OF AIR QUALITY

CONTENTS

1.0 INTRODUCTION

Air pollutants can be measured directly when they are emitted – for example, by placing instruments on factory smokestacks – or as concentrations in the ambient outdoor air. To track ambient concentrations, researchers create networks of air-monitoring stations, which can be ground based or mounted on vehicles, balloons, airplanes, or satellites. In the laboratory, scientists use tools including laser spectrometers and electron microscopes 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.

3.0 MAIN CONTENT

3.1 Measurements of Air Pollution

There are many ways to measure air pollution, with both simple chemical and physical methods and with more sophisticated electronic techniques. There are four main methods of measuring air pollution.

1. **Passive sampling methods**
   This method provides reliable, cost-effective air quality analysis, which gives a good indication of average pollution concentrations over a period of weeks or months. Passive samplers are so-called because the device does not involve any pumping. Instead the flow of air is controlled by a physical process, such as diffusion. Diffusion tubes are simple passive samplers, which provide very useful information regarding ambient air quality. They are available for a number of pollutants, but are most commonly and reliably used for nitrogen dioxide and benzene. The tubes, which are 71 mm long with an internal diameter of 11 mm, contain two stainless steel gauzes placed at one end of a short cylinder. The steel gauzes contain a coating of triethanolamine, which converts the nitrogen dioxide to nitrite. The accumulating nitrates are trapped within the steel gauze, ready for laboratory analysis. The tube is open to the atmosphere at the other end, which is exposed downwards to prevent rain or dust from entering the tube. To ensure that all the nitrogen dioxide originates from the test

site, the tubes are sealed before and after exposure. The tubes are manually distributed and collected, and are analyzed in a laboratory.

2. Active sampling methods

This method use physical or chemical methods to collect polluted air, and analysis is carried out later in the laboratory. Typically, a known volume of air is pumped through a collector (such as a filter, or a chemical solution) for a known period of time. The collector is later removed for analysis. Samples can be collected daily, providing measurements for short time periods, but at a lower cost than automatic monitoring methods.

3. Automatic methods

The advantage of this method is that it produces high-resolution measurements of hourly pollutant concentrations or better, at a single point. Pollutants analyzed include ozone, nitrogen oxides, Sulphur dioxide, carbon monoxide and particulates. The samples are analyzed using a variety of methods including spectroscopy and gas. The sample, once analyzed is downloaded in real-time, providing very accurate information.

4. Remote optical/long path-analyzers

This method use spectroscopic techniques. Real-time measurements of the concentrations of a range of pollutants including nitrogen dioxide and Sulphur dioxide can be done using these analyzers.

The amount of pollution in the air, however sampled, is usually measured by its concentration in air. The concentration of a pollutant in air may be defined in terms of the proportion of the total volume that it accounts for. Concentrations of pollutant gases in the atmosphere are usually measured in parts per million by volume (ppmv), parts per billion by volume (ppbv) or parts per trillion (million million) by volume (pptv). Pollutant concentrations are also measured by the weight of pollutant within a standard volume of air, for example microgrammes per cubic metre (μgm^{-3}) or milligrammes per cubic metre (mgm^{-3}).

3.2 Air Quality Index (AQI)

The AQI is a nationally uniform color-coded index for reporting and forecasting daily air quality. It is used to report on the most common ambient air pollutants that are regulated under the Clean Air Act: ground-level ozone, particle pollution (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). The AQI tells the public how clean or polluted the air is and how to avoid health effects associated with poor air quality.

The AQI focuses on health effects that may be experienced within a few hours or days after breathing polluted air and uses a normalized scale from 0 to 500; the higher the AQI value, the greater the level of pollution and the greater the health concern. An AQI value of 100 generally corresponds to the level of the short-term National Ambient Air Quality Standard for the pollutant. AQI values at and below 100 are generally considered to be satisfactory. When AQI values are above 100, air quality is considered to be unhealthy, at first for members of populations at greatest risk of a health effect, then for the entire population as AQI values get higher (greater than 150).

The AQI is divided into six categories that correspond to different levels of health concern. The breakpoints between these categories are selected based on a review of the health effects evidence. Some individuals are much more sensitive to air pollution than others. Checking the AQI each day will help these people notice at what levels they begin to experience effects. The levels of health concern listed below are general guidelines used as a reference so that people can figure out their own sensitivity to air pollution.

- Good: Air quality is good and poses little or no risk.
- Moderate: Air quality is acceptable; however, there may be some health concern for a small number of unusually sensitive people. While EPA cannot identify these people, studies indicate that there are people who experience health effects when air quality is in the moderate range.
- Unhealthy for Sensitive Groups: When air quality is in this range, people who are in sensitive groups, whether the increased risk is due to medical conditions, exposure conditions, or innate susceptibility, may experience health effects when engaged in outdoor activities. However, exposures to ambient concentrations in this range are not likely to result in effects in the general population. For particle pollution, the sensitive groups include people with heart and lung disease, older adults, children, people with diabetes, and people of lower SES.
- Unhealthy: When air quality is in this range, everyone who is active outdoors may experience effects. Members of sensitive groups are likely to experience more serious effects.
- Very Unhealthy: When air quality is in this range, it is expected that there will be widespread effects among the general population and more serious effects in members of sensitive groups.
- Hazardous: Air quality in this range triggers health warnings of emergency conditions by media outlets. The entire population is more likely to be affected by serious health effects.

Air quality indices have two main purposes:

1. To relay necessary air quality information to the public so that people can modify their behaviour and stay healthy.
2. By monitoring pollution levels, countries can assess the effectiveness of their policies and adjust as needed to achieve better air quality in the future.

When air quality indices record high levels, government agencies deal with such instances through any of the following ways:

- Sensitive groups, including children, the elderly and people with respiratory and cardiovascular problems are advised not to take part in any outdoor activities
- Factories that emit large amounts of pollutants are ordered to shut down or cut production. People are also encouraged to use public transport to reduce vehicle emissions. This has happened severally in China where the authorities have increased their efforts to bring China pollution to manageable levels.
- People are asked to wear protective masks to avoid breathing in pollutants, particularly $PM_{2.5}$ and ground ozone.

4.0 CONCLUSION

Air quality measurement enables effective monitoring of air pollution, this helps to advise the public on the possible effects of air pollution on public health and measures to be taken.

5.0 SUMMARY

This study unit discussed the different ways to measure air pollution and how air quality index can be used to inform the public on air pollution and associated health risks.

6.0 TUTOR-MARKED ASSIGNMENT

1. Briefly discuss the different ways to measure air pollution?
2. What is air quality index?
3. What are the purposes of air quality index?

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MODULE 4 ASSESSMENT OF AIR QUALITY

UNIT 1 AIR QUALITY ASSESSMENT TECHNOLOGIES

CONTENTS

1.0 INTRODUCTION

The environment and public health is greatly impacted by air quality. The purpose for the assessment of air quality is to reduce the negative effects of air pollution. The data generated from air quality assessment help the government and other regulatory authorities to develop legislation, policies, and plans to manage emissions and monitor ambient air quality. Air quality assessments inform air quality management activities by providing an understanding of how pollutant sources, emission characteristics, topography, and meteorological conditions contribute to local air quality. Specific air quality assessment tools can help answer a variety of questions which are integral to air quality management activities.

2.0 OBJECTIVES

By the end of this unit, the student should be able to discuss the different air quality assessment tools.

3.0 MAIN CONTENT

3.1 Air quality assessment tools

Air quality assessment tools can help provide information on important sources, emissions, as well as meteorological conditions that contribute to poor local air quality. Information generated from the use of air quality assessment tools can inform decisions on permitting of emissions, industrial siting, and land use; all can impact local air quality, which in turn can influence air pollution related health effects of a population.

The main tools for air quality assessment are:

- Emissions inventories/measurement;
- Source apportionment;
- Mobile monitoring;
- Land use regression;
- Dispersion models.

All these assessment tools are interdependent in scope and application. Accordingly, all these tools should be regarded as complementary components in any integrated approach to exposure assessment or determining compliance against air quality criteria.

3.2 Emission Inventories

A crucial component of an air quality management plan is a reasonable quantitative knowledge of the sources of the various emissions. Emissions inventories are databases of pollution sources located within a specific geographical area, along with their estimated or actual emissions. The pollutants included in inventories generally include the criteria pollutants, such as PM ($PM_{2.5}$ and PM_{10}), So_x, NO_x, VOC_s, CO, NH_3, and ozone. Sources of emissions are organized into stationary and mobile categories, with stationary sources further broken down into point and area sources.

- Point sources include larger facilities, such as pulp mills, smelters, power plants; wood products plants and stacks in major industrial sites (see Figure 1).
- Area sources include stationary sources that are too small and numerous to count individually e.g. forest fires, emissions from vehicle refueling, off-road vehicles, commercial and domestic fuel combustion (see Figure 1).
- Mobile sources include any sources powered by an internal combustion engine that move under their own power; these include all on-road vehicles, off-road vehicles (e.g., construction equipment, sports equipment, gardening equipment) etc. Mobile sources are often considered as line sources as it is not practicable to consider the emissions from each car separately but rather to sum up the emissions along the road (considered as a line; see Figure 1).

Biogenic or natural sources, such as deserts, eroded areas, and agricultural emissions are a non-anthropogenic source category, mostly being to area sources.

Figure 1: A copper smelter in Ilo Perú (left). Dietrich Schwela, WHO, Traffic congestion in a street in Bangkok (right). Karl Fjellstrom, (2002). Waste deposit in Lagos, Nigeria (below). (Dietrich Schwela, WHO)

Pollutant emissions from each source are calculated using a variety of data. For point sources, data generally come from stack sampling and monitoring, as required of larger facilities by the permitting process. For point sources where stack monitoring data is not available, such as smaller facilities that are not required to conduct monitoring, estimation methods are used to calculate emissions rates of pollutants. The use of monitoring data allows for more accurate calculations of emissions from facilities, compared with those generated by estimation methods. These methods typically include the use of emission factors and a production or activity level. Form any common industrial processes and control equipment, an existing emission factor can be found for similar facilities. For example, the United States Environmental Protection Agency (USEPA) maintains a large database of these factors, called the AP-42 Emission Factors (US EPA, 2010). Emission factors are usually expressed as a mass of contaminant emitted per unit of input energy or raw material consumed (called the activity level). Once the emission factor and activity rate are known, the overall emissions from a source or activity can be calculated using equation 1 (US EPA, 2010).

Equation 1 also takes into consideration emissions reduction activities which can reduce total emissions.

$E = A \, x \, EF \, x \, (1 - ER/100)$ (1)
where:

E = emissions;
A = activity rate;
EF = emission factor, and

ER = overall emission reduction efficiency, %
Emissions, from the majority of area sources in inventories, are estimated using emission factors and activity levels or a simple count of the number of facilities within the area of study. Emissions from sources in specialized categories, such as open burning, can be estimated with models. All mobile source categories are estimated with models developed for each category (i.e., on-road, off-road, aircraft, etc.). While these models are based on empirical data and emission factors, they do take into account relevant local data, including: vehicle fleet distribution and demographics, average vehicle use cycles and mileage, fuel characteristics, average weather, and changing engine emission criteria and limits. Similarly, estimations of emissions from natural sources, such as forest fires, are generally calculated using models (e.g., vegetation growth) or a combination of empirical data and emission factors.

Once the inventory has been completed it is important to conduct an emissions verification exercise to ensure that the accuracy and precision of estimates remain within acceptable parameters. Verification involves ascertaining the completeness and consistency of the data input and involves checks on:

- How definitions of sources and of pollutants have been applied;
- The completeness of the data entered for each sector, sub-sector and activity;
- The consistency of the inventory at different levels of spatial disaggregation;
- The transparency of the emissions inventory—whether the data inputs are fully traceable to their references.

Verification can also involve the use of dispersion and modelling studies to assess the inventory in relation to measured air quality.

4.0 CONCLUSION

Data collected in emissions inventories can be used to understand emissions trends over time, as well as highlight sources that require targeted emission reduction interventions. While on their own, they do not provide information on ambient concentrations, emissions inventories can feed into other assessment tools, such as dispersion models, to better characterize pollutant concentrations.

5.0 SUMMARY

In this unit we introduced air quality assessment technology tools and discussed emission inventory as a tool for air quality assessment.

6.0 TUTOR-MARKED ASSIGNMENT

1. List the tools used in air quality assessment
2. What is emission inventory and how is it used to assess air quality?
3. Briefly describe emission verification.

7.0 REFERENCES/FURTHER READING

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UNIT 2 SOURCE APPORTIONMENT, MOBILE MONITORING AND LAND USE REGRESSION

CONTENTS

1.0 INTRODUCTION

Air quality assessments inform air quality management activities by providing an understanding of how pollutant sources, emission characteristics, topography, and meteorological conditions contribute to local air quality.

2.0 OBJECTIVES

At the end of this unit, the student should be able to know the different air quality modelling methods and how they can be used by government and regulatory agencies in formulating polices in air quality management.

3.0 MAIN CONTENT

3.1 Source Apportionment

Source apportionment techniques aim to estimate, or apportion, the contribution of different pollution sources to ambient concentrations within a given area. Source apportionment is conducted by first understanding the particular make up of a mixture of air pollution, then linking these pollutants to specific sources. Understanding the composition of a pollution mixture is an important step in determining the potential health impacts of exposure.

Types of Models

Models of varying complexity have been developed to conduct source apportionment. These models aim to attribute ambient pollutant concentrations at specific locations (receptors) to specific sources. Common models include chemical-mass balance (CMB), principle component analysis (PCA) and a related technique called positive matrix factorization (PMF). The key difference between these models is the requirement of prior knowledge/data; while CMB models rely on chemical source profiles of emission sources, as well as on the chemical composition of ambient air at receptor locations, PMF and PCA require only chemical composition information at receptors.

In order to conduct a CMB assessment for PM, filter samples are collected and undergo laboratory analysis to determine the composition of the collected samples. Additionally, the chemical profile of pollutants emitted from all major sources in the air shed must be specified. The contribution of each source to the filter chemical make-up is then calculated by combining the sources linearly. The method is improved when sources have unique chemical tracers, making it easier to match the filter PM chemical composition to a specific source. As very few pollutants are source-specific, only non-reactive chemical tracers may be used as indicators of specific pollutants. For example, levoglucosan, a tracer for wood smoke, is often used in the analysis of PM to apportion the contribution of wood burning to a particulate sample.

Unlike CMB, PCA and PMF models can be used when the chemical composition of emissions from potential sources are unknown. PCA and PMF are very similar; both are statistical models that use multivariate receptor analysis to identify sources of a pollutant mixture. Despite these similarities, PMF is thought to be superior to PCA for several reasons. In PMF, unlike for PCA, it is possible to account for missing data, values below the limit of detection and uncertainties in each of the data values, by assigning weights to the data values. PMF is also more realistic since negative concentrations are excluded, unlike in PCA. Using both models, the chemical constituents of a sample are analyzed and the relationships between the constituents, expressed as a covariance matrix, are investigated. When particular chemical species vary together, they are assigned to the same factor. The chemical make-up of each factor is then interpreted and identified with a specific source. Information from a PMF model can be further refined with the use of meteorological data, including wind direction, to provide better information on the geographical location of the source. For example, if a particular factor occurs when wind is from a specific direction, and the factor is chemically associated with a source in that direction, then the factor may be attributed to that source.

3.2 Mobile Monitoring

Mobile monitoring uses a mobile platform, typically a vehicle, to collect pollutant measurements across an area of interest. This type of monitoring is useful to: (1) provide insight about areas that are not well represented by fixed-site monitoring stations; (2) capture small-scale spatial variability of pollutants; (3) identify localized pollutant hot spots, particularly for emissions that vary in concentration over small spatial scales, such as residential wood burning and traffic; (4) provide data for model development or validation. Mobile monitoring has the capability of being rapidly deployed, therefore, can also be used in emergency situations, such as characterizing the spatial distribution of a chemical plume resulting from an accidental release or smoke from forest fires. For these reasons, mobile monitoring provides detailed information beyond what can be typically characterized by traditional fixed-site monitoring networks, so can be used to improve exposure estimates and inform air quality management decisions.

Mobile monitoring is typically conducted by equipping a vehicle with air pollutant monitors. The use of a geographical positioning system (GPS) allows precise locations to be assigned to air pollution measurements. There are two sampling methods that can be used to conduct mobile monitoring: (1) measurements can be collected while the vehicle is in motion or (2) can be stationed for periods of time at designated locations.

Generally, the purpose of collecting measurements while the vehicle is in motion is to gather a high density of measurements over an area of interest. Continuous monitors are suitable for this approach and are typically used to collect real-time measurements at high frequencies (less than 1 minute). Several types of pollutants such as PM_4 and air toxics have been measured, using this sampling method. Some measurements, such as PM, do not provide source-specific information, making it difficult to attribute specific sources to the mobile measurements. However, different techniques, such as choosing an appropriate sampling period or instrument selection, can help to identify or isolate the sources of interest. For example, to characterize $PM_{2.5}$ generated from residential wood burning, mobile monitoring can be conducted during cold, calm winter evenings. During these conditions, wood burning activity is expected to be relatively high while the relative contribution of traffic to ambient $PM_{2.5}$ is expected to be lower. Selecting an instrument, such as a multi-wavelength aethalometer or multi-wavelength nephelometer, instruments that measure light attenuation and scattering of a sample (respectively) at two or more wavelengths, can help to distinguish some particle sources, such as diesel exhaust or wood smoke. Supplementary sampling at fixed-sites can also help to characterize the chemical contents of $PM_{2.5}$ within the region of interest.

In cases where sampling is conducted while the vehicle is stationary, the vehicle essentially serves as a temporary monitoring station. The vehicle is stationed at designated sampling sites in an area of interest for longer sampling periods (from hours to days). Sampling can be conducted for pollutants such as: PM, NO_2, SO_2, ozone, VOCs, PAHs, other air toxics, as well as for meteorological conditions with continuous and non-continuous monitors. This approach is useful for obtaining ambient air quality information that would otherwise not be available through existing fixed-site monitoring networks.

3.3 Land Use Regression

Land use regression (LUR) is a modelling approach that can be used to describe the distribution of air pollution within urban and suburban areas. It was first developed by public health researchers in the mid-1990s to examine neighborhood-scale variability in long-term concentrations of urban air pollutants. At the time, there was new evidence to suggest that increasing exposure to city-wide air pollution had a negative impact on important indicators of public health. LUR was developed to support epidemiologic studies investigating the public health effects of air pollution due to ambient air pollution variability within a single city. More recently, LUR has gained attention in the air quality management and urban planning communities.

Although LUR is typically used to model pollution related to vehicle traffic, the method has also been applied to sources like residential wood smoke and marine traffic. Regardless of the source under consideration, the premise of any LUR model is that the pollutant concentration at a specific location is a function of the physical characteristics of that location and its surroundings. For example, LUR assumes that the nitrogen oxide (NO_X) concentrations around a house may be associated with the volume of traffic around that house. Likewise, the concentration of wood smoke-related particulate matter (PM) around that house may be related to the density of houses in the neighborhood with wood-burning appliances. The concept is easy to understand and the method is generally straightforward to apply.

Conducting LUR

There is no standard way of conducting LUR, but detailed descriptions of different approaches can be found in the scientific literature. The first step is always to measure a pollutant at multiple locations around an area. These locations are generally fixed, but mobile monitoring has been used in some cases. Under ideal circumstances, the sites are specifically selected to optimize the spatial variability in pollutant concentrations. Physical and geographic characteristics that might be associated with those concentrations are measured around each site, using a Geographic Information System (GIS). These potentially-predictive variables typically describe site location, including land use, population density, and traffic patterns. Once sampling is complete and the potentially-predictive variables are generated, multiple linear regression is used to determine the association between measured concentrations and the most predictive variables. The resulting equation can be used to estimate pollutant concentrations wherever all of the predictors can be measured; concentration maps with high spatial resolution can be generated by rendering the regression model in the GIS.

Studies to date have used a variety of methods to choose sampling locations, from convenience sampling (i.e., using a pre-established air monitoring network) to sophisticated location-allocation models that optimize the estimated variability in measurements while maximizing the distance between samplers. While there is little evidence to support using any single method, LUR is most informative when models are built on data that reflect the full within-area variability of the pollutant in question. Likewise, there are no definitive guidelines on the number of sites to sample, but to capture the necessary variability, a practical minimum of 40 has been. Finally, the sampling period should be chosen to suit the specific objectives of the study. For example, if using LUR to predict the long-term average of a pollutant that follows distinct seasonal trends (i.e., NO_X), it is advisable to sample during periods that are known a priori to approximate the annual mean.

For the other side of the regression equation, it is important to consider which data will be used to generate the potentially-predictive set of variables. Although the availability of geographic data depends upon local circumstances, most LUR studies on traffic-related pollution have used variables that quantify traffic intensity (sometimes specified by vehicle class), road classification density, distances to certain road types, population/building density, areas of land use classifications, and topography. Some studies have attempted to improve model fit by including a wider range of data from other sources, such as meteorological models and remote sensing platforms. In general, LUR can accommodate any spatial dataset that may help to describe the within-area variability of pollutant concentrations.

4.0 CONCLUSION

The different air quality assessment tools we have discussed can be used to identify particular sources that are important contributors to local air pollution, thus, enabling them to be targeted for emissions reduction strategies. Information about important polluters can inform decisions on emissions permitting and industrial siting in a region. A better understanding of sources and of pollution composition can also better inform the assessment of health impacts once the exposure is better characterized.

5.0 SUMMARY

In this Unit, we have learnt that air quality assessment technologies can be used to monitor the local air quality. And the information gotten using these assessment technologies can be very helpful to decisions makers in monitoring air quality and hence protection of a population from pollution related health effects.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is source apportionment?
2. Discuss the different models that can be used in source apportionment.
3. Briefly discuss how air quality can be assessed using mobile monitoring.
4. Explain land use regression

7.0 REFERENCES / FURTHER READING

Dockery, D., Pope, C., Xu, X., Spengler, J., Ware, J. and Fay, M. (1993). An association between air pollution and mortality in six U.S. cities. *N Engl J Med.* 329:1753-1759.

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UNIT 3 AIR QUALITY MODELLING

CONTENTS

1.0 INTRODUCTION

Ambient air quality modelling, in conjunction with monitoring, plays an important role in assessing existing and potential risks to air quality, particularly as part of an initial assessment of new developments. Air pollution models are the only method that quantifies the deterministic relationship between emissions and concentrations/depositions, including the consequences of past and future scenarios and the determination of the effectiveness of abatement strategies. This makes air pollution models indispensable in regulatory, research, and forensic applications. The Gaussian Plume Model was developed for modelling point sources and is used in calculating the maximum ground level impact of plumes and the distance of maximum impact from the source. Air pollution modelling at urban or larger scales are done using Lagrangian modeling and Eulerian modeling.

The first step in undertaking air quality modelling is to clearly define the objectives and expected outcomes. This can be done by addressing questions such as:

- What is the reason for the air quality modelling?
- What questions need to be answered by modelling work?
- What pollutants or environmental indicators need to be modelled in order to provide the information required?
- What data and information are already available and how can these help?
- What considerations need to be made about background concentrations of pollutants?
- What type of pollutant source/s need to be modelled?
- What are the geographical features near the pollutant source/s?
- How the modelled data is best utilized and reported to describe the issues under investigation?

2.0 OBJECTIVES

By the end of this unit, the student should be able to know how to measure air quality.

3.0 MAIN CONTENT

3.1 Dispersion Modelling

When a pollutant is emitted into the air, it is transported and diluted by the atmosphere and may be transformed or removed before it reaches a receptor (site). It is often assumed that air quality is determined only by how much is emitted into the air. While the amounts emitted into the air are very important to monitor, ambient concentrations are also a function of meteorology, topography, time, and the distance between sources and receptors. Because of this, the ambient concentrations are not related in a simple way to the emission amount. Dispersion models take these influencing factors into account to predict ambient concentrations at specific sites. An air quality dispersion model is a system of science-based equations that mathematically describes how pollutants are dispersed and transformed in the atmosphere. Concentrations of pollutants at specific receptors are estimated by placing sources (from an emission inventory) into a dispersion model which takes into account the interactions between sources, meteorology, and topography as the pollutants are transported and diluted by wind. Dispersion models can help to provide a cause-effect link between emissions into the air and the resulting ambient concentrations. For example, large reductions in emissions from a stack located on a hill above a community may have a very small effect on the community's air quality since the plume is so high it seldom reaches ground level, where the emissions can be breathed in. However, the air quality in a community downwind may be improved considerably as the emissions from the stack may have the greatest impact on that community's air quality. Dispersion models can help to determine the contribution of each source to ambient concentrations in an air shed.

3.2 Types of Dispersion models

Different types of dispersion models can be used to assess the impact of pollutant sources on air quality, depending on the information required and the data available.

- A Screening model can be used to provide a quick calculation of a worst case concentration that could occur from a source under different emissions and meteorological conditions. Through screening, further modelling needs can be determined. Screening models are simple and quick to run because they require few inputs, since they use a built-in set of meteorological conditions. Example of screening model is SCREEN3.
- A Refined model is more scientifically sound than a screening model and requires more input data and expertise to run. These models require hourly meteorological data over a period of time (e.g., a year) and from the region of interest in order to make predictions that are site specific and more detailed as compared to a screening model. The output consists of predicted concentrations for a given pollutant, for time averages from 1 hour to annually at specified receptor locations. The model output provides a rich dataset to understand the air quality impacts of meteorology on source emissions. An example of a refined model is AERMOD.
- An Advanced model includes comprehensive treatments of the physics and chemistry of emissions in the atmosphere and thus requires considerable expertise and computer resources to set up, run, and interpret the results. Advanced models are typically used to assess air quality impacts from large areas (such as cities) and over broad emission sectors for a

selected time period (a few days is typical, but longer periods of time can also be modelled). CALPUFF is an example of an advanced modelling system.

Data requirements
The types of input data required can be categorized into the following types:

1. Emissions: Information on the type of pollutant and source characteristics are required, including the source type (point source such as a stack, an area source such as a sewage lagoon, a line source such as a highway), emission rates, exit conditions (temperature, flow rates), and physical release characteristics, such as elevation and diameter.
2. Atmospheric Conditions: A dispersion model requires a description of the atmosphere, since the transport and mixing of the contaminant depends on atmospheric conditions.
3. Wind speed and direction as well as temperature and sometimes other data, such as clouds, precipitation, humidity and atmospheric stability, may be required.
4. Geophysical Description: The underlying topography and land characteristics must be specified.
5. Model Options/Switches: A model may have different ways in which the physics and chemistry are treated. The selection of a particular treatment is controlled by specifying options in the model; the correct selection of options can be important for realistic results.

3.3 Strengths of Dispersion Models

Dispersion models are widely accepted and utilized as an integral part of air management programs. Dispersion modelling can help to assess the contribution of sources to ambient air quality levels by directly attributing sources and their contributions to ambient concentrations that are a consequence of emissions, meteorology, and location. This can help identify high exposure scenarios (i.e., high exposure sites, meteorological conditions that favor high pollutant concentrations) as well as evaluate the effectiveness of scenarios for air quality-related interventions.

3.4 Limitations of Dispersion Models

Despite the value they provide, dispersion models may not be appropriate to use in all air quality assessments. Dispersion models can be quite complex and can require a large amount of input data. If data are unavailable, incomplete or of poor quality, the usefulness of dispersion model results are limited. Some of the more complicated models have large input data requirements, making them more difficult to run, restricting their use to circumstances where the input data are available. Additionally, since dispersion models provide predictions, they may overestimate or underestimate the contribution of particular sources or pollutants to air quality, and must be validated by comparing the predictions with actual measurements. Finally, dispersion modelling only predicts outdoor ambient concentrations and does not offer a way to account for the activity of individuals, which will affect their personal exposures (e.g., time spent in different locations, movement into buildings).

4.0 CONCLUSION

Air quality modeling allows the estimation of the effect of a change in one or more sources that emit a pollutant of concern on ambient air quality. This is can be useful in predicting the impact of and potential risks of pollution. Models are thus indispensable regulatory tools.

5.0 SUMMARY

In this Unit, we learnt air quality modelling and how it can be used to predict the impacts and possible risks of pollution.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is an air quality model?
2. Discuss the types of data required in air quality modelling
3. What are the strength and limitations of dispersion modelling?
4. Mention two types of models that can be used for modelling air quality in an urban area.

7.0 REFERENCES/FURTHER READING

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