NATIONAL OPEN UNIVERSITY OF NIGERIA

COURSE CODE : ESM341

COURSE TITLE:
INTRODUCTION TO INSTRUMENTATION MEASUREMENTS AND FIELD METHODS IN ENVIRONMENTAL SCIENCE

COURSE GUIDE

ESM341
INTRODUCTION TO INSTRUMENTATION MEASUREMENTS AND FIELD METHODS IN ENVIRONMENTAL SCIENCE

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Introduction

The Webster's 9th Collegiate Dictionary defines *Environment as"*... the complex of physical, chemical, and biotic factors (such as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determines its form and survival*"*. Environmental Science is thus described as that field of knowledge that studies how humans and other species interact with one another and with the non-living environment. It is both a physical and social science that integrates knowledge from a wide range of disciplines, including physics, chemistry, biology, geology, geography, economics, political science, sociology, psychology, and philosophy.

Instrumentation is concerned with the techniques in Environmental Sciences, which involves data collection, manipulation and information presentation. Instrumentation is used in almost every activity and generating system, where consistent and reliable operations are required to provide the means of monitoring, recording and controlling a process to maintain it at a desired state. A typical environmental activity yields many process variables that have to be measured and manipulated. Variables such as boiler level, temperature and pressure, turbine speed, generator output and many others have to be controlled prudently to ensure a safe and efficient station operation. Instrumentation is often referred to as the power behind scientific investigations. This course therefore introduces you to basic instrumentation used in Environmental Science.

Its study therefore requires a sound, broad based education in these areas. The present course structure however employs a beginner’s approach to the study of instrumentation and measurements in Environmental Science. The course has thirteen (13) units.

The first unit of this course introduces you to the scope of instrumentation in environmental science and technology. It informs you what to expect in the course of the study of this course material.

The second unit is on the instrumentation for field observations. Emphasis is however on remote sensing related equipments. The concepts of remote sensing and allied instruments are discussed. Laboratory equipment in this category includes the atomic absorption spectrophotometer, mass spectrometer and colorimeter. Information about these instruments and their operation techniques are given in the course material. Unit three dwells on vegetation and biota investigation using a quadrat survey technique. The use, application of quadrat and mode of interpretation of data collected using this survey method are discussed in this unit. Unit four discusses the principle and instrumentation for pH and electrical conductivity's determination. Both the analogue and electrical probing techniques are considered.

Unit five discusses the principle of some laboratory techniques, especially the AAS, colorimeter and mass spectrometer. The sixth and seventh units focus on air sampling; two dimensions to this are observed. These include the short and long term/integrated approaches. Relevant instrumentation for these approaches is described. Unit eight focuses on a more general term, sampling. This unit also digresses a bit into the social investigative procedure of sampling; it discusses different approaches to sampling, and the advantages and disadvantages of each approach. Bias and errors in sampling procedures are also considered important, and discussed. Unit nine highlights the main requirements for quality control assurance in Environmental Science. Unit ten describes some examples of electronic direct reading instrumentations. Units eleven, twelve and thirteen focus on important aspects of environmental science, namely biological, noise and sound and meteorological variables, respectively.

The Course

This Course Guide tells you briefly what to expect from this material. The objective of this course is to equip the students with the knowledge in the field of laboratory instrumentation that will improve the research and education in Environmental Science at the bachelor's level at the National Open University of Nigeria. Adequate instrumentation is indispensable in performing cutting-edge research.

Knowledge of instrumentation is critical in the light of the highly sensitive and precise requirements of modern processes and systems. Rapid development in instrumentation technology coupled with the adoption of new standards makes a firm, up-to-date foundation of knowledge more important than ever in most science and engineering fields. Understanding this, the course material has covered a wide range of scope in the Introduction to Instrumentation and Measurements.

Course Aim

The aim of this study is to provide an understanding and appreciation of instrumentation in environmental analyses

Course Objectives

Sequel to the aim above, this course sets to achieve some objectives. After reading this course, you should be able to:

- outline and give examples of types of instrumentation in environmental science
- describe the different categories of laboratory instruments and distinguish among them
- describe remote sensing and its techniques;
- describe a Quadrat; and how you will conduct a study with one
- describe the methods for ph and electrical determination in soils and water samples
- describe an AAS, colorimeter, spectrometer and chromatography system
- identify the types of instrumentation for air sampling
- describe the conditions necessary for the adoption of integrated sampling procedure; and
- describe some integrated air sampling instruments
- define sampling and describe it purpose in research;
- outline and describe sources of errors in sampling; and
- describe the importance of sample size
- the records that you need to keep as an investigator;
- the field activities during and after field work, especially when sample collections are involved
- describe the direct reading instruments and their uses
- describe the operating principles of the instruments;
- list the usefulness of a number of the direct reading instruments
- identify the materials required for field work;
- describe the sampling instruments for different aspects of biological studies
- describe the component of sound measuring system
- describe some sound measuring instruments
- describe the types of meteorological stations; and
- mention some climate / weather elements and instruments for their measurements

Working through the Course

This course involves that you would be required to spend a lot of time to read. The contents of this material is very dense and require you spending great time to study it. This accounts for the great effort put into its development in the attempt to make it very readable and comprehensible. Nevertheless, the effort required of you is still tremendous. I would advise that you avail yourself the opportunity of attending tutorial sessions where you would have the opportunity of comparing knowledge with your peers.

The Course Material

You will be provided with the following materials;

1. Course Guide
2. Study Units

In addition, the course comes with a list of recommended textbooks which though are not compulsory for you to acquire or indeed read, but are necessary complements to the course material.

Study Units

The following are the study units contained in this course:

Module 1

Unit 1 Scope of Instrumentation in Environmental Science and Technology
Unit 2 Instrumentation for Field Observations: Remote Sensing Related Equipments
Unit 3 Principles of Quadrat Survey
Unit 4 pH and Electrical Conductivity in Soil and Water Samples
Unit 5 Introduction to Laboratory Techniques and Instrumentation

Module 2

Unit 1 Instrumentation for Air Sampling and Analyses
Unit 2 Integrated or Long Term Air Sampling
Unit 3 Sampling as an Instrument for Environmental Investigation
Unit 4 Quality Control Assurance in Sampling

Module 3

Unit 1 Electronic Direct Reading Instrumentation
Unit 2 Biological Sample Collection: Freshwater
Unit 3 Instrumentation for Noise and Sound Measurements
Unit 4 Meteorological Variables and their Observations

Textbooks and References

Field Sampling Manual (2003). *British Columbia Field Sampling Manual*, 2003 Edition (Permittee) ISBN 0-7726-2741-X, Prepared and published by Water, Air and Climate Change Branch, Ministry of Water, Land and Air Protection, Province of British Columbia (Available online).

Jain, Anil K. (1989). *Fundamentals of Digital Image Processing*. New Jersey: Prentice-Hall.

Campbell, J.B. (1987). *Introduction to Remote Sensing***.** New York: The Guilford Press.

Salant, P. and Dillman D. A. (1994). *How to Conduct Your Own Survey*. John Wiley & Sons, Inc.

Patton, M.Q. (1990). *Qualitative Evaluation and Research Methods*. Newbury Park London & New Delhi: SAGE Publications.

From the Field to the Lab (2008). A Citizen's Guide to Understanding and Monitoring Lakes and Streams, ://www.ecy.wa.gov/ Programs/wq/plants/management/ joysmanual/index.html.

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Platt, U. (1999). *Modern Methods of the Measurement of Atmospheric Trace Gases*, Invited Lecture, *Phys. Chem. Chem. Phys*., 1, 5409 – 5415.

Kramer, K.J.M. (1994). What about Quality Assurance before the Laboratory Analysis? *Marine Pollution Bulletin*, 29: 222-227.

Kratochvil, B. and Taylor, J.K. (1981). *Sampling for Chemical Analysis*. *Analytical Chemistry*, 53: 924A - 938A.

Kratochvil, B.; Wallace, D. and Taylor, J.K. (1984). *Sampling for Chemical Analysis*, *Analytical Chemistry*, 56: 113R - 129R.

British Columbia Environmental Laboratory Manual for the *Analysis of Water, Wastewater, Sediment and Biological Materials*, (1994). (ed.). Environmental Protection Department, Ministry of Environment, Lands and Parks, Victoria, Canada (Available online).

Assessment

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

Tutor-Marked Assignment

The TMA is the continuous assessment component of your course. It accounts for 30% of the total score. You will be given TMAs to answer. You must answer all these before you are allowed to write the end of course examination. The TMAs would be given to you by your facilitator and returned after you have done them.

Final Examination and Grading

This examination concludes the assessment component for the course. It constitutes 70% of the whole course. You will be informed of the time for the examination. It may or not coincide with the University semester's examination

Summary

This course intends to provide you with some underlying knowledge of water resources and the way they are assessed. By the time you complete studying this course, you will be able to answer the following questions:

- Make a categorisation of instruments in Environmental Science into data collection and laboratory analysis instruments.
- Compare the samplers for water and air investigations.
- Discuss the requirements for successful field work. How do you think that knowledge of the instrumentation will make analyses easier?
- Are the required instrumentations easily assessable? What can you do if you find out that the instrumentation for a particular activity is not available?

- How do we use a quadrat?
- Describe how you will analyse for some named gases in air sample. What instruments will you use?

- How will you measure sound and noise? What instruments are you going to use?

I wish you success in this course. In particular, I hope you will be able to appreciate the importance of instrumentation in Environmental Science.

Best wishes.

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MODULE 1

UNIT 1 SCOPE OF INSTRUMENTATION IN ENVIRONMENTAL SCIENCE AND TECHNOLOGY

CONTENTS

1.0 INTRODUCTION

Instrumentation is used in almost every activity and generating system, where consistent and reliable operations are required. Instrumentation provides the means of monitoring, recording and controlling a process to maintain it at a desired state. A typical environmental activity yields many process variables that have to be measured and manipulated. Variables such as boiler level, temperature and pressure, turbine speed, generator output and many others have to be controlled prudently to ensure a safe and efficient station operation. Instrumentation is often referred to as the power behind scientific investigations. This unit introduces you to instrumentation used in Environmental Science.

2.0 OBJECTIVES

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

- define the term *instrumentation*
- outline and give examples of types of instrumentation in environmental science
- describe the different categories of laboratory instruments and distinguish among them.

3.0 MAIN CONTENT

3.1 What is instrumentation?

The meaning of instrumentation cannot be positioned to a particular discipline. It is not rigid, depending on who or what is defining it. It could be generally described as the study, development and manufacture of scientific instruments and equipment. But for our class, we will simply define instrumentation as instruments and procedures used in collecting and analysing data in a study.

3.2 Types of Instrumentation for Environmental Studies

Different types of data are required for different categories of environmental studies; hence different instruments and procedures for their data collection and analyses exist too. But for the sake of explanation, the different methods of data acquisition can be summarily described as the following:

a. Instrumentation for field observations:

Instrumentation for these includes land survey equipments, both analogue and digital. Instruments for analogue approach to field survey include tape, arrow, Günter chain, etc. Digital instruments include Total Stations, Global Positioning Systems (GPS).

There are also some indirect methods of extracting information, especially from aerial photographs and satellite imageries.

Other categories of instrument for field surveys include samplers, which are of various types depending on the parameter to sample; air, water, sediment and soil samplers. We also have testers or field equipments for direct observation, including pH and electrical conductivity meters, quadrats; for vegetation sampling, tape, ball of string, scissors, clipboard, pens and paper.

b. Instrumentation for laboratory analyses

In a particular application the selection of a technique will be based on the particular requirements:

1. what species (parameters) are to be measured;

2. is the simultaneous determination of several parameters necessary; and

3. what are the required accuracy, time resolution, and spatial resolution?

4. logistic requirements like power consumption, mounting of light sources or retro-reflectors or accommodation of the instrument on mobile platforms.

3.2.1 Classification of laboratory equipments

Laboratory techniques are both specialised and universal techniques. Specialised techniques allow only one parameter (specie) to be detected by an instrument, e.g. UV absorption detection. On the other hand universal techniques allow one to measure many species with one instrument.

Another fundamental property of instruments is the spatial range of the measurements, usually expressed in terms of in situ or remote sensing measurements. While in situ measurements come close to the ideal to determine specie concentrations in a ‘spot’ in space that is usually very close to the instrument, remote sensing techniques allow one to make measurements from a large distance, perhaps as far as from a satellite instrument in the earth’s orbit. It thus usually give averages of the concentration over a relatively large area.

Remote sensing techniques always rely on the sensing of electromagnetic radiation. Examples of laboratory instruments belonging to either category include

(i) gas chromatographic (universal technique, in situ),
(ii) optical spectroscopy (universal technique, in situ and remote sensing),
(iii) mass spectrometry (MS),
(iv) any other (in situ) technique, where the most commonly employed principles include chemiluminescence (e.g. for the detection of NO or O), photoacoustic detection, electrochemical techniques, matrix isolation), and chromatography (IC).

It is important that you note that field surveys equipment such as total stations, GPS and aerial and satellite sensors are also remote sensing devise. This is because they are a devise that obtain information from the real world surface without being in physical contact with the object from which information is being obtained. You will learn more in the subsequent unit.

4.0 CONCLUSION

This Unit has introduced you to the concept of introduction in Environmental Science. You may not be able to achieve anything reasonable without you understanding both the theoretical and technical principles of this important concept. This is the basis for this material.

5.0 SUMMARY

So far you have learnt that instrumentation is a term used to describe a collection of instruments and procedures used in collecting and analysing data in a study. Instrumentation is use for field observations and laboratory analysis. It is based on results from these activities using required instrumentation that results could be obtained and presented. Instruments can either be digital or analogue; they can use in situ (on the spot) technique or remote sensing technique. Before you proceed to the next unit however, it is believed that you are now able to define the term *instrumentation*, give the different categories of instruments that we use in either the field or laboratory.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is instrumentation?
2. Describe the two categories of instrumentation in Environmental Science.
3. List 5 examples of field and laboratory equipments that use remote sensing technique.

7.0 REFERENCES/FURTHER READING

Lum, K. P., Betteridge, J. S., Macdonald, R. R. (1982). *Environmental Technology Letters* 3, 57-62.

Field Sampling Manual, (2003). *British Columbia Field Sampling Manual*, 2003 Edition (Permittee) ISBN 0-7726-2741-X, Prepared and published by Water, Air and Climate Change Branch, Ministry of Water, Land and Air Protection, Province of British Columbia.

UNIT 2 INSTRUMENTATION FOR FIELD OBSERVATIONS: REMOTE SENSING RELATED EQUIPMENTS

CONTENTS

1.0 INTRODUCTION

In the earlier Unit, we were informed that instrumentations can either be digital or analogue, and can operate using in situ (involving physical contact) or remote sensing technique. Do you think that instruments that are digital are most likely to work with remote sensing technique? Yes and No. Yes because many are as you will note here. No because some are not, as you would have learnt in ESM 223 (Water Resources Evaluation) of some equipment such as the Current meter.

But to the business at hand, remote sensing techniques can be used by either field or laboratory based instruments as you will learn at the end of this unit. Now let’s go.

2.0 OBJECTIVES

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

- describe Remote sensing and its techniques
- name and describe some equipments that use remote sensing techniques.

3.0 MAIN CONTENT

3.1 What is Remote Sensing?

Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. Campbell (1996) defines Remote sensing as the practice of deriving information about the Earth's atmosphere or land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the earth's

3.2 Remote Sensing Technique

In much of remote sensing, the technique involves a process of interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved. Note, however that remote sensing also involves the sensing of emitted energy and the use of non-imaging sensors.

The seven elements in Fig. 2.1 below comprise the remote sensing process from beginning to end

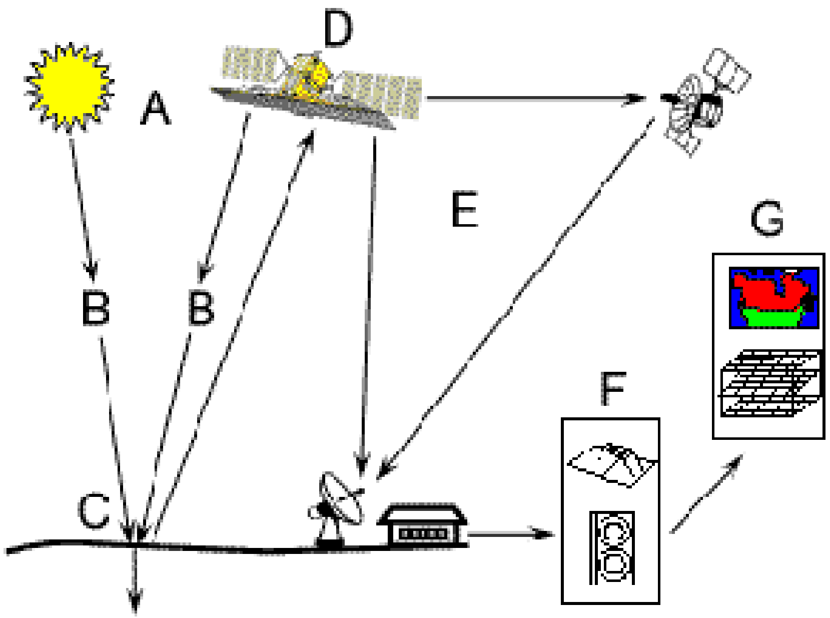


Fig. 2.1: Process of the remote sensing technique

- **Energy Source or Illumination (A)**

This is the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.

- **Radiation and the Atmosphere (B)**

As the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

- **Interaction with the Target (C)**

Once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.

- **Recording of Energy by the Sensor (D)**

After the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.

- **Transmission, Reception, and Processing (E)**

The energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).

- **Interpretation and Analysis (F)**

The processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.

- **Application (G)**

The final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

3.3 Remote Sensing Related Equipments

Spectrometers

A spectrometer is an optical instrument used to measure properties of light over a specific portion of the electromagnetic spectrum, typically used in spectroscopic analysis to identify materials. The variable measured is most often the light's intensity but could also, for instance, be the polarization state. The independent variable is usually the wavelength of the light, normally expressed as some fraction of a meter, but sometimes expressed as some unit directly proportional to the photon energy, such as wave number or electron volts, which has a

reciprocal relationship to wavelength. A spectrometer is used in spectroscopy for producing spectral lines and measuring their wavelengths and intensities.
Spectrometer is a term that is applied to instruments that operate over a very wide range of wavelengths, from gamma rays and X-rays into the far infra red. If the region of interest is restricted to near the visible spectrum, the study is called spectrophotometry.

In general, any particular instrument will operate over a small portion of this total range because of the different techniques used to measure different portions of the spectrum. Below optical frequencies (that is, at microwave and radio frequencies), the spectrum analyzer is a closely related electronic device

Fig. 2.2: An image of a typical spectrophotometer

Colorimeters

These are based on the principle of colorimetry or colourimetry. It is defined as the quantitative study of color perception. It is similar to spectrophotometry, but may be distinguished by its interest in reducing spectra to tristimulus values, from which the perception of color derives. It is also interested in the determination of the spectral absorbance of a solution. Colorimeter is a device used to test the concentration of a solution by measuring its absorbance of a specific wavelength of light.

Controls

1 Wavelength selection;
2 Printer button;
3 Concentration factor adjustment;
4 UV mode selector (Deuterium lamp);
5 Readout;
6 Sample compartement;
7 Zero control (100% T);
8 Sensitivity switch

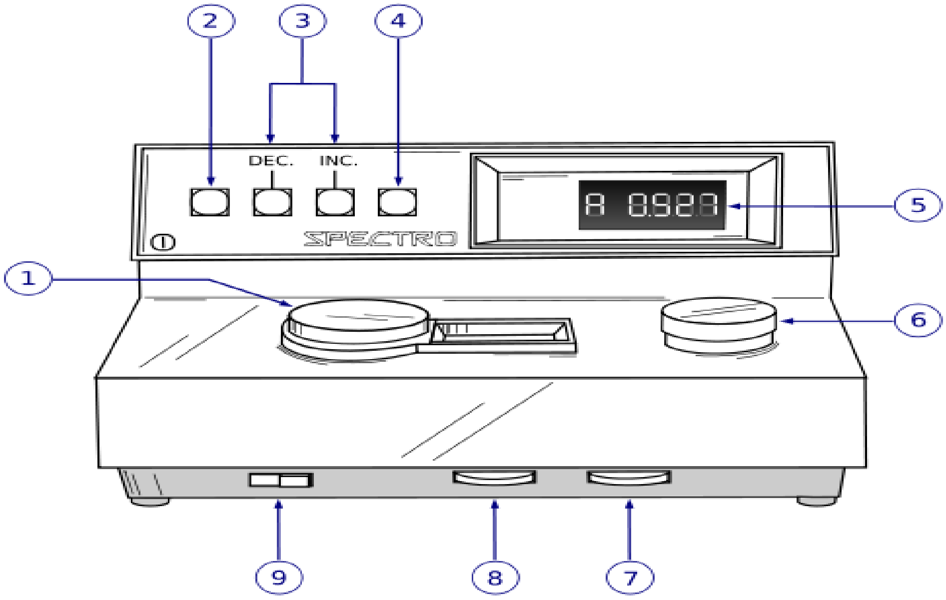


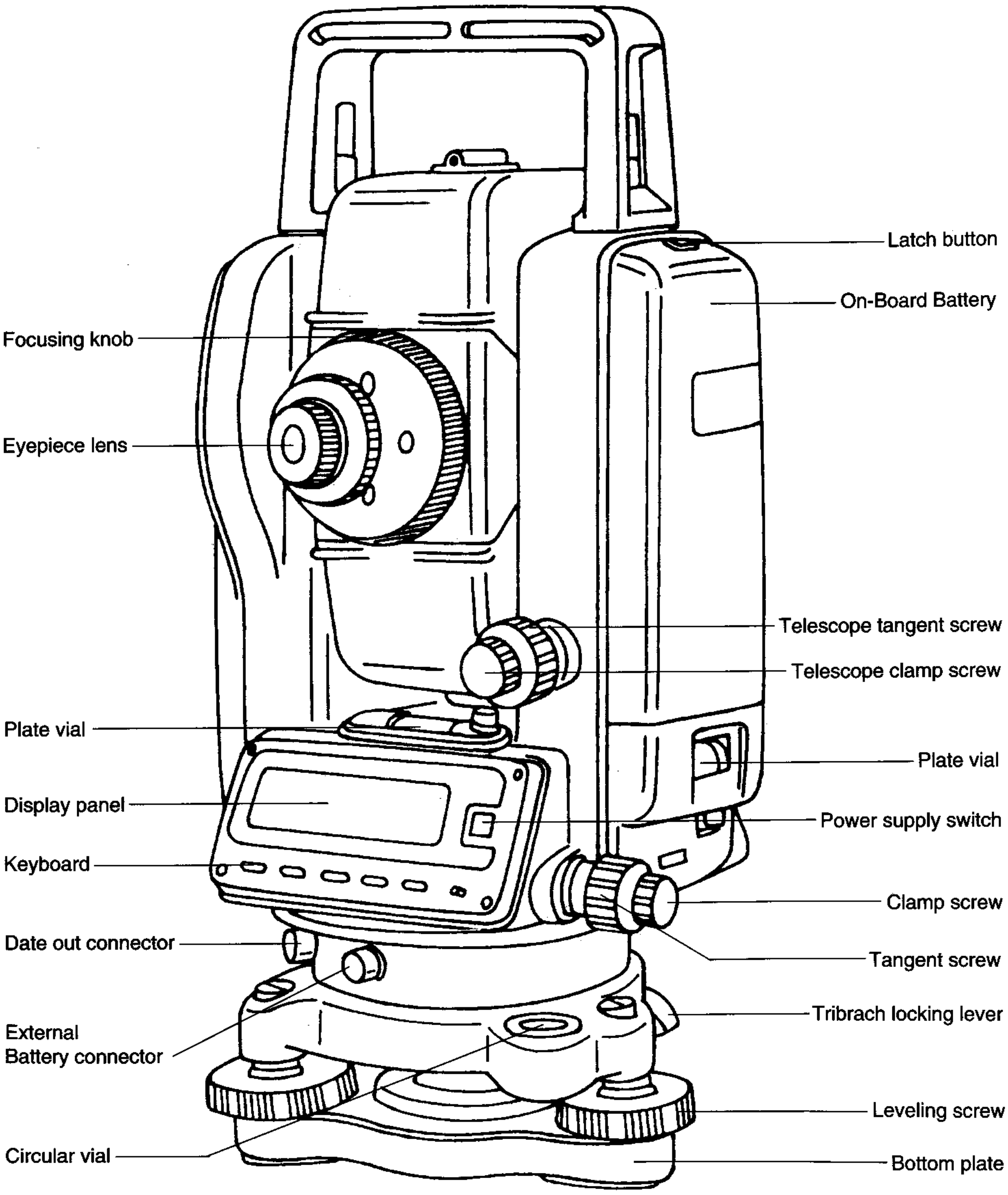
Fig 2.3: A typical colorimeter

Total Stations and Global Positioning System (GPS)

A total station is an optical instrument used in modern surveying and archaeology as well as by police, crime scene investigators, private accident reconstructionists and insurance companies to take measurements of scenes. It is a combination of an electronic theodolite (transit), an electronic distance meter (EDM) and software running on an external computer known as a data collector.

With a total station one may determine angles and distances from the instrument to points to be surveyed. With the aid of trigonometry and triangulation, the angles and distances may be used to calculate the coordinates of actual positions (X, Y, and Z or northing, easting and elevation) of surveyed points, or the position of the instrument from known points, in absolute terms. The data may be downloaded from the theodolite to an external computer and application software will generate a map of the surveyed area.

Some modern total stations are 'robotic' allowing the operator to control the instrument from a distance via remote control. This eliminates the need for an assistant staff member to hold the reflector prism over the point to be measured. The operator holds the reflector him/herself and controls the total station instrument from the observed point. Below (Fig. 2.4) are images of a total station.



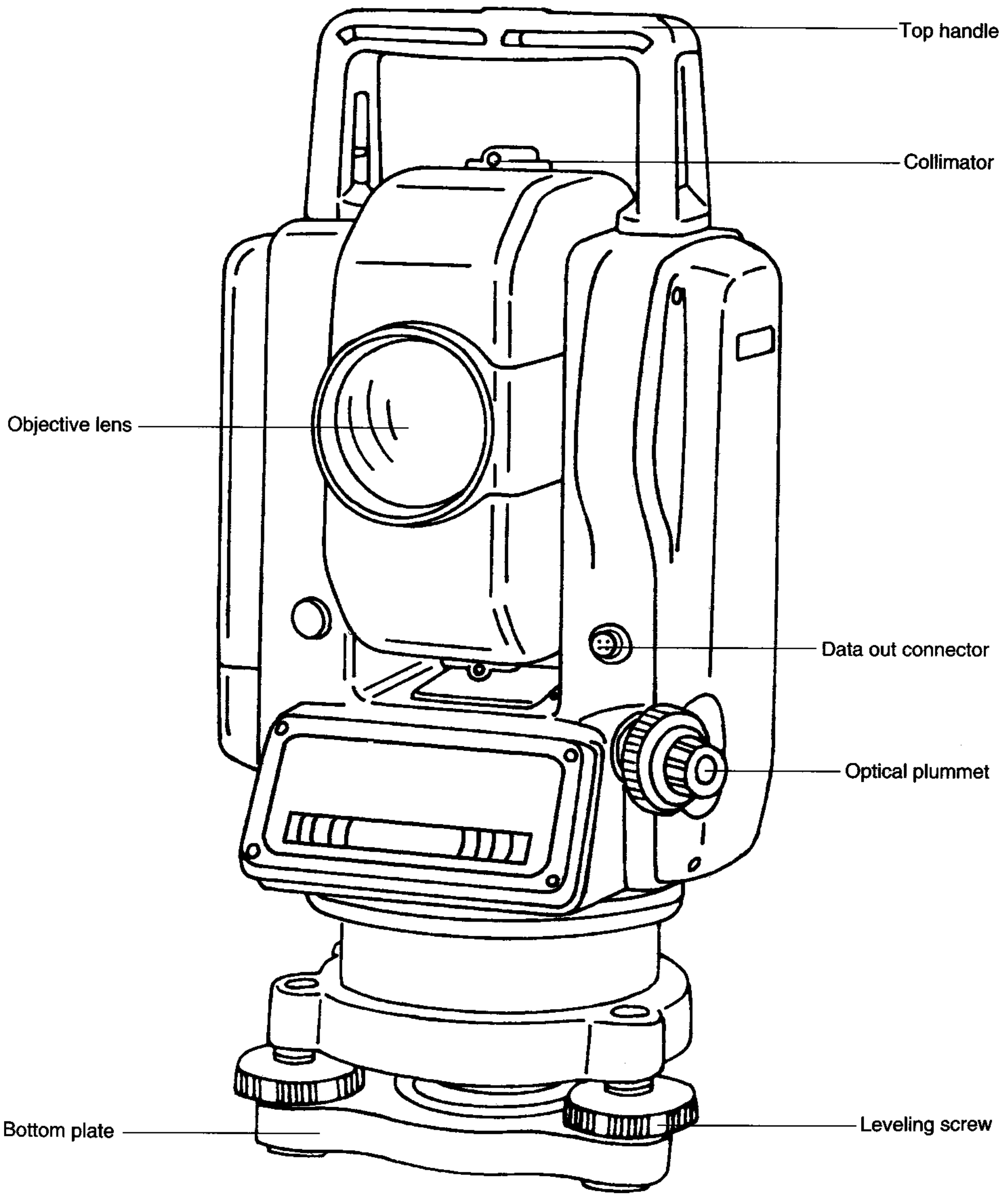


Fig. 2.4: Image of a Total station

Global Positioning Systems

A GPS receiver is used to locate positions on the earth surface. It calculates its position by carefully timing the signals sent by the constellation of GPS satellites high above the Earth. Each satellite continually transmits messages containing the time the message was sent, a precise orbit for the satellite sending the message (the ephemeris), and the general system health and rough orbits of all GPS satellites (the almanac). These signals travel at the speed of light through outer space, and slightly slower through the atmosphere. The receiver uses the arrival time of each message to measure the distance to each satellite thereby establishing that the GPS receiver is approximately on the surfaces of spheres centered at each satellite. The GPS receiver also uses when appropriate the knowledge that the GPS receiver is on (if vehicle altitude is known) or near the surface of a sphere centered at the earth center. This information is then used to estimate the position of the GPS receiver as the intersection of sphere surfaces. The resulting coordinates are converted to a more convenient form for the user such as latitude and longitude, or location on a map, and then displayed.

Fig. 2.4: A GPS being use to track positions

Remote Sensing imageries

These are images/ries derived from aerial photo and satellite observations. Examples of investigations and suitable satellite sensors are given below:

Investigation	**Suitable sensors**
Chlorophyll concentration	Landsat, ASTER, MODIS
Biomass	Air Photos, MODIS
Canopy Structure and Height	Lidar, IFSAR
Absorbed Photosynthetically Active Radiation (APAR)	MODIS, Landsat, IKONOS
Evapotranspiration	Landsat, SPOT, CASI, MODIS, ASTER
Soil Moisture	Radarsat, ERS-1,2
Surface Temperature	SeaWIFS, GOES, AVHRR, Daedalus,MODIS
Ocean Properties	POSEIDON/TOPEX, SeaWIFS , MODIS

4.0 CONCLUSION

You have learnt in this unit that some basic instrumentation in Environmental investigations are remotely controlled, with little manual involvement. The advantage of this is that manual error is likely to be reduced, but what of the errors from the machines? This means that the machines have to be rightly calibrated and tested before use.

5.0 SUMMARY

Remote sensing has been defined as the art, science and technique of obtaining information from parts of the earth’s system with a device that is not in physical contact with the object of interest. The process involved has been described as starting from a source of illumination to when the result is produced and desirably applied. You have learnt that based on this principle, some instruments for environmental investigations work; equipment such as spectrophotometers, GPS, Aerial photography, Total stations etc work on remote sensing principles. They are fast, accurate, yielding timely results only if properly calibrated and use. Some examples have been given too to illustrate this. The next few units will be more specific.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is remote sensing?
2. Describe the technique of remote sensing
3. List and describe 3 remote sensing equipments used for environmental investigations

7.0 REFERENCES/FURTHER READING

Jain, Anil K. (1989). *Fundamentals of Digital Image Processing***.** New Jersey: Prentice-Hall.

Campbell, J.B. (1987). *Introduction to Remote Sensing***.** New York: The Guilford Press.

UNIT 3 PRINCIPLES OF QUADRAT SURVEY

CONTENTS

1.0 INTRODUCTION

This Unit elucidates the general aspect of Quadrat Survey; its purpose and approach for ecological study. Ecology is the scientific study of the distribution and abundance of life and the interactions between organisms and their natural environment. The Environment is a complete ecological units that function as natural systems without massive human intervention, including all vegetation, animals, microorganisms, rocks, atmosphere and natural phenomena that occur within their boundaries. Therefore an ecological investigation is that which is concerned with study of all the biotic (living) and abiotic (non living organisms) in an environment. But because the total land environment cannot be studied, for obvious reasons discussed in Unit 1, samples have to be taken. An acceptable way of doing this is to conduct a Quadrat survey. And by the end of this Unit, it is expected that you would have learnt to achieve the following objectives

2.0 OBJECTIVES

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

- describe a Quadrat
- describe how you will construct one
- describe how you will conduct a study with a Quadrat
- discuss the effect of the shape of a Quadrat in sampling.

3.0 MAIN CONTENT

3.1 What is a Quadrat?

If we want to know what kind of plants and animals are in a particular habitat and how many there are of each species, it is usually impossible to go and count each and every one present. It would be like trying to count different sizes and colours of grains of sand on the beach. This problem is usually solved by taking a number of samples from around the habitat, making the necessary assumption that these samples are representative of the habitat in general. In order to be reasonably sure that the results from the samples do represent the habitat as closely as possible, careful planning beforehand is essential.

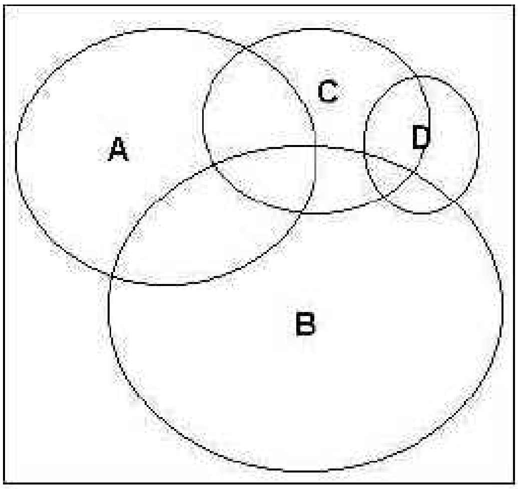
Samples are usually taken using a standard sampling unit of some kind. This ensures that all of the samples represent the same area or volume (water) of the habitat each time. The usual sampling unit is a Quadrat.
Quadrats normally consist of a square frame, the most frequently used size being $1m^2$ (see Fig. 3.1). The purpose of using a Quadrat is to enable comparable samples to be obtained from areas of consistent size and shape. Rectangular Quadrats and even circular Quadrats have been used in some surveys. It does not really matter what shape of Quadrat is used, provided it is a standard sampling unit and its shape and measurements are stated in any write-up. It may however be better to stick to the traditional square frame unless there are very good reasons not to, because this yields data that is more readily comparable to other published research. (For instance, you cannot compare data obtained using a circular Quadrat, with data obtained using a square Quadrat. The difference in shape of the sampling units will introduce variations in the results obtained).

3.2 A Quadrat

Choice of Quadrat size depends to a large extent on the type of survey being conducted. For instance, it would be difficult to gain any meaningful results using a $0.5m^2$ Quadrat in a study of a woodland canopy! Small Quadrats are much quicker to survey, but are likely to yield somewhat less reliable data than large ones. However, larger Quadrats require more time and effort to examine properly. A balance is therefore necessary between what is ideal and what is practical. As a general guideline, $0.5 - 1.0m^2$ Quadrats would be suggested for short grassland or dwarf heath, taller grasslands and shrubby habitats might require 2m Quadrats, while Quadrats of $20m^2$ or larger, would be needed for woodland habitats. At the other end of the scale, if you are sampling moss on a bank covered with a very diverse range of moss species, you might choose to use a $0.25m^2$ Quadrat.

3.3 How to use a Quadrat

To record percentage cover of species in a Quadrat, look down on the Quadrat from above and estimate the percentage cover occupied by each species (e.g. species A – D, Fig. 2.4). Species often overlap and there may be several different vertical layers. Percentage cover may therefore add up to well over 100% for an individual Quadrat.



The estimation can be improved by dividing the Quadrat into a grid of 100 squares each representing 1% cover. This can either be done mentally by imagining 10 longitudinal and 10 horizontal lines of equal size superimposed on the Quadrat, or physically by actually dividing the Quadrat by means of string or wire attached to the frame at standard intervals. This is only practical if the vegetation in the area to be sampled is very short, otherwise the string/wire will impede the laying down of the Quadrat over the vegetation.

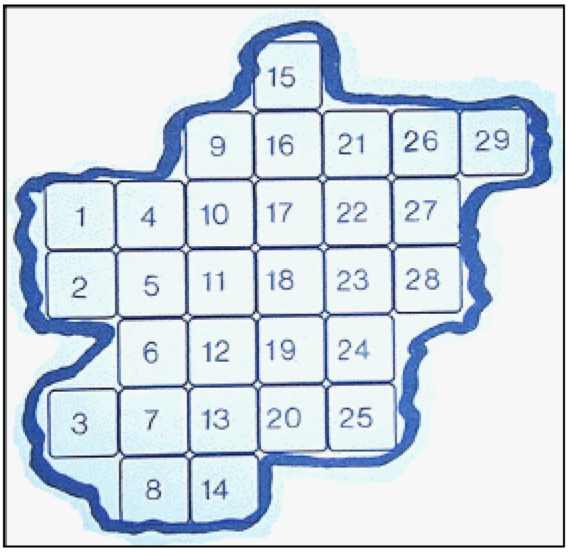


Fig. 3.1: A numbered grid map of an area to be sampled

Quadrats are most often used for sampling, but are not the only type of sampling units. It depends what you are sampling. If you are sampling aquatic microorganisms or studying water chemistry, then you will most likely collect water samples in standard sized bottles or containers. If you are looking at parasites on fish, then an individual fish will most likely be your sampling unit. Similarly, studies of leaf miners would probably involve collecting individual leaves as sampling units. In these last two cases, the sampling units will not be of standard size. This problem can be overcome by using a weighted mean, which takes into account different sizes of sampling unit, to arrive at the mean number of organisms per sampling unit

3.4 Sampling Techniques in Quadrat Survey

There are three main ways of taking samples.

a. Random Sampling

Random sampling is usually carried out when the area under study is fairly uniform, very large, and or there is limited time available. When using random sampling techniques, large numbers of samples/records are taken from different positions within the habitat. A Quadrat frame is most often used for this type of sampling. The frame is placed on the ground (or on whatever is being investigated) and the animals, and/ or plants inside it counted, measured, or collected, depending on what the survey is for. This is done many times at different points within the habitat to give a large number of different samples.

In the simplest form of random sampling, the Quadrat is thrown to fall at ‘random’ within the site. However, this is usually unsatisfactory because a personal element inevitably enters into the throwing and it is not truly random. True randomness is an important element in ecology, because statistics are widely used to process the results of sampling. Many of the common statistical techniques used are only valid on data that is truly randomly collected. This technique is also only possible if Quadrats of small size are being used. It would be impossible to throw anything larger than a $1m^2$ Quadrat and even this might pose problems. Within habitats such as woodlands or scrub areas, it is also often not possible to physically lay Quadrat frames down, because tree trunks and shrubs get in the way. In this case, an area the same size as the Quadrat has to be measured out instead and the corners marked to indicate the Quadrat area to be sampled.

A better method of random sampling is to map the area and then to lay a numbered grid over the map. A (computer generated) random number table is then used to select which squares to sample in. For example, if we have mapped our habitat, and have then laid a numbered grid over it as shown (Fig. 2.4), we could then choose which squares we should sample in by using the random number table.

b. Systematic Sampling

This can be achieved in either of the following two ways; as line or belt transects. Line transect approach is useful for showing zonation of species along some environmental gradient e.g. down a sea shore, across a woodland edge or where there is some kind of continuous variation along a line, e.g. across the heathland strips or to sample linear habitats, e.g. a roadside verge or where physical conditions demand it, e.g. sampling a vertical rock face, using a rope to climb it.

A belt transect will however supply more data than a line transect. It will give data on the abundance of individual species at different points along the line, as well as on their range. As well as showing species ranges along the line, a belt transect will also allow bar charts to be constructed showing how the abundance of each individual species changes within its range. Belt transect data will also allow the relative dominance of species along the line to be determined

3.5 What interval should be used?

For any form of Quadrat survey, the interval at which samples are taken will depend on the individual habitat, as well as on the time and effort which can be allocated to the survey.

a. Too great an interval may mean that many species actually present are not noted, as well as obscuring zonation patterns for lack of observations;

b. Too small an interval can make the sampling extraordinarily time consuming, as well as yielding more data than is needed. This can cause problems with presenting the data (line transects) as well as sometimes making it harder to see patterns of zonation because of too much 'clutter'.

c. It is important to make sure that the interval chosen does not happen to coincide with some regularly occurring feature of the habitat. For example, if sampling an old field with ridge and furrow systems still obvious, the interval should not be such that all samples are taken on a ridge, or all the samples in a furrow. (Unless, of course, the purpose of the survey is to identify any differences between ridges and furrows!)

The ideal interval will be chosen by balancing the complexity of the individual habitat with the purpose of the survey and the resources available to carry it out.

4.0 CONCLUSION

In this unit, you have learnt about the use of a Quadrat in ecological research and how different plant or animal species can be sampled and studied without bias, and with minimum error. You should at this point be able to describe, in simple terms, a Quadrat and explain its usefulness.

5.0 SUMMARY

In this Unit, we have learnt that:

- An effective way of carrying out ecological study is to conduct a quadrat survey.
- And this is done by taken samples from each quadrat.
- Usual sampling unit is a quadriat.
- Quadrats normally consist of a square frame and the most frequently used size being $1m^2$
- The purpose of using a quadrat is to enble comparable samples to be obtained from areas of unsistent size and shape.
- Choice of qudrats to be used depends to a large extent on the type of survey being conducted.
- Quadrats are most often used for sampling but they are not the only type of sampling units.
- There are three main ways of taking samples namely:

a. Radom sampling which usually carried out when the area under study is fairly uniform.
b. Systematic sampling which comprises.

i. Line transacts which is used for showing zonation of species along some environmental gradient eg. Down a seashore or across a wood land,
ii. A belt transect which will supply more data than a line transact.

- The intervals to be used in a quadrat survey will depend on the individual habitat, time and effort to be allocated to the survey.

6.0 TUTOR-MARKED ASSIGNMENT

1. Sketch and describe a Quadrat.
2. Mention 3 techniques in the use of a Quadrat.
3. Describe how you will use a Quadrat on the field.

7.0 REFERENCES/FURTHER READING

Webster, M. (1985). *Webster`s New Collegiate Dictionary*. Merriam - Webster Inc.

Salant, P. and Dillman, D. A. (1994). *How to conduct your own Survey*. John Wiley & Sons, Inc.

Patton, M.Q. (1990). *Qualitative Evaluation and Research Methods*. Newbury Park London & New Delhi: SAGE Publications.

UNIT 4 pH AND ELECTRICAL CONDUCTIVITY IN SOIL AND WATER SAMPLES

CONTENTS

1.0 INTRODUCTION

Part of the chemical characteristics of soil and water is the determinant of their acidity and solute properties. pH and Electrical conductivity seem to be the easiest way to define the chemical constituents of any substances. Both variables are known as composite variables because they tend to define the properties in terms of their overall chemical constituents. This section elucidates more on how these two variables could be derived from a given substances, what they mean and how such results are interpreted

2.0 OBJECTIVES

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

- characterize pH and electrical conductivity
- describe the methods for pH and electrical determination in soils and water samples.

3.0 MAIN CONTENT

3.1 What Are pH and Electrical Conductivity?

It is often useful to characterize an environment, such as a body of water, by measuring its pH and electrical conductivity (EC). pH is a measure of the acidity of the water or soil based on its hydrogen ion concentration and is mathematically defined as the negative logarithm of the hydrogen ion concentration, or pH = -log(H+), where the brackets around the H+ symbolize "concentration"

The pH of a material ranges on a logarithmic scale from 1-14, where pH 1-6 are acidic, pH 7 is neutral, and pH 8-14 are basic. Lower pH corresponds with higher (H+); while higher pH is associated with lower (H+).

Electrical conductivity (EC) is a measurement of the dissolved material in an aqueous solution, which relates to the ability of the material to conduct electrical current through it. EC is measured in units called Seimens per unit area (e.g. mS/cm, or miliSeimens per centimeter), and the higher the dissolved material in a water or soil sample, the higher the EC will be in that material.

3.2 How are pH and Electrical Conductivity Measured?

A meter and probe or litmus paper can be used to measure the pH of a sample. The more accurate, but expensive, of these methods is the meter and probe. pH meters are calibrated using special solutions, or buffers with a known pH value. Calibration protocols can be found in manufacturer's instruction.

Using litmus or pH paper is the simpler and less expensive way of measuring pH. This method employs special strips of paper that change color based on the pH of a sample solution. The strips come in a variety of resolutions, from simple acid vs. base comparison to a narrow resolution of pH values. These strips of paper can measure the difference 0.2-0.3 pH in a sample. Litmus paper changes colour based on whether the sample solution is acidic or basic, turning red or blue, respectively. pH strips indicate a sample's pH by changing color as well; these colours are indicated on the package and vary for different pH ranges and manufacturers.

Electrical conductivity can be measured using a meter and probe as well. The probe consists of two metal electrodes spaced 1 cm apart (thus the unit of measurement is microSeimens or milliSeimens per centimeter). A constant voltage is applied across the electrodes resulting in an electrical current flowing through the aqueous sample. Since the current flowing through the water is proportional to the concentration of dissolved ions in the water, the electrical conductivity can be measured. The higher the dissolved salt/ion concentration, the more conductive the sample and hence the higher the conductivity reading.

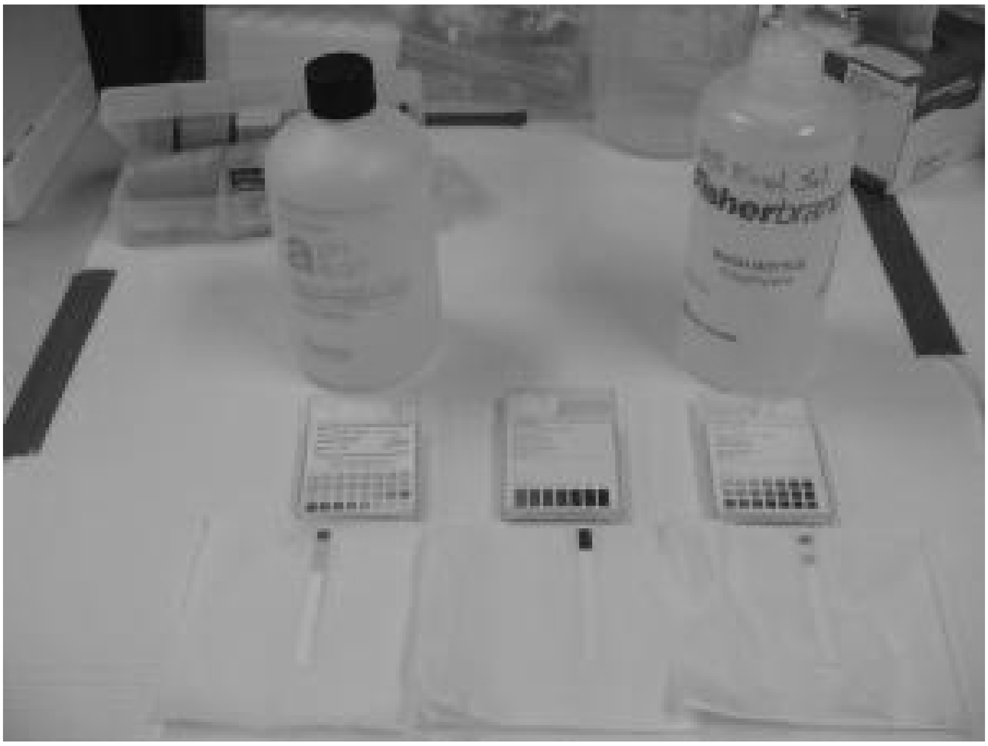
3.3 Protocols and Concerns for pH and EC Measurements

The following are general protocols for measuring pH and EC. Manufacturer's instructions and guidelines should be followed, if available

Measuring pH using litmus paper or pH strips:

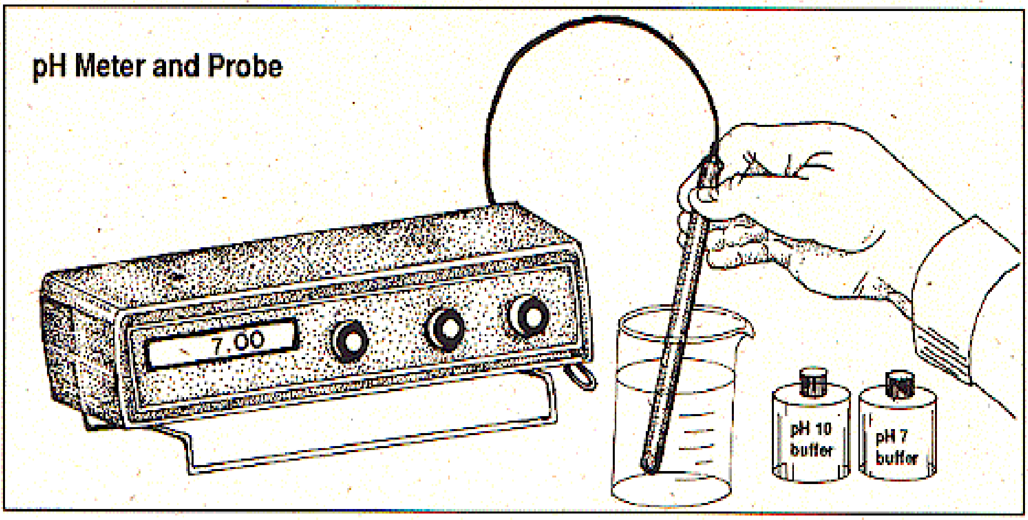
- Place a droplet of sample on the paper - be sure you drop or pour the sample over the paper rather than dipping the paper into the sample, as the latter may contaminate the sample.

- Observe colour change on the paper. If using litmus paper the paper will turn a red or pink color if the sample is acidic, while a blue paper indicates a basic sample. If using pH strips, colors corresponding to pH values should be listed on the packaging.



These pH strips can measure pH in a series of ranges by putting sample on a strip and comparing its colour change with colors on the box that correspond to a certain pH. The strip on the left measures pH 0-7 and shows results of a strong acid sample; the center strip is pH range 5-10 and shows results of a 6.97 buffer solution sample; the strip on the right measures a broad range (pH 1-14) and shows results of a 10% bleach water solution sample.

3.3.1 Measuring pH of a liquid using a pH Meter and Probe



- Turn on the pH meter and calibrate the probe using two standard solutions (pH 4, 7, and 10 buffers are recommended, dependant on the range you are measuring). Calibration procedures vary by instrument, so following the manufacturer's instructions is highly recommended. pH meters should be calibrated before each use (before each series of samples, not between each sample itself) or when measuring a large range of pH.

- Check calibration by measuring the pH of the standard solutions in measure rather than calibrate mode.

- Collect sample water in a glass or plastic container. Collect enough so the probe tip can be submerged in sample; either rinse the probe with deionized water (and blot dry) or with sample before inserting the probe into the collection vessel.

- Submerge the probe into the sample and wait until the pH reading on the meter stabilizes. Many meters have automatic temperature correction (ATC), which calculates the pH taking into account temperature, if your meter does not have this feature, you may need to adjust a knob on the meter to correct the pH for temperature. Record the measurement when the pH reading is stable.

3.3.2 Measuring EC of a liquid Sample using a Meter and Probe

- Turn on the EC meter and calibrate the probe using a standard solution of known conductivity (choose a standard close to what you believe the sample is). Calibration procedures vary by instrument, so following the manufacturer's instructions is highly recommended. Be sure to rinse the probe thoroughly before and after calibration using deionized water and carefully blot the probe dry using a clean wipe. EC meters should be calibrated before each use (before each series of samples, not between each sample itself) or when measuring a large range of EC.

- Check calibration by measuring the EC of the standard solutions in measure rather than calibrate mode.

- Collect sample water in a glass or plastic container. Collect enough so the probe tip can be submerged in sample; either rinse the probe with deionized water (and blot dry) or with sample before inserting the probe into the collection vessel.

- Submerge the probe into the sample and wait until the EC reading on the meter stabilizes. Many meters have automatic temperature correction (ATC), which calculates the EC taking into account temperature, if your meter does not have this feature, you may need to adjust a knob on the meter to correct the EC for temperature. Record the measurement when the EC reading is stable.

These three meters and probes can measure pH (left) and electrical conductivity (center and right

3.3.3 Measuring Soil pH

Soil pH can be measured using a pH meter (usually mixing the soil sample with water or a salt solution) or by adding a dye to the soil and observing a color change that can be compared with a chart for pH determination. The latter method can be done using a kit that contains the necessary chemicals.

3.3.4 Measuring Soil EC

Soil EC can be measured via electrodes inserted directly into the ground or by extracting soil water using a lysimeter (an instrument that uses suction to extract soil or groundwater from the ground. EC of groundwater can also be measured using a probe inserted into a well (a perforated tube inserted into the ground that can measure water table height) or piezometer (a tube only open at the bottom that measures the water potential at the depth where the opening is located). The electrode method employs a special series of probes, two of which send electrical current through the soil and two of which measure the voltage drop. To measure soil water EC, water is extracted from a lysimeter, well, or piezometer and measured. Alternately, a probe attached to a meter can be lowered into a well or piezometer and the liquid EC can be measured in that manner.

3.4 Results Analysis

pH and EC measurements can vary greatly and are affected by several environmental factors including, climate, local biotic (plants and animals), bedrock and surficial geology, as well as human impacts on the land. Common values of pH and EC for particular environments can be found in the literature, such as peer-reviewed journal articles or textbooks. In general, pH readings between 1-6 are considered acidic, 7 is neutral, and 8-14 are basic. Relatively dilute waters, such as distilled water or glacial melt water have low electrical conductivities, ranging from zero to the microSeimen range, whereas temperate streams and lakes, especially those with a significant groundwater contribution, generally have higher electrical conductivities.

4.0 CONCLUSION

Now you can determine the pH and EC of your sample. How will you do this and what is the importance of such activities? I believe that this is what you have learnt in this unit. At the end of the summary answer the Tutor-Marked Assignment.

5.0 SUMMARY

You have learnt from this unit that pH and EC are variables that collectively describe the chemical properties of substances. They can be measured separately, however, pH can be measured through the qualitative approach of a litmus test and the use of electrode method. EC cannot be determined by litmus test but by electrode coupled to an EC meter. The samples could be obtained from anywhere. The impact of some environmental factors on the results of either of the variables was also discussed.

6.0 TUTOR-MARKED ASSIGNMENT

1. Differentiate between pH and electrical conductivity.
2. Describe how you will determine the pH and EC in a water sample using electrode probes

7.0 REFERENCES/FURTHER READING

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UNIT 5 INTRODUCTION TO LABORATORY TECHNIQUES AND INSTRUMENTATION

CONTENTS

1.0 INTRODUCTION

Important field or laboratory instruments are the Atomic Absorption Spectrophotometer (AAS) and colorimeter. They are both based on the principle discussed under 'spectrophotometer' in Unit 2. AAS and Colorimeter, Spectrophotometer and Chromatography are important techniques for analysis of samples in either liquid or gaseous forms. These basic techniques are important in chemical analyses. Please note their similarities and differences as you read along.

2.0 OBJECTIVES

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

- describe an AAS, colorimeter, spectrometer and chromatography system
- compare and make contrast in the workings of the equipments
- describe the importance of the techniques.

3.0 MAIN CONTENT

3.1 AAS

AAS is an instrument / technique for determining the concentration of a particular metal element in a sample. It can be used to analyze the concentration of over 62 different metals in a solution. Although it dates to the 19th century, the modern form was largely developed during the 1950s by a team of Australian chemists. They were led by Alan Walsh and worked at the CSIRO (Commonwealth Science and Industry Research Organization) Division of Chemical Physics in Melbourne, Australia.

Atomic absorption spectrophotometry provides accurate quantitative analyses for metals in water, sediments, soils or rocks. Samples are analyzed in solution form, so solid samples must be leached or dissolved prior to analysis

Atomic absorption units have four basic parts: interchangeable lamps that emit light with element-specific wavelengths, a sample aspirator, a flame or furnace apparatus for volatilizing the sample, and a photon detector (Fig. 5.1a). In order to analyze for any given element, a lamp is chosen that produces a wavelength of light that is absorbed by that element. Sample solutions are aspirated into the flame. If any ions of the given element are present in the flame, they will absorb light produced by the lamp before it reaches the detector. The amount of light absorbed depends on the amount of the element present in the sample. Absorbance values for unknown samples are compared to calibration curves prepared by running known samples.

The technique typically makes use of a flame to atomize the sample but other atomizers such as a graphite furnace or plasmas, primarily inductively coupled plasmas, are also used

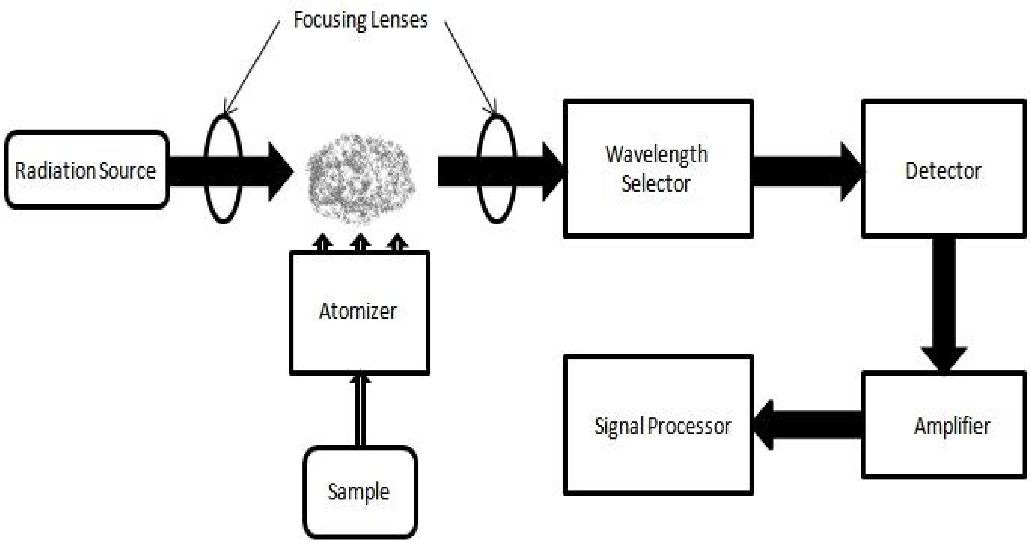


Fig. 5.1: A block diagram of a typical AAS

A liquid sample is normally turned into an atomic gas in three steps:

1. **Desolvation –** the liquid solvent is evaporated, and the dry sample remains

2. **Vaporization –** the solid sample vaporises to a gas

3. **Atomization –** the compounds making up the sample are broken into free atoms.

3.2 Colorimetric Analysis

Colorimetric equipment is similar to that used in spectrophotometry. Some related equipment is also mentioned for completeness. A colorimeter is a device used to test the concentration of a solution by measuring its absorbance of a specific wavelength of light.

To use this device, different solutions must be made, and a control (usually a mixture of distilled water and another solution) is first filled into a cuvette and placed inside a colorimeter to calibrate the machine. Only after the device has been calibrated can you use it to find the densities and/or concentrations of the other solutions. You do this by repeating the calibration, with cuvettes filled with the other solutions. The filter on a colorimeter must be set to red if the liquid is blue. The size of the filter initially chosen for the colorimeter is extremely important, as the wavelength of light that is transmitted by the colorimeter has to be same as that absorbed by the substance.

For your information, a cuvette is a kind of laboratory glassware; usually a small tube of circular or square cross section, sealed at one end, made of plastic, glass, or optical grade quartz and designed to hold samples for spectroscopic experiments. The best cuvettes are as clear as possible, without impurities that might affect a spectroscopic reading. Like a test tube, a cuvette may be open to the atmosphere on top or have a glass or Teflon cap to seal it up. Parafilm can also be used to seal it.
The essential parts of a colorimeter are:

- a light source (often an ordinary low-voltage filament lamp)
- an adjustable aperture
- a set of colored filters
- a cuvette to hold the working solution
- a detector (usually a photoresistor) to measure the transmitted light
- a meter to display the output from the detector

In addition, there may be:

- a voltage regulator, to protect the instrument from fluctuations in mains voltage.
- a second light path, cuvette and detector. This enables comparison between the working solution and a "blank", consisting of pure solvent, to improve accuracy.

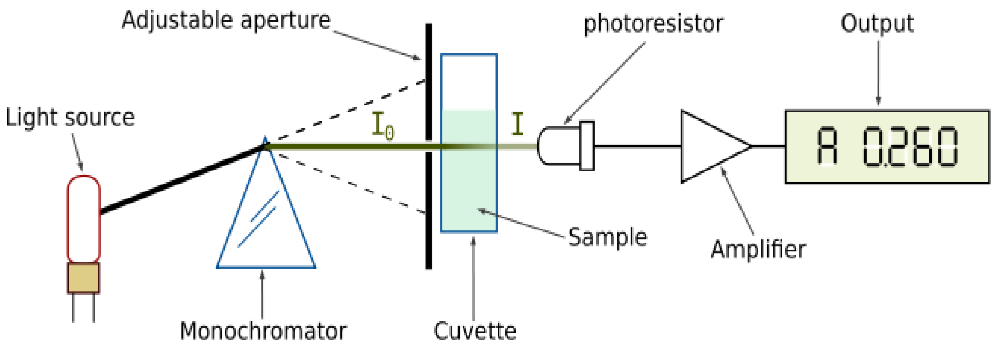


Fig. 5.2: Composition of a typical colorimeter

3.3 Mass Spectrometry

This is an analytical technique that identifies the chemical composition of a compound or sample based on the mass-to-charge ratio of charged particles. A sample undergoes chemical fragmentation forming charged particles (ions). The ratio of charge to mass of the particles is calculated by passing them through electric and magnetic fields in a mass spectrometer.

The design of a mass spectrometer has three essential modules: an *ion source*, which transforms the molecules in a sample into ionized fragments; a *mass analyzer*, which sorts the ions by their masses by applying electric and magnetic fields; and a *detector*, which measures the value of some indicator quantity and thus provides data for calculating the abundances of each ion fragment present. The technique has both qualitative and quantitative uses, such as identifying unknown compounds, determining the isotopic composition of elements in a compound, determining the structure of a compound by observing its fragmentation, quantifying the amount of a compound in a sample, studying the fundamentals of gas phase ion chemistry (the chemistry of ions and neutrals in a vacuum), and determining other physical, chemical, or biological properties of compounds.

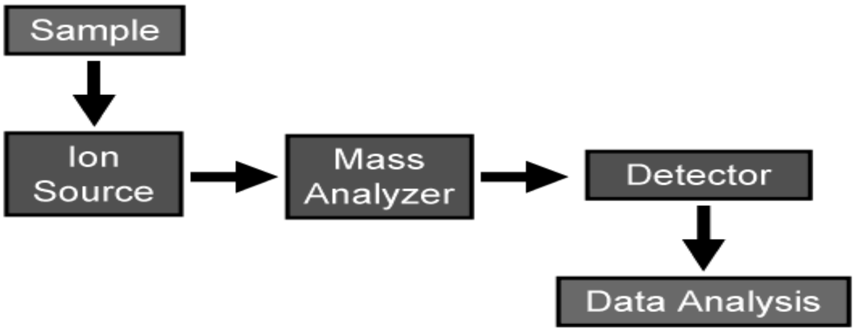


Fig. 5.3: an operational scheme of a Mass Spectrometer

3.4 Chromatography

Chromatography is the collective term for a family of laboratory techniques for the separation of mixtures. It involves passing a mixture dissolved in a "mobile phase" through a *stationary phase*, which separates the analyte to be measured from other molecules in the mixture and allows it to be isolated.

Chromatography may be preparative or analytical. Preparative chromatography seeks to separate the components of a mixture for further use (and is thus a form of purification). Analytical chromatography normally operates with smaller amounts of material and seeks to measure the relative proportions of analytes in a mixture. The two are not mutually exclusive. The procedure could be specific, examples of wich are GC and ion exchange chromatography.

Gas chromatography (GC), also sometimes known as Gas-Liquid chromatography, (GLC), is a separation technique in which the mobile phase is a gas. Gas chromatography is always carried out in a column, which is typically "packed" or "capillary".

GC is based on a partition equilibrium of analyte between a solid stationary phase (often a liquid silicone-based material) and a mobile gas (most often Helium). The stationary phase is adhered to the inside of a small-diameter glass tube (a capillary column) or a solid matrix inside a larger metal tube (a packed column). It is widely used in analytical chemistry; though the high temperatures used in GC make it unsuitable for high molecular weight biopolymers or proteins (heat will denature them), frequently encountered in biochemistry, it is well suited for use in the petrochemical, environmental monitoring, and industrial chemical fields. It is also used extensively in chemistry research.

Ion exchange chromatography utilizes ion exchange mechanism to separate analytes. It is usually performed in columns but the mechanism can be benefited also in planar mode. Ion exchange chromatography uses a charged stationary phase to separate charged compounds including amino acids, peptides, and proteins. In conventional methods the stationary phase is an ion exchange resin that carries charged functional groups which interact with oppositely charged groups of the compound to be retained. Ion exchange chromatography is commonly used to purify proteins using FPLC.

4.0 CONCLUSION

So far you have learnt about the operations of some laboratory equipments, i.e. AAS, colorimeter, chromatography system and a mass spectrometer. But there are many more questions to answer. Which properties of samples will these techniques determine; metals, non metals or gases? These are the issues to think about and ask your teacher in the class.

5.0 SUMMARY

The unit has introduced us to some methods for the determination of some basic ions in scientific investigations. Three important methods have been highlighted, and these include the AAS, chromatography, mass spectrometry and chromatography techniques. These have been briefly discussed and their principles of operations. But now, it is essential that you attempt these questions to assess your understanding of this unit.

6.0 TUTOR-MARKED ASSIGNMENT

1. Make a contrast among AAS, Colorimeter, Mass Spectrometer and chromatography system.
2. What features are common to the three techniques?

7.0 REFERENCES/FURTHER READING

American Public Health Association, American Water Works Association, and Water Environment Federation. (2005). *Standard Methods for the Examination of Water and Wastewater, 21st edition.* American Public Health Association, Washington, D.C

Atomic Absorption and Fluorescence Spectrophotometry with a Carbon Filament Atom Reservoir, Part IX: *The direct Determination of Silver and Copper in Lubricating Oils*, J.F. Alder, and West, T.S., Anal. Chim. Acta., 58**,** 331 (1972).

MODULE 2

UNIT 1 INSTRUMENTATION FOR AIR SAMPLING AND ANALYSES

CONTENTS

1.0 INTRODUCTION

Determination of the gases in air is a complex task because of the wide variety of compounds of interest and the lack of standardised sampling and analysis procedures. This unit will introduce you to the procedure and instrumentation of carbon monoxide (CO) and carbon IV oxide (CO_2), nitrogen IV oxide (NO_2), aerosols and particulate matter. Please note that this unit will only discuss one of the two identified methods of air sampling, the grab or short term method. You are also advised to check the manual of any equipment you adopt for use in analysis for specific information. Notwithstanding the methods discussed in this material are accepted worldwide.

2.0 OBJECTIVES

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

- identify the types of instrumentation for air sampling
- identify and describe the methods of air sampling for short term analysis
- assess the features of grab approach to air sampling.

3.0 MAIN CONTENT

3.1 Types of Air Sampling Instrumentation

Two kinds of air sampling instrumentation are known. They are:

1. methods requiring laboratory analysis of collected samples; and

2. direct reading instrumentation capable of sampling a volume of air, performing immediate analysis internally, and displaying results visually

The first group of activities involved two methods, namely

1. **Grab, instantaneous or short term:** using this approach, a volume of air containing a gaseous contaminant is collected over a short period of time, usually from seconds to less than 2 minutes. Results of the sample analysis are representative of the air – borne concentration of the contaminant, at the sampling location at that point in time.

2. **Integrated (average or long term)** sample in which known volume of air is metered through an appropriate absorbing or adsorbing medium to remove the gaseous contaminant from the sample air stream. Depending on the circumstances, the sample period may vary from partial period sample of less than one hour to a full 8 hour sample. Analysis of these samples yield integrated, average, or long term data reflecting the overall condition of the air for that sample period.

3.1.1 Grab Samples

Grab sampling is best employed in monitoring several phases of a cyclic process and for determining peak concentrations where levels of a contaminant generated by an activity vary over time. A wide spectrum of gas collection devises have been used to collect grab samples, including evacuated flasks, or metal cylinders, syringes, plastic bags, and gas and liquid – displacement containers

3.1.1.1 Evacuated Containers

These are usually heavy walled, glass containers ranging in size from 200 to 1000 cubic centimetres (cc), in which air has been partially or completely removed. These air collection devices have been successfully used in the mining industry.

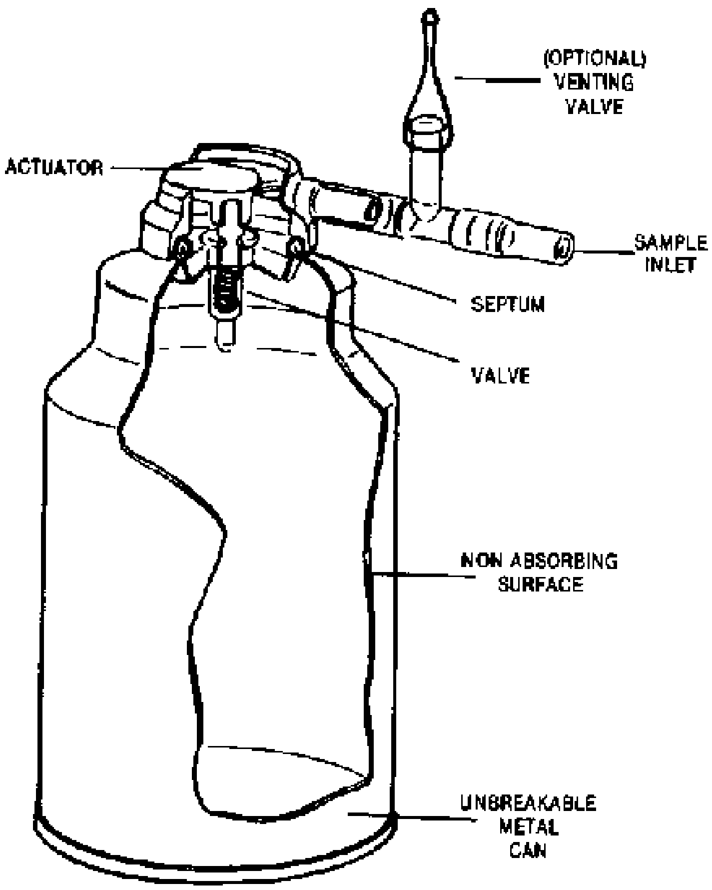


Fig. 6.1: A typical steel evacuated sampler

Modern Evacuated Containers are smaller, 50 to 250 cc glass bulbs that have been evacuated with a vacuum pump and he neck sealed by heating and drawing the open end to a tip during the final stages of evacuation. To collect an air sample, the etched tip of the bulb is broken; the surrounding atmosphere enters and fills it to atmospheric pressure. The container is then resealed and submitted to the laboratory for analysis.

Fig. 6.1 shows a lightweight, steal evacuated container lined with a non absorbing interior surface. It was first designed and used as a breath alcohol tester in forensic applications. Its use has however been presently extended to air sampling for a variety of organic vapours including benzene, methyl ethyl ketone, styrene, and vinyl chloride. Sample collection is achieved by pressing a button which activates the sampler. After the sample has been collected, the sampler is submitted to the laboratory for analysis.

With the availability of more sensitive analysis analytical instrumentation however, smaller sample volumes have been found to be adequate. This led to the use of 10 cc vacutainer syringe system

3.1.1.2 Vacutainer Syringe system

The operation of this instrument is similar to that of the conventional hypodermic syringes. The vacutainer system is an evacuated glass test tube shaped vessel, capped with a self – sealing butyl rubber spectrum.

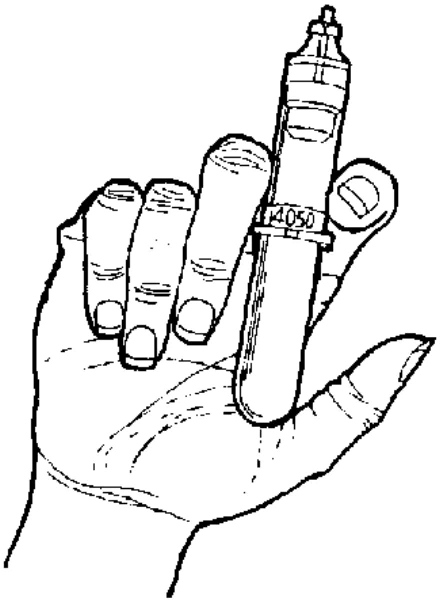


Fig. 6.2: A Vacutainer Syringe system

To draw a sample, the tube is inserted into a holder equipped with a needle which punctures the rubber septum allowing air from the surrounding atmosphere to be drawn into the tube. After the sample is drawn, the glass tube is removed from the holder and the septum self seals. Advantages of the Vacutainer system are that the syringes are small, light weight, economical, convenient and simple to use. Hypodermic syringes have also been used in similar way to collect air samples.

3.1.1.3 Gas Sampling Bags

These have been used successfully to collect air samples containing organic and inorganic gases and as a static system for the preparation of known concentrations of gases for the calibration of air sampling instrumentation. Grab bag sampling provides a simple, uncomplicated, and relatively economical means of collecting and transferring air samples to a laboratory for analysis.

An important feature of plastic bag sampling is that it offers the option of short term sampling or for a longer period, depending on the size of the bag and the pump flow rate. Common field application of this technique is the use of a single portable analytical instrument to analyse multiple samples on site (where they are collected). Immediate on – site testing of a gas has an important advantage in that it greatly reduces the possibility of gas decomposition before analysis.

Plastic bags are commercially available and come in a variety of sizes and shapes with the 1 – 15 litre volume appearing to be the most useful for grab or short term sampling. In addition, most plastic air sampling bags can be obtained with a number of convenient accessories, such as twist – lock open and shut – off valves, through which air can be easily sampled or discharged, and special permanent or replaceable rubber septums, through which air samples can be removed with a syringe.

3.1.1.4 Gas or Liquid Displacement Collectors

These are primarily 250 – 300 ml glass aspirator bulbs fitted with end tubes which can be conveniently opened and closed with a greased stop –cocks. Air samples are collected by aspirating the test atmosphere through the sample container with a suitable source of suction (bulb aspirator, hand pump, battery, or electrically operated vacuum pump) until its original content of air is replaced. Larger aspirator vessels can be used where large volumes of test atmosphere or longer term sampling are required.

Air samples can also be collected by liquid displacement. This method entails filling the container with a suitable liquid (usually water) and allowing it to drain out at sampling location, whereupon the test atmosphere enters the container as the liquid is displaced. Application of this method is limited to gases which are insoluble or non reactive with the displaced liquid. Although these methods were once routinely used for collecting air samples in work atmospheres and in laboratory studies, they receive little use today in developed countries because of more convenient and accurate methods.

3.1.2 Features of Grab Air Sampling

Because the quantity of material collected with gas sampling is often small, sensitive analytical methods are required to test and measure concentrations of the gaseous contaminant collected. This has been a limiting factor in using the grab sample in the past. Consequently, grab sampling has, to a large extent been restricted to the collection of gross quantities of gases in the air such as methane, oxygen, carbon dioxide, carbon monoxide, and nitrogen. However the use of grab samples for the collection of low levels of gaseous contaminants has been greatly extended by advances in the refinement of sensitive analytical procedures and instruments based on chromatography and spectrophotometry.

Grab samplers should not be used to collect reactive gases such as hydrogen sulphide, oxides of nitrogen, sulphur oxides, etc unless the samples can be analysed within a short time after collection. Without prompt analysis, these gases can react with dust particles, moisture in the stopper, sealant compounds, and the glass container to alter a sample's chemical composition and result in an erroneous estimate of the concentration. This problem can sometimes be overcome by collection the reactive gas in a convectional vacuum – type (evacuated) sample container prepared with an appropriate absorbing reagent to stabilise and preserve the sample until analysis can be accomplished.

Another important feature of grab sampling is that the collection efficiency is normally 100%. However, sample decay can occur for several reasons. To limit or avoid this source of error, after introducing the sample of contaminated air into the container, it should be properly sealed to prevent sample loss and analysed in the field or submitted to the laboratory as soon as possible.

Unlike convectional liquid and solid sorbent sampling, gas flow measurements are not necessary with grab sampling devices because the air sample collected can be metered directly from the sample container into the analytical instrument, or measured volumes of the air sample can be drawn from the sampling device with a syringe and injected directly into the injection port of the analytical instrument. However, it is necessary to include the temperature and pressure (normally 25^oC and 760mm mercury) at which the air sample was collected in order that results of the sample analysis can be reported in terms of standard conditions.

4.0 CONCLUSION

In conclusion we learnt about the various types of air sampling instrumentation. The various Grap Samples were also discussed in this unit.

5.0 SUMMARY

This unit has demonstrated the importance of air sampling. You have learnt that there are two basic types; grab and integrated approaches. You have also learnt the different instruments used for grab samples as well as the specific importance of each. This unit has equally revealed to you some features of grab samples. You should therefore be able to do the following Tutor-Marked Assignment.

6.0 TUTOR-MARKED ASSIGNMENT

1. State 2 differences between grab sampling and integrated sampling procedures air study.
2. Write 3 features of the grab samples.
3. Mention 4 instruments for grab sampling of the air

7.0 REFERENCE/FURTHER READING

Platt, U. (1999). *Modern Methods of the Measurement of Atmospheric Trace Gases.* Invited Lecture, Phys. Chem. Chem. Phys., 1, 5409 – 5415.

UNIT 2 INTEGRATED OR LONG TERM AIR SAMPLING

CONTENTS

1.0 INTRODUCTION

Integrated sampling procedure for air borne gaseous agents is desired when (a) significant temporal variation is noticed in the volume of the contaminant(s) (b) when ambient concentrations of the contaminant (s) are low and sampling over an extended period of time is required to satisfy the sensitivity requirements of the analytical method, and / or (c) to obtain reliable estimate of the concentration of the contaminant in the air and the exposure of the people to it.

The collection of integrated samples usually involves extraction and concentration of gaseous contaminants from a sample air stream, employing the principles of absorption, adsorption or condensation. However, only those dealing with the principle of absorption will be treated in this course material. You are therefore expected to be able to do the following tasks at the end of this unit

2.0 OBJECTIVES

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

- describe the conditions necessary for the adoption of integrated sampling procedure
- describe some integrated air sampling instruments.

3.0 MAIN CONTENT

3.1 The Principle of Absorption

In this method the gaseous contaminant is extracted from the sampled air stream and concentrated in solution by drawing it through an absorbing liquid or reacting it with an absorbing reagent. Four basic absorbers can be used: simple gas wash bottles, spiral or helical absorbers, fritted bubblers, and glass beaded columns. The selection of an appropriate absorbing device depends upon the solubility and reactivity of the gaseous agent been collected.

3.2 Examples of Integrated Air Samplers

Simple gas wash bottles such as the Greenberg – Smith and midget impinger are suitable for sample collection of non reactive gases that are highly soluble in absorbing liquids and form near perfect solutions such as methanol in water and esters in alcohols. High collection efficiency can also be achieved by utilising specific absorbing reagents which react rapidly with the gaseous contaminant, chemically changing it to a more stable form. The midget impinger has been the most widely used gas washing bottle for sampling of gases. They can be used to collect general area air samples from a stationary point position; they can be held to a point device breathing zone samples.

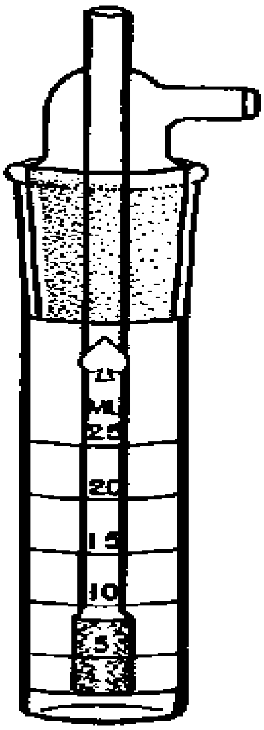


Fig. 7.1: A midget impinger

A serious problem often encountered in the field is accidental spillage of the absorbed liquid by the field man bending over and inverting the impinger. However, spillproof impringers have been developed and are commercially available. The collection efficiency can be increased by entraining two or more impingers in series.

Spiral Type Absorbers

These are examples of gas wash bottles that can be used to collect gaseous substances that are only moderately soluble or slow reacting with reagents in the absorbing medium. These absorbers are essentially the same as those for simple gas wash bottles except that the spiral or helical structure design provides for higher collection efficiency by forcing the air sample to travel a spiral or helical path through the liquid. This takes five to ten times longer than the simple wash bottle; allows a longer contact between the sampled air and the absorbing solution.

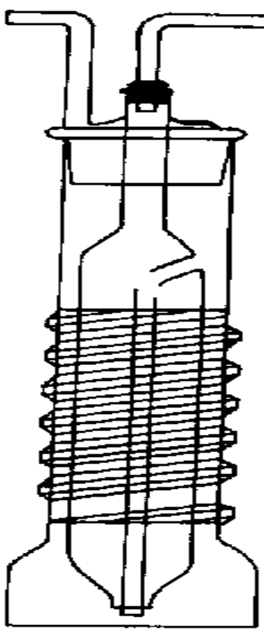


Fig. 7.2: Spiral absorber

Fritted Bubblers

These are the most commonly used absorbing devices in the field today for sampling gaseous air contaminants in ambient work atmospheres. They are more efficient collectors than simple gas wash bottles and can be used to collect gases that are only slightly soluble or reactive with the absorbing liquid medium. The principle involves drawing the air sample through a sintered or fritted glass bubbler which is submerged in an absorbing solution or reagent. As the sampled air is drawn through the fritted bubbler, many small bubbles and a heavy froth develop, increasing the surface area and contact time between the gaseous contaminant and the absorbing solution. Air bubble size is dependent upon the nature of the absorbing liquid and diameter of the orifices from which the bubbles emerge.

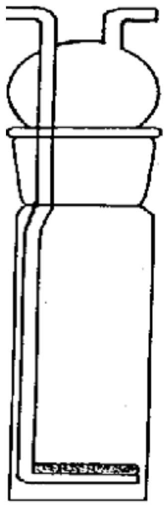


Fig. 7.3: Fritted bubbler

Frits are classified as fine, coarse and extra coarse depending on the number of openings per unit area. Coarse frits are used when a rapid sample rate is desired and when the gaseous contaminant sampled is appreciably soluble and/or reactive in the absorbing liquid medium. Medium porosity frits are used gases that are more difficult to collect, and fine porosity frits are used for highly volatile gaseous substances that are extremely difficult to collect. In general, smaller bubbles and greater generated froth effectuate greater surface area and contact time between the gaseous contaminant and the absorbing solution – hence, greater collection efficiency. Columns packed with glass pearl beads coated with an appropriate absorbing medium are used in special situations where a concentrated solution of a gaseous contaminant is required. The beads provide a large surface area for collection of the gaseous contaminant. This absorption method has been used successfully in the past to collect benzene and other aromatic hydrocarbon vapours in nitric acid.

4.0 CONCLUSION

This unit has ended our concern for sampling in air survey. It however deals with the practices that are not peculiar to air sampling only but to every components of the earth system; all that you study as a student of environmental science student.

5.0 SUMMARY

The knowledge that you acquired from previous study should have been updated after reading this unit. Why do we need to adopt the integrated sampling procedure for air study and what are the instruments that could be used? This unit has highlighted the answers to these questions. It is therefore hope that you will not have problem with it. Well before venturing into that, you must answer the following questions to let us know that you have gained something from this unit.

6.0 TUTOR-MARKED ASSIGNMENT

1. State 3 reasons why integrated sampling procedure is desired.
2. Describe 2 instruments that are used for integrated air sampling.

7.0 REFERENCE/FURTHER READING

Platt, U. (1999). *Modern Methods of the Measurement of Atmospheric Trace Gases*. Invited lecture, Phys. Chem. Chem. Phys., 1, 5409 – 5415.

UNIT 3 SAMPLING AS AN INSTRUMENT FOR ENVIRONMENTAL INVESTIGATION

CONTENTS

1.0 INTRODUCTION

The goal of science is to understand and explain the physical universe. Environmentalists observe the physical, chemical and biological (microbiological) world, and try to categorize and understand the phenomena they observe. This Lecture Unit is a discussion that attempts to introduce you to sampling and instrumentation in environmental researches. It is mainly designed to equip beginners with knowledge on the general issues on sampling; purpose, dangers and how to minimize them, types of sampling and guides for deciding the sample size. It is intended to prepare readers to the next series of activities on Instrumentation.

According to Webster(1985), to research is to search or investigate exhaustively. It is a careful or diligent search, studious inquiry or examination especially investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts or practical application of such new or revised theories or laws, it can also be the collection of information about a particular subject. For a clear flow of ideas, however, the definitions of sampling, population and sample are given.

Sampling is the act, process, or technique of selecting a suitable sample, or a representative part of a population for the purpose of determining parameters or characteristics of the whole population

A **population** is a group of individuals' persons, objects, or items from which samples are taken for measurement.

A **sample** is a finite part of a statistical population whose properties are studied to gain information about the whole. When dealing with people, it can be defined as a set of respondents (people) selected from a larger population for the purpose of a survey.

Well, before we go further, it is essential that you know your learning expectations for the Unit. These are included in the learning objectives stated below.

2.0 OBJECTIVES

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

- define sampling and describe it purpose in research
- outline and describe sources of errors in sampling
- describe the importance of sample size.

3.0 MAIN CONTENT

3.1 What is the Purpose of Sampling?

To draw conclusions about populations from samples, we must use inferential statistics which enables us to determine a population's characteristics by directly observing only a portion (or sample) of the population. We obtain a sample rather than a complete enumeration (a census) of the population for many reasons. Obviously, it is cheaper to observe a part rather than the whole, but we should prepare ourselves to cope with the dangers of using samples. In this lecture, we will investigate various kinds of sampling procedures. Some are better than others but all may yield samples that are inaccurate and unreliable. We will learn how to minimize these dangers, but some potential error is the price we must pay for the convenience and savings the samples provide.
There would be no need for statistical theory if a census rather than a sample was always used to obtain information about populations. But a census may not be practical and is almost never economical.

There are six main reasons for sampling instead of doing a census. These are discussed as follows:

a. The Economic Advantage

Obviously, taking a sample requires fewer resources than a census. For example, let us assume that you are one of the very curious students around. You have heard so much about the NOUN and now that you are there, you want to hear from the insiders. You want to know what all the students at NOUN think about the quality of learning they do, you know that all the students are different so they are likely to have different perceptions and you believe you must get all these perceptions so you decide because you want an indepth view of every student, you will conduct personal interviews with each one of them and you want the results in 20 days only. Let us assume this particular time you are doing your research NOUN has only 20,000 students and those who are helping are so fast at the interviewing art that together you can interview at least 10 students per person per day in addition to your 18 credit hours of course work. You will require 100 research assistants for 20 days and since you are paying them minimum wage of N5.00 per hour for ten hours (N50.00) per person per day, you will require N100,000.00 just to complete the interviews. Analysis will just be impossible. You may decide to hire additional assistants to help with the analysis at another N100,000.00 and so on, assuming you have that amount on your account.

As unrealistic as this example is, it does illustrate the very high cost of census. For the type of information desired, a small wisely selected sample of NOUN students can serve the purpose. You don`t even have to hire a single assistant. You can complete the interviews and analysis on your own. Rarely does a circumstance require a census of the population, and even more rarely does one justify the expense.

b. The Time Factor

A sample may provide you with needed information quickly. For example, you are a Doctor and a disease has broken out in a village within your area of jurisdiction, the disease is contagious and it is killing within hours nobody knows what it is. You are required to conduct quick tests to help save the situation. If you try a census of those affected, they may be long dead when you arrive with your results. In such a case just a few of those already infected could be used to provide the required information.

c. The Very Large Populations

Many populations about which inferences must be made are quite large. For example, consider the population of University Graduates in Nigeria, a group numbering 4,000,000. The responsible agency in the government has to plan for how they will be absorbed into the differnt departments and even the private sector. The employers would like to have specific knowledge about the student`s plans in order to make compatiple plans to absorb them during the coming year. But the big size of the population makes it physically impossible to conduct a census. In such a case, selecting a representative sample may be the only way to get the information required from graduates.

d. The Partly Accessible Populations

There are some populations that are so difficult to get access to that only a sample can be used. Like people in prison, crashed aeroplanes in the deep seas, presidents etc. The inaccessibility may be economic or time related. A particular study population may be so costly to reach like the population of planets that only a sample can be used. In other cases, a population of some events may be taking too long to occur that only sample information can be relied on. For example natural disasters like a flood that occurs every 100 years or take the example of the flood that occured in Noah`s days. It has never occured again.

e. The Destructive Nature of the Observation

Sometimes the very act of observing the desired characteristic of a unit of the population destroys it for the intended use. Good examples of this occur in quality control. For example to test the quality of a fuse, to determine whether it is defective, it must be destroyed. To obtain a census of the quality of a lorry load of fuses, you have to destroy all of them. This is contrary to the purpose served by quality-control testing. In this case, only a sample should be used to assess the quality of the fuses

f. Accuracy and Sampling

A sample may be more accurate than a census. A sloppily conducted census can provide less reliable information than a carefully obtained sample.

3.2 Sources of Bias and Error in Sampling

A sample is expected to mirror the population from which it comes. However, there is no guarantee that any sample will be precisely representative of the population from which it comes. Chance may dictate that a disproportionate number of untypical observations will be made like for the case of testing fuses, the sample of fuses may consist of more or less faulty fuses than the real population proportion of faulty cases. In practice, it is rarely known when a sample is unrepresentative and should be discarded.

a. Sampling Error

What can make a sample unrepresentative of its population? One of the most frequent causes is sampling error. Sampling error comprises the differences between the sample and the population that are due solely to the particular units that happen to have been selected. For example, suppose that a sample of 100 women are measured and are all found to be taller than six feet. It is very clear even without any statistical prove that this would be a highly unrepresentative sample leading to invalid conclusions. This is a very unlikely occurance because naturally such rare cases are widely distributed among the population. But it can occur. Luckily, this is a very obvious error and can be detected very easily. The more dangerous error is the less obvious sampling error against which nature offers very little protection. An example would be like a sample in which the average height is overstated by only one inch or two rather than one foot which is more obvious. It is the unobvious error that is of much concern.

There are two basic causes for sampling error.

i. **Chance:** That is the error that occurs just because of bad luck. This may result in untypical choices. Unusual units in a population do exist and there is always a possibility that an abnormally large number of them will be chosen. For example, in a recent study in which I was looking at the number of trees, I selected a sample of households randomly but strange enough, the two households in the whole population, which had the highest number of trees (10,018 and 6345) were both selected making the sample average higher than it should be. The average with these two extremes removed was 828 trees. The main protection agaisnt this kind of error is to use a large enough sample.

ii. **Sampling bias** is a tendency to favour the selection of units that have paticular characteristics. Sampling bias is usually the result of a poor sampling plan. The most notable is the bias of non response when for some reason some units have no chance of appearing in the sample. For example, take a hypothetical case where a survey was conducted recently by a Graduate school to find out the level of stress that graduate students were going through. A mail questionnaire was sent to 100 randomly selected graduate students. Only 52 responded and the results were that students were not under stree at that time when the actual case was, that it was the highest time of stress for all students except those who were writing their thesis at their own pace. Apparently, this is the group that had the time to respond. The researcher who was conducting the study went back to the questionnaire to find out what the problem was and found that all those who had responded were third and fourth PhD students.

Bias can be very costly and has to be gaurded against as much as possible. For this case, N2,000.00 had been spent and there were no reliable results, in addition, it cost the reseacher his job since his employer thought if he was qualified, he should have known that before hand and planned on how to avoid it. A means of selecting the units of analysis must be designed to avoid the more obvious forms of bias. Another example would be where you would like to know the average income of some community and you decide to use the telephone numbers to select a sample of the total population in a locality where only the rich and middle class households have telephone lines. You will end up with high average income which will lead to the wrong policy decisions.

b. Non Sampling Error (Measurement Error)

The other main cause of unrepresentative samples is non sampling error. This type of error can occur whether a census or a sample is being used. Like sampling error, non sampling error may either be produced by participants in the statistical study or be an innocent by product of the sampling plans and procedures. A non sampling error is an error that results solely from the manner in which the observations are made.

The simplest example of non sampling error is inaccurate measurements due to malfuntioning instruments or poor procedures. For example, consider the observation of human weights. If persons are asked to state their own weights themselves, no two answers will be of equal reliability. The people will have weighed themselves on different scales in various states of poor caliberation. An individual`s weight fluctuates diurnally by several pounds, so that the time of weighing will affect the answer. The scale reading will also vary with the person`s state of undress. Responses therefore will not be of comparable validity unless all persons are weighed under the same circumstances.

Biased observations due to inaccurate measurement can be innocent but very devastating. A story is told of a French astronomer who once proposed a new theory based on spectroscopic measurements of light emitted by a particular star. When his colleaugues discovered that the measuring instrument had been contaminated by cigarette smoke, they rejected his findings. In surveys of personal characteristics, unintended errors may result from the manner in which the response is elicited, the social desirability of the persons surveyed, the purpose of the study and the personal biases of the interviewer or survey writer

c. The Interviewer's Effect

No two interviewers are alike and the same person may provide different answers to different interviewers. The manner in which a question is formulated can also result in inaccurate responses. Individuals tend to provide false answers to particular questions. For example, some people want to feel younger or older for some reason known to themselves. If you ask such a person their age in years, it is easier for the idividual just to lie to you by over stating their age by one or more years than it is if you asked which year they were born since it will require a bit of quick arithmetic to give a false date and a date of birth will definitely be more accurate.

d. The Respondent Effect

Respondents might also give incorrect answers to impress the interviewer. This type of error is the most difficult to prevent because it results from out right deceit on the part of the respondee. An example of this was observed in a astudy where some farmers were asked how much maize they harvested previous year. In most cases, the men tended to lie by saying a figure higher than what they actually got. To decide which one was right, whenever possible I could in a tactful way verify with an older son or daughter. It is important to acknowledge that certain psychological factors induce incorrect responses and great care must be taken to design a study that minimizes their effect.

e. Knowing the Study Purpose

Knowing why a study is being conducted may create incorrect responses. A classic example is the question: What is your income? If a government agency is asking, a different figure may be provided than the respondent would give on an application for a home mortgage. One way to guard against such bias is to camouflage the study goals. Another remedy is to make the questions very specific, allowing no room for personal interpretation. For example, "Where are you employed?" could be followed by "What is your salary?" and "Do you have any extra jobs?" A sequence of such questions may produce more accurate information.

f. Induced Bias

Finally, it should be noted that the personal prejudices of either the designer of the study or the data collector may tend to induce bias. In designing a questionnaire, questions may be slanted in such a way that a particular response will be obtained even though it is inacurrate. For example, an agronomist may apply fertilizer to certain key plots, knowing that they will provide more favourable yields than others. To protect against induced bias, advice of an individual trained in statistics should be sought in the design and someone else aware of search pitfalls should serve in an auditing capacity.

3.3 Types of Samples

There are three primary kinds of samples: the convenience, the judgement sample, and the random sample. They differ in the manner in which the elementary units are chosen.

a. The Convenient Sample

A convenience sample results when the more convenient elementary units are chosen from a population for observation.

b. The Judgement Sample

A judgement sample is obtained according to the discretion of someone who is familiar with the relevant characteristics of the population.

c. The Random Sample

This may be the most important type of sample. A random sample allows a known probability that each elementary unit will be chosen. For this reason, it is sometimes referred to as a probability sample. This is the type of sampling that is used in lotteries and raffles. For example, if you want to select 10 players randomly from a population of 100, you can write their names, fold them up, mix them thoroughly then pick ten. In this case, every name had an equal chance of being picked. Random numbers can also be used.

i. A Simple Random Sample

A simple random sample is obtained by choosing elementary units in such a way that each unit in the population has an equal chance of being selected. A simple random sample is free from sampling bias. However, using a random number table to choose the elementary units can be cumbersome. If the sample is to be collected by a person untrained in statistics, then instructions may be misinterpreted and selections may be made improperly. Instead of using a least of random numbers, data collection can be simplified by selecting say every 10th or 100th unit after the first unit has been chosen randomly as discussed below. such a procedure is called systematic random sampling.

ii. A Systematic Random Sample

A systematic random sample is obtained by selecting one unit on a random basis and choosing additional elementary units at evenly spaced intervals until the desired number of units is obtained. For example, there are 100 students in your class. You want a sample of 20 from these

100 and you have their names listed on a piece of paper may be in an alphabetical order. If you choose to use systematic random sampling, divide 100 by 20, you will get 5. Randomly select any number between 1 and five. Suppose the number you have picked is 4, that will be your starting number. So student number 4 has been selected. From there you will select every 5th name until you reach the last one, number one hundred. You will end up with 20 selected students.

iii. A Stratified Sample

A stratified sample is obtained by independently selecting a separate simple random sample from each population stratum. A population can be divided into different groups may be based on some characteristic or variable like income of education. Like any body with ten years of education will be in group A, between 10 and 20 group B and between 20 and 30 group C. These groups are referred to as strata. You can then randomly select from each stratum a given number of units which may be based on proportion like if group A has 100 persons while group B has 50, and C has 30 you may decide you will take 10% of each. So you end up with 10 from group A, 5 from group B and 3 from group C.

iv. A Cluster Sample

A cluster sample is obtained by selecting clusters from the population on the basis of simple random sampling. The sample comprises a census of each random cluster selected. For example, a cluster may be some thing like a village or a school, a state. So you decide all the elementary schools in Newyork State are clusters. You want 20 schools selected. You can use simple or systematic random sampling to select the schools, then every school selected becomes a cluster. If yout interest is to interview teachers on their opinion of some new program which has been introduced, then all the teachers in a cluster must be interviewed. Though very economical cluster sampling is very susceptible to sampling bias. Like for the above case, you are likely to get similar responses from teachers in one school due to the fact that they interact with one another.

d. Purposeful Sampling

Purposeful sampling selects information rich cases for indepth study. Size and specific cases depend on the study purpose. There are about 16 different types of purposeful sampling. They are briefly described below for you to be aware of them.

4.0 CONCLUSION

In this unit, you have learnt that using a sample in research saves mainly money and time, if a suitable sampling strategy is used; appropriate sample size selected and necessary precautions taken to reduce on sampling and measurement errors, then a sample should yield valid and reliable information.

5.0 SUMMARY

You have learnt in this Unit the meaning, purpose and the sources of errors inherent in sampling techniques. Taking samples rather than the total population for study will save you a great deal of money, time and other resources. However, your assessment may not yield realistic results if the samples are bias. You have also learnt this in this Unit. You should at this point attempt to identify the need to investigate a sample of dataset in your work place, neighbourhood or research area. Subsequent Units will teach you to obtain information from the samples in the environment; ecological, air, water, land, etc. I hope you will read to understand them. So come along. But... wait a minute; can you identify some reasons why we carry out scientific investigation?

6.0 TUTOR-MARKED ASSIGNMENT

1. Highlight THREE reasons for sampling in research.
2. Outline and describe different error sources in researches.
3. Describe FIVE sampling methods.

7.0 REFERENCES/FURTHER READING

Salant, P. and D. A. Dillman (1994). *How to Conduct your own Survey*. John Wiley & Sons, Inc.

Patton, M.Q. (1990). *Qualitative Evaluation and Research Methods*. Newbury Park London & New Delhi: SAGE Publications

UNIT 4 QUALITY CONTROL ASSURANCE IN SAMPLING

CONTENTS

1.0 INTRODUCTION

A thorough scientific investigation will include quality assurance. This includes a range of management and technical practices designed to guarantee that the results of the investigation is objective. Objectivity is the keyword in research; a biased investigation has no home in scientific world. Quality Assurance or Quality Control ensures that all the requirements of an investigation are of adequate scientific credibility to permit statistical interpretations that lead to meaningful management decisions. Quality Assurance not only ensures that the instrumentation and sampling processes are in control but also presents estimates of the sampling error, especially sampling variance. If some component of a sampling program is found not to be in control, then remedial response must be immediately initiated as soon as the problem is discovered, and both the problem and the remedial response must be thoroughly documented. The rest of this unit therefore informs us about the requirements for a successful research in science.

2.0 OBJECTIVES

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

- mention all the records that you need to keep as an investigator
- explain all the field activities during and after field work, especially when sample collections are involved
- explain what to do to ensure objective datasets.

3.0 MAIN CONTENT

An investigator aspiring to collect objective samples for investigation should note the following items highlighted below:

3.1 Guidelines Related to Use of Sample Containers

1. Sample containers should be supplied by the analyzing laboratory pre-cleaned and capped, and preferably within sealed plastic-film, dust-protection. The sample containers should be checked periodically for contamination both by the analyzing laboratory and by submission of sample blanks or low level standards. Warehouse storage of uncapped bottles is not acceptable.

Cleaning of old bottles for reuse may be appropriate for some situations, but is inappropriate for many situations due to increased likelihood of contamination. Good practice calls for recycling rather than reuse of bottles. (This also applies to preservative vials). It is rather sympathetic that this ideal situation may not work in many part of the developing world, including Nigeria, where it is a nightmare getting research funded. Most students, even their lecturers may not afford this either. It is therefore not uncommon to see us cleaning the old bottles for use. The quality of the results is more likely to be altered to. Please discuss this issue in your discussion class too.

2. Bottle cleaning must be carried out under laboratory conditions, and should not be done in the field. Rinsing of bottles with sample prior to sample collection is strongly discouraged. Sample containers must be sufficiently robust to take fairly rough handling in the field without rupturing or leaking. It is usual for different sample types and different groups of analytes to require specific types of sample containers and/or specific types of container lids. The analyzing laboratory should be consulted before sampling commences to ensure appropriate sample containers and lids are used.

3. As a rule, nothing but a sample preservatives should ever be placed into a sample container. Never permit a thermometer, pH probe, or such like to be placed into a sample bottle, unless that bottle is a throw-away intended for no other purpose.

3.2 Guidelines Related to Field Activities

1. Label all samples with unambiguous identification of exact date, place and time of sampling plus name of sampler.
2. Record all details relevant to the sampling in a field note book;

unusual conditions and variations from usual sampling techniques especially require thorough documentation.

3. Ensure that instruments and equipment are regularly maintained and calibrated; maintenance logs shall be kept.

4. Follow common sense approaches to avoid contaminating samples, clean sample collection equipment regularly, and check equipment cleanliness and performance by running blanks and reference samples where appropriate.

5. Where practical, collect samples from areas that are fairly homogeneous in time and space (i.e., avoid sampling situations where a small distance in time or space will yield very different results). Where it is not practical to avoid such situations, special attention will be required to achieve representative samples.

6. Collect replicate samples towards ascertaining the precision of the sampling method, or the analytical procedure, and also the local heterogeneity. Total assay error (sum of analytical error plus sampling error) should preferably be <10% of local heterogeneity (as variance), and must not exceed 20% of local heterogeneity (as variance). Analytical error (as variance) should fall below 4% of local heterogeneity (as variance)

3.3 Field Sampling Record Keeping

The Field sampling record system should be designed to ensure sample and sampler traceability, including dates and samplers' initials or signatures. If a sample numbering system is employed, it must be designed to eliminate the possibility of a sample mix-up. The record storage system should be designed for easy retrieval. A policy on the length of the storage and disposal of records shall be established. A policy shall also be established for the ownership of field notebooks, and their deposition when an individual sampler ceases employment on a project or with a company.

Sample History Requirements

Documentation and procedures on sample history should be maintained, including:

a. Method of sample collection
b. Time and location of sampling
c. Name of sampler(s)

d. Chemical preservative added or other sample treatment
e. Type of sample containers used
f. Storage conditions
g. Time and condition of sample on receipt at laboratory

Sampling Methods Documentation

An inventory of sampling methods shall be maintained that will include:

a. All current methods
b. All previous methods
c. Date of transition from one method to another

Sampling method and procedures documentation shall include:

i. A description of the procedure in sufficient detail that an experienced sampler, unfamiliar with the specific sampling method, should be able to perform the sample collection and treatment.
ii. Procedures for preparation of preservative reagents, if employed.
iii. Operating instructions for the sampling equipment, that is supplemental to the manufacturer's operating manuals.
iv. Method specific requirements for quality control sample preparation and analysis.
v. Quality control criteria (i.e., acceptable limits).

3.4 Contamination Control

Effective separation of incompatible activities must be ensured. The process of sample collection or sample pre-treatment must not interfere with nor lead to contamination of other monitoring or sampling in progress. For example, a series of nearby sites sampled consecutively in a small stream should be sampled from the downstream sequentially upstream. Similarly, a series of contaminated sites should be sampled preferably from least contaminated to most contaminated.

3.5 Duplicates and Replicates

Replicate samples are multiple (i.e., two or more) samples collected at the same location and time, by the same person, and using the same equipment and procedures. The smallest number of replicates is two (i.e., a duplicate). The purpose of collecting replicate samples is to obtain the precision for each analyte analyzed within these samples. The observed variance will be the sum of the local environmental variance, the analytical variance, plus the sampling variance. There are various methods to estimate the sources of variation in results.

Replicate analyses of replicate samples has been reported to be a particularly useful Quality Control approach in that it permits identification of analytical uncertainty sampling uncertainty, and environmental heterogeneity via analysis of variance (ANOVA) calculations.

4.0 CONCLUSION

How much you understand what is in this unit will be told in your attitude to research? I suppose this unit has generated some issues of controversy that I need to know if you understand the contents. How much hindrance would your field attitude, financial problem, our unfriendly or uneducated environment cost us the objectivity we need in research. It is essential that the reason of you taking part in this course is to change your attitude towards field research.

5.0 SUMMARY

This study has focused on the conditions that will guide you towards achieving an objective research work. To achieve this, your instrumentation and sampling should be guided by a quality control policy. You have learnt in this unit that all appropriate records must be kept and all sampling containers labeled. You have also learnt that that your sample collection at one site does not interfere with sample from another site. It is important that you always remember what you have learnt about duplicates and replicates of samples. This is very necessary to achieve precision. In all, let this unit be your guide as you begin the study of proper instrumentation and sampling process in scientific research.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are duplicates, and why are samples required to be duplicated?
2. Enumerate five information that must be contained in a field record.
3. Highlight five activities that should be done on the field concerning sample collection

7.0 REFERENCES/FURTHER READING

Kramer, K.J.M. (1994). *What about Quality Assurance before the Laboratory Analysis*? *Marine Pollution Bulletin*, 29: 222-227.

Kratochvil, B. and Taylor, J.K. (1981). *Sampling for Chemical Analysis*. Analytical Chemistry, 53: 924A - 938A.

Kratochvil, B.; Wallace, D.,and Taylor, J.K. (1984). *Sampling for Chemical Analysis*. Analytical Chemistry, 56: 113R - 129R.

MODULE 3

UNIT 1 ELECTRONIC DIRECT READING INSTRUMENTATION

CONTENTS

1.0 INTRODUCTION

The rapid development of portable and sensitive electronic direct reading instrumentation, for evaluating workroom atmospheres has largely been due to the borrowing of air sampling and analysis technology already developed in the disciplines of radiation protection and air pollution control. This unit introduces you to the principles and workings of the group of electronic direct reading instruments. The specific objectives of the unit includes your ability to.

2.0 OBJECTIVES

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

- describe the direct reading instruments and their uses
- describe the operating principles of the instruments
- mention the usefulness of a number of the direct reading instruments.

3.0 MAIN CONTENT

3.1 What are Direct Reading Instruments?

This is the class of instruments that incorporates the capability of electronic sensors utilising infrared and ultraviolet radiation, flame and photo ionisation, and chemiluminescence capable of detecting and measuing airborne concentrations of gases in a matter of seconds. Most of these instruments can be equipped with automatic continous recording devices which generate real time data as well as time weighted data depending on the kind of exposure information required.

3.2 Operating Principles of Direct Reading Instrumentation

The operating principles of direct reading instrumentation are based on the physical and/ or chemical properties of the gaseous agents they detect or quantify. As a group, these principles are based on two phenomena:

The first principle is the physical principle in which the electronic detector or sensor element that generates the electrical signal with its information content is immediate to the air sampling process. An example is the mercury vapour meter where the principle involved is the absorption of ultraviolet (UV) light by mercury vapour which has a strong absorption line in the UV spectrum.

The second principle is the chemicophysical principle, in which a gas undergoes a chemical eaction, and a physical method is used to detect the changes caused by this reaction. Either the consumption of one of the reactants or the production of the product is measured. In either case a physical property of a reactant or of a product is measured. Oxidation – reduction reactions are typical example of chemicophysical detection methods. The chemical part is the oxidation or reduction of the contaminant; the physical part is a measurement of the number of electrons required to regenerate one of the reactants. The Mast ozone meter employs a chemicophysical method of detection to measure the quantity of ozone in a sample.

3.3 Examples of Direct Reading Instruments (DRI) and Applications

Table 10.1. below shows examples of some DRI and the gases detection to which they are applicable.

Table 10.1: Major methods of detection for common gases (X indicates the existence of commercially available instrument employing the listed method of detection)

	Chemical variables in gases									
Detector	**NH_3**	**Cl_2**	**NOx**	**SOx**	**O_3**	**$COCl_2$**	**Hg**	**H_2S**	**C**	**S**
Flame Photometric				X						
Chemilumninescence			X		X					
Colorimetry	X		X	X						
Coulometry				X	X					
Electrical conductivity	X			X			X			
Flame ionisation									X	
IR Photometry			X							
Photoionisation									X	X
Derivative spectrometry			X	X					X	X
Thermal conductivity		X	X	X		X		X		
Voltammetric								X		
Electrochemical		X	X	X	X	X				
Microcoulomb Redox			X							
Mass Spectrometry					X					
Electron Impact Spectrometry			X	X						
Electron Capture			X							
UV Photometry		X	X		X	X		X	X	X

4.0 CONCLUSION

I will rather conclude this unit by letting you understand that the instruments whose principles have been discussed are now produced under different brand names. You should also quote the brand name of the one you choose to use in the practical class in future. This is essentially to drive home the importance of accuracy, precision and reliability of the results obtained. You should also note that most of the apparatus described are used in the laboratory, because they often come in huge sizes. Nonetheless, the handheld equivalent will be excellent to use on the field.

5.0 SUMMARY

The principles of the direct reading instruments have been highlighted, with their specific examples. Please note that you will rely on the knowledge that you have acquired in the previous units to understand some of these principles. It may need that re-read them before going beyond this stage. Now I bid you bye to air survey. But before I finally leave you, I advise that you attempt these questions.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe the direct reading instrument.
2. Mention 10 instruments and example of parameters they can determine in a sample.

7.0 REFERENCES/FURTHER READING

American Public Health Association, American Water Works Association, Water Environment Federation (1992). Standard Methods for the Examination of Water and Wastewater. 18th edition. *Edited by:* Greenberg, A.E., Clesceri, L.S., Eaton, A.D., and Franson, M.A.H. *Published By:* American Public Health Association.

UNIT 2 BIOLOGICAL SAMPLE COLLECTION: FRESHWATER

CONTENTS

1.0 INTRODUCTION

This section covers the minimum requirements to ensure quality and consistency of the field aspects of biological data collection. The essential tasks in biological sampling are to collect representative samples that meet the requirements of the research interest, and to prevent deterioration and contamination of the samples before analysis. The information here is the most acceptable ones used at present. It should be emphasized that in unusual circumstances or with development of new methods, experienced professional judgment is a necessary component of method choice and application.

2.0 OBJECTIVES

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

- identify the materials required for field work
- describe the sampling instruments for different aspects of biological studies.

3.0 MAIN CONTENT

3.1 Preparation for each sampling trip

This is critical since oversights are not usually noticed until you reach the first station. The most effective way to prepare for a sampling trip is with a checklist that is designed to meet the requirements of each project.

Other than considering site-specific instructions, the checklist should identify the following needs:

1. Type and number of (labelled) bottles, including extras
2. Field equipment such as sediment grabs, invertebrate samplers, fish nets, tow nets, etc.
3. Preservatives
4. Appropriate quantity of ice packs and coolers
5. Logbooks
6. Personal gear (for all possible weather conditions such as survival suits, raincoats, protective footwear, etc.)
7. First aid kit and other safety equipment (life jackets, survival suits)
8. Camera or video equipment as required
9. Laboratory requisition forms (partially filled out)

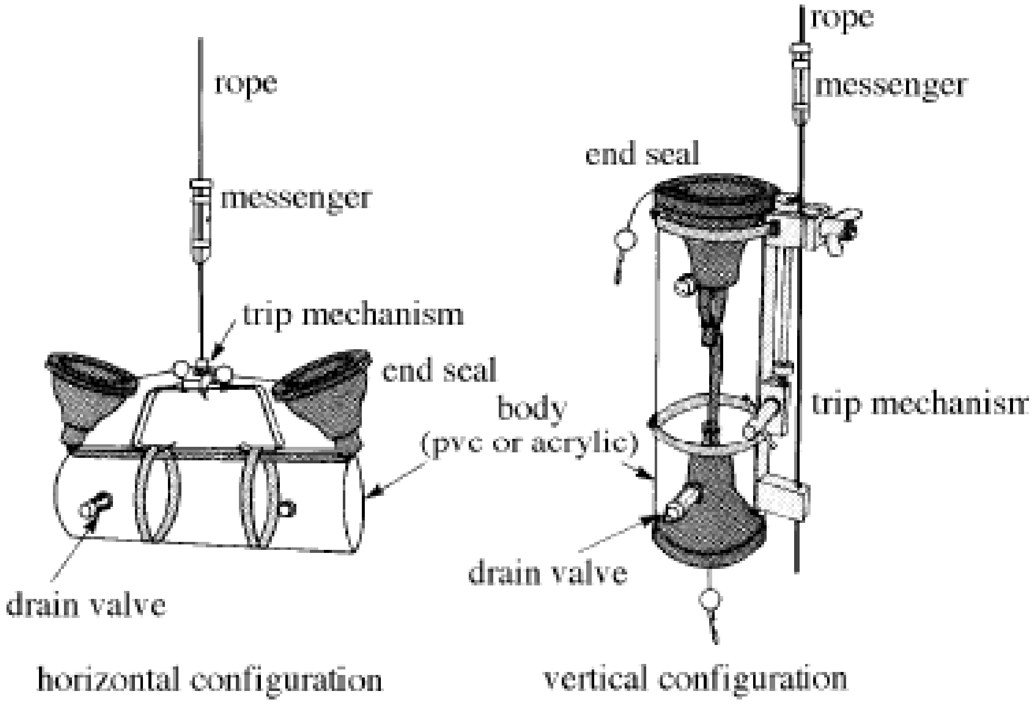
3.2 Locating the Site in the Field

It is your responsibility to locate all sampling stations accurately. Only if the same location is sampled consistently can temporal changes in the water quality be interpreted with confidence. Therefore, accurate station location descriptions (that identify key landmarks) must be prepared on the first visit to every sampling site. Good photographic documentation is the best way of ensuring that each site is easily recognized. A map that labels the sample sites should accompany the site identification logbook. This logbook can be in the form of a 3-ring binder with a map of the site. The basic site location data (latitudes, longitudes, map sheet number, site identification number, etc.) should be incorporated into the database

3.3 Description of Samplers used in biological sampling from freshwaters

a. Van Dorm Sampler

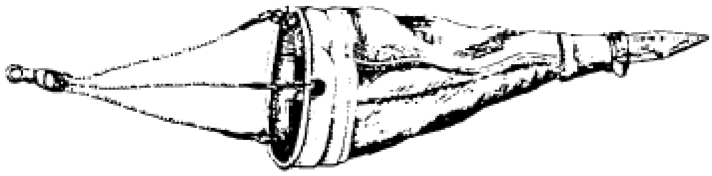
Deep samples are usually collected by Van Dorn sampler. Note that Van Dorn samplers are available in both horizontal and vertical configurations. The advantage of the vertical configuration is that the water within the open bottle is flushed out as the bottle is lowered so that one can be guaranteed that the water was collected from the indicated depth. The advantage of the horizontal configuration is that a very narrow depth range is sampled. Vertical configurations are usually used in large lakes. Horizontal configurations are used for samples to be collected at or just above/below a very sharp thermocline, or to be collected near the lake bottom. Horizontal configurations are mandatory for very shallow lakes.



Van Dorn Sampler

b. Conical Net

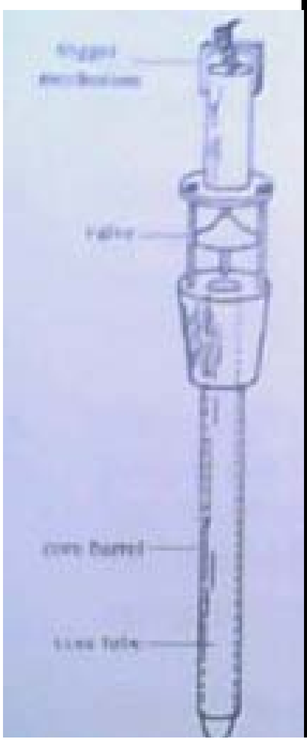
Zooplankton or planktonic animals are free floating and suspended in open or pelagic waters. They are thus generally collected with a conical net that has a specific mesh size (ranging from as small as 64 µm to as large as 256 µm). Small mesh openings will clog more readily than larger ones, but small organisms will pass readily through larger openings. The mesh size required for a particular lake will depend on the productivity of the lake and the purpose of the study. The preferred net mesh, when appropriate, is 64 µm with a net mouth diameter of 20 cm. The net is lowered to a particular depth and pulled directly up through the water column (known as a vertical tow). Alternatives to the vertical tow are the horizontal and oblique tows in which various strata of the lake are sampled individually (a horizontal tow) or as a composite (oblique tow). These are elaborate techniques that require specialized equipment rigged to the boat and a tow net that has remote open and close capabilities. Unless there is specific need for data from horizontal and oblique tows they are not used.



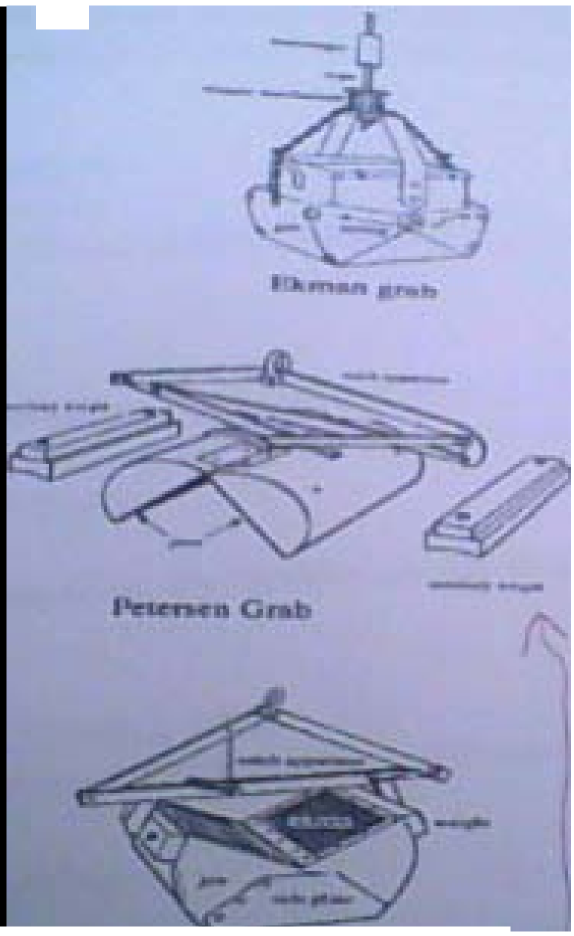
Plankton tow net

c. Sediment Grab Samplers

These are often use to sample benthic invertebrates in lakes or large slow moving rivers are generally collected in the same fashion as sediment samples. The processing of the sample once it has been collected is where the techniques differ. The type of grab sampler to be used at a particular site will depend on the site conditions and the purpose of the study. They range from grab samplers, to core sampler which is most commonly used.



Kajak-Brinkhurst Sediment Core Sampler

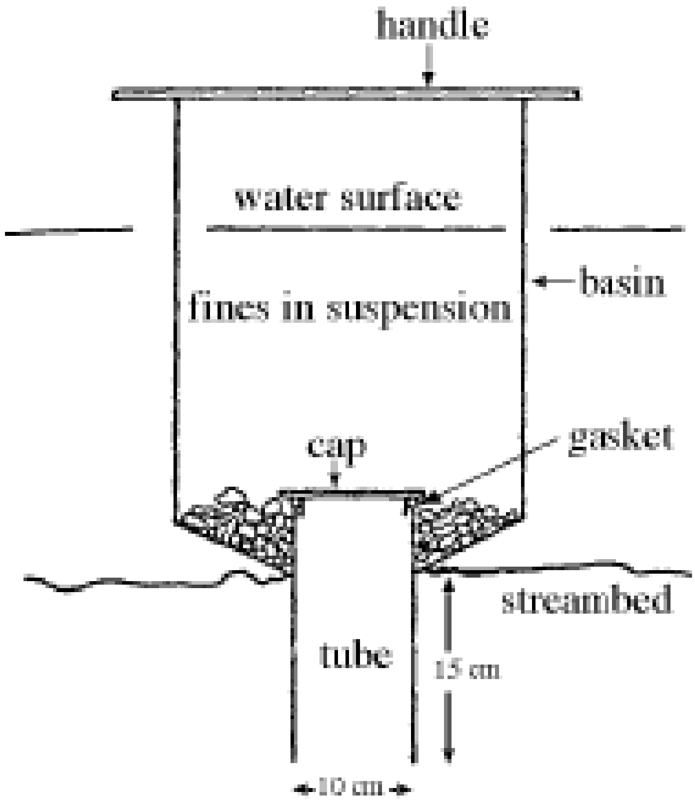


Common Sediment Grab Samplers

d. Sediment Particle Size Samplers

Although the previously mentioned samplers can be used for the purpose of determining the distribution of streambed particle sizes, they are not ideal. Much of the very fine sediments are lost because of the pressure wave that precedes these samplers and washout as the samplers are retrieved. Better estimates of particle size distribution can be obtained through the use of sediment traps (over a prescribed time frame), or samplers that collect an entire portion of the streambed (i.e., McNeil sampler and Freeze core sampler). The freeze core sampling technique is elaborate and cumbersome; consequently, it will not be discussed here.

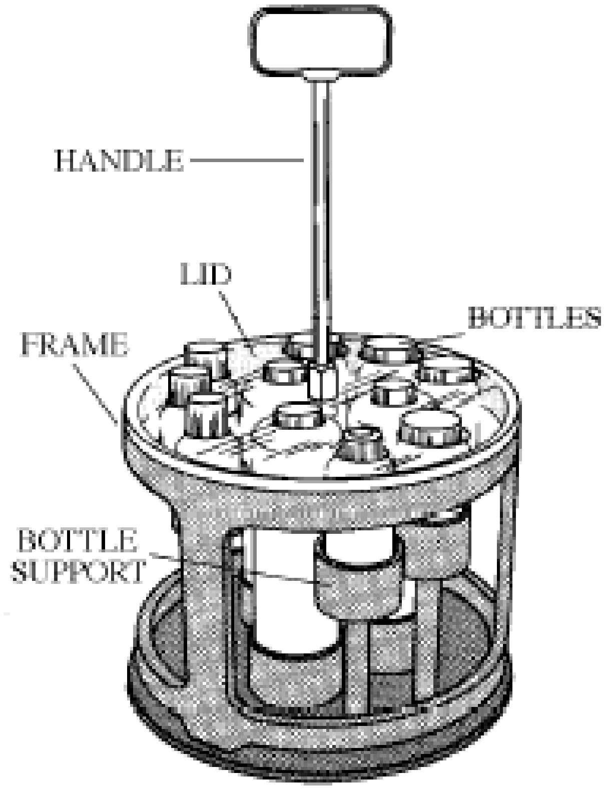
Sediment traps are simply open buckets of a given volume that are filled with cleaned gravel and immersed in the streambed. They are collected at a later date and submitted for mechanical analysis of sediment particle size. The McNeil sampler consists of a cylinder that defines the portion of the streambed to be sampled and an attached basin that is used to store the collected sediments and trap the suspended fines.



McNeil sediment size sampler

e. Multiple samplers

Some sample stations are designed to be sampled from a bridge. This allows the collection of samples from the central flow of rivers where wading is not an option. The samples can be collected using an apparatus called a **multiple sampler** that is lowered over the side of the bridge. Since the multiple sampler holds more than one bottle, it has the advantage of allowing all containers (therefore, all variables) to be sampled at the same time and at the same place. This allows for more precise cross-referencing among the variables. Other pieces of equipment for single bottles are also available and can be used in situations that are appropriate. The precise location at which the sampling device is lowered from the bridge should be marked to ensure that the same section of the river is sampled each time.



Generalized multiple sampler

f. Temperature

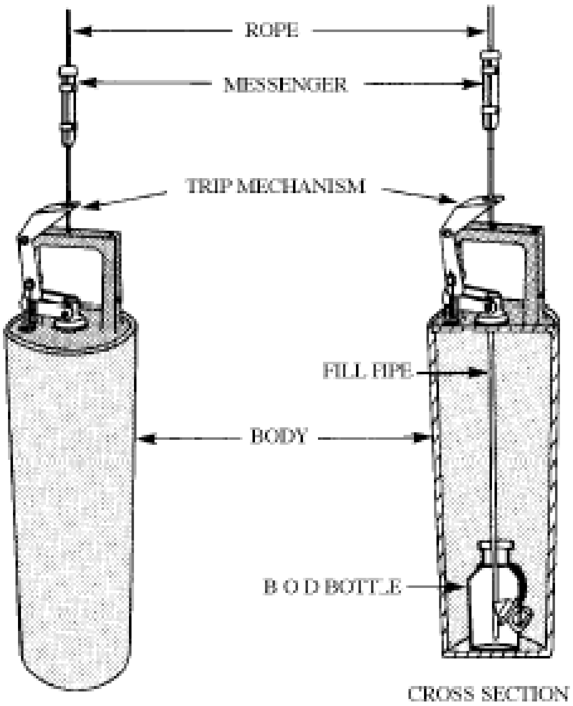
Temperature can be measured with an alcohol-filled thermometer or with an electronic thermometer that has been calibrated against a certified thermometer. All thermometers must be checked against a reference thermometer by a laboratory before use and annually thereafter. Thermometers that do not meet the data quality objective of the project (e.g., ± 0.5°C of the true temperature) must be discarded

(a) Measure surface water temperatures directly in the water, allowing the thermometer to come to equilibrium before recording the value.

(b) For deep waters, collect a grab sample (e.g., with a Van Dorn - section 4.1.2.3) and decant some water into a 1 litre “field bottle” (never measure the temperature in a sample bottle that is being submitted to the laboratory for other analysis). Measure the temperature immediately, allowing the thermometer to come to equilibrium before recording the value

g. Dissolved Oxygen (DO)

Dissolved oxygen can be measured by either chemical titration (Winkler method) or the membrane electrode method. Both have the potential of being accurate and reliable, but both methods require some training so that accurate measurements can be made. Meters provide a convenient and inexpensive way of measurement and are the most commonly used method. A well-calibrated oxygen meter membrane electrode system is preferred for obtaining a depth-profile of DO in a lake or deep river. Sampling for DO measurements requires particular care, since any contact between the sample and the air will modify the results. If percent saturation is to be determined, then the water temperature must be measured at the same time and location. Additionally, barometric pressure or altitude is required to determine percent saturation accurately.



Dissolved Oxygen sampler

4.0 CONCLUSION

This Unit has discussed what you need to know about the basis of field work for biological study. A number of samplers have been mentioned here but only few of their features have been described.

5.0 SUMMARY

Biological study is an essential activity within the scope of Environmental Science. It involves a series of research activities ranging from field sampling to laboratory analyses. Examples of the sampling instruments are discussed here. Water, sediment samplers as well as samplers for biota features are identified, and their features discussed. Also highlighted are the essentials of field sampling, such as the requirements for a field trip, and the requirements for locating a suitable sampling site. You will learn more of this in literatures, and as you participate in specific practical exercises. It is essential that you find out if some of these are available in your organisations, and see how you can make use of them. Now see if you can answer these questions.

6.0 TUTOR-MARKED ASSIGNMENT

1. Mention 5 items that you should take to the field.
2. Identify 3 examples of water, sediment and biota sampler. Describe each of the samplers.

7.0 REFERENCES/FURTHER READING

American Public Health Association, American Water Works Association, Water Environment Federation (1992). *Standard Methods for the Examination of Water and Wastewater*. 18th edition. *Edited by:* Greenberg, A.E., Clesceri, L.S., Eaton, A.D., and Franson, M.A.H. *Published By:* American Public Health Association.

British Columbia Environmental Laboratory Manual for the Analysis of Water, Wastewater, Sediment and Biological Materials (1994). *Environmental Protection Department*, Ministry of Environment, Lands and Parks, Victoria, Canada.

http://www.qp.gov.bc.ca/statreg/reg/W/WasteMgmt/217_97.htm

UNIT 3 INSTRUMENTATION FOR NOISE AND SOUND MEASUREMENTS

CONTENTS

1.0 INTRODUCTION

There is no single method or process exists for measuring noise. Hearing safety and health professionals can however use a variety of instruments to achieve this. The choice of a particular instrument and approach for measuring and analyzing noise depends on many factors, not the least of which will be the purpose for the measurement and the environment in which the measurement will be made.

2.0 OBJECTIVES

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

- describe the component of sound measuring system
- describe some sound measuring instruments.

3.0 MAIN CONTENT

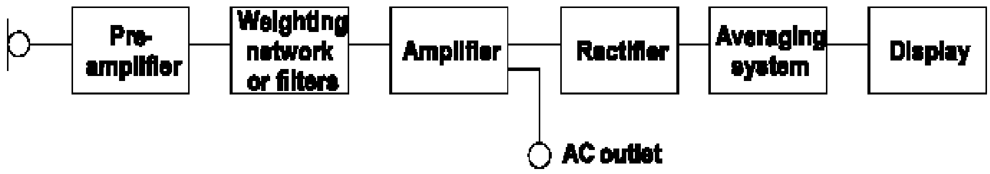
3.1 Components of Sound Measuring System

Many types of measuring systems can be used for the measurement of sound depending on the purpose of the study, the characteristics of sound and the extent of information that is desired about the sound.

The various elements in a measuring system are:

a. the transducer; that is, the microphone;
b. the electronic amplifier and calibrated attenuator for gain control;
c. the frequency weighting or analyzing possibilities;
d. the data storage facilities;
e. the display.

Not all elements are used in every measuring system. The microphone can, for instance, be connected to a sound level meter or directly to a magnetic tape recorder for data storage and future measurement or reference. An example of the components of the sound level meter is shown in the Figure below



Sound level meter block diagram

The two main characteristics are:

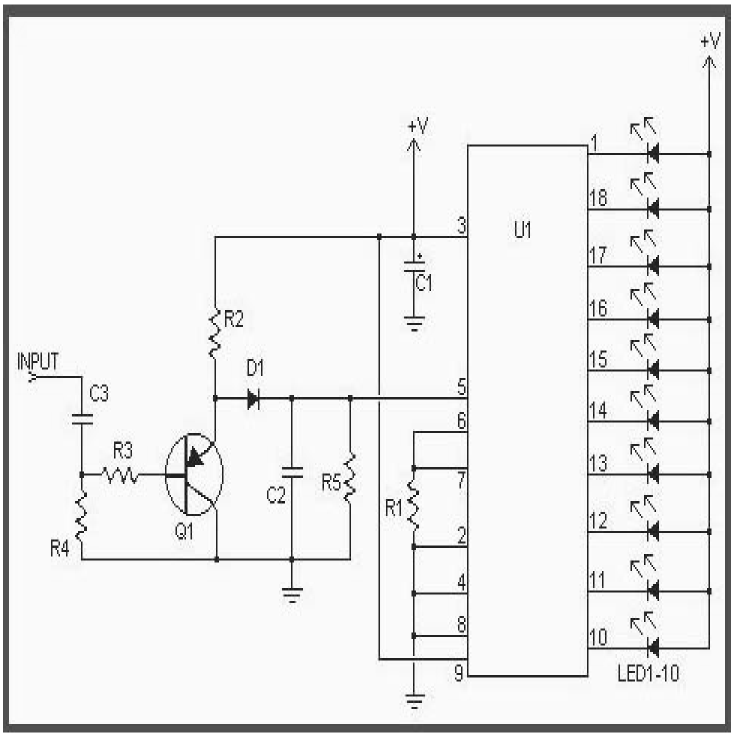
- **The frequency response:** that is, the deviation between the measured value and the true value as a function of the frequency. As the ear is capable of hearing sounds between 20 Hz and 20 kHz, the frequency response of the sound level meter should be good, with variations smaller than 1 dB, over that range;

- **The dynamic range:** that is, the range in dB over which the measured value is proportional to the true value, at a given frequency (usually 1000 Hz). This range is limited at low levels by the electrical background noise of the instrument and at high levels by the signal distortion caused by overloading the microphone or amplifiers.

3.2 Sound and Noise Measuring Equipment

3.2.1 Sound Level Meter

The sound level meter is the basic measuring instrument for noise exposures. It consists of a microphone, a frequency selective amplifier, and an indicator. At a minimum, it measures sound level in dB SPL. An integrating function may be included to automate the calculation of the noise dose. The Figure below shows the circuit configuration of a sound meter



Electric circuit of a sound meter

3.2.2 Noise Dosimeter

Measuring noise with a sound level meter is relatively simple when the noise levels are continuous and when the person remains essentially stationary during the work shift. A noise dosimeter is preferred for measuring a person's noise exposure when the noise levels are varying or intermittent, when they contain impulsive components, or when the worker moves around frequently during the work shift.

The noise dosimeter may be thought of as a sound level meter with an additional storage and computational function. It measures and stores the sound levels during an exposure period and computes the readout as the percent dose. Many dosimeters available today can provide an output in dose using various exchange rates (e.g., 3, 4, and 5 dB), 8-hr criterion levels (e.g., 80, 84, 85, and 90 dBA), and sound measurement ranges (e.g., 80 to 130dBA).

In noise dosimetry, the microphone is attached on the worker whose exposure is being measured. The placement of the microphone is important in estimating the person's exposure, as Kuhn and Guernsey (1983) have found large differences in the sound distribution about the body. ANSI (1996) specifies that the microphone be located on the midtop of the person’s more exposed shoulder and that it be oriented approximately parallel to the plane of this shoulder.

A Noise Dosimeter and Its Placement on Human Body

3.2.3 Magnetic Tape Recorders

Magnetic tape recorders are used to make a permanent recording of the noise for future analysis or reference. Some HIFI audio recorders can be used, providing their frequency response and dynamic range are suitable. For general surveys, small recorders with a frequency response of + 3 dB in the range 30 Hz to 16 kHz and a dynamic range of 40 dB may be sufficient. For precise measurements and frequency analyses, higher quality instrumentation is needed. The real objectives of the instrument have to be assessed since the relative price of these instruments may vary in the range of 1 to 20. As the dynamic range of an analog recorder is no more than 40 to 50 dB, usually it is difficult or impossible to record impulse noise as met in industry or as used for measuring the reverberation time. Some digital recorders (referred to as DAC recorders) are now available: they have a much broader dynamic range (around 90 dB) and a good frequency response (20 – 18000 Hz). Besides analog and digital recorders, there are also frequency modulated (FM) recorders which are of special interest for measuring vibration as their frequency range extends down to DC.

3.2.3.1 Use of a Tape Recorder

The criteria for the selection of a tape recorder are:

a. The frequency response at the different speeds. Usually the limits are directly proportional to the speed;

b. the range of speeds;

c. the dynamic range;

d. the cross channel attenuation;

e. the presence of band pass filters enabling the elimination of low frequency noise;

f. the quality of the indicating device and of the input potentiometers, preferably graduated in dB;

g. the possibility of controlling the output signal;

h. the protection against dust;

i. the protection against vibration susceptibility which increases the internal noise level;

3.2.4 Calibrators

Microphones are individually calibrated at the factory, and the calibration chart must be delivered with the instrument. In the field, calibration is performed by applying a known sound pressure level at a fixed frequency to the microphone. Calibrators are small, battery driven and operate on different principles. One operates at 250 Hz and produces a sound level of 124 dB, accurate to + 0.2 dB. To obtain the best results, the microphone should be well sealed in the coupler opening. A change in atmospheric pressure alters the calibration level slightly, but a correction can be made using the barometer which is provided as a part of the instrument set. Another example is a pocket unit, which operates at 1000 Hz. The calibration level is 94 dB with an accuracy of + 0.5 dB.

The use of a calibrator as defined by IEC 60942 is recommended for checking the accuracy of hand-held indicating instruments, and must be used when tape recording data, as explained previously. Accurate calibration of equipment used in the field is essential as it provides for consistency in measurements, allows accurate comparison of measurements made over long time intervals, brings to light any slight changes in the accuracy of instrumentation, and allows reanalysis of data, if this is required at a later date. This care in the use of calibration for field measurements should be backed up by regular laboratory calibration using more accurate techniques, in order to check the frequency response as well as the amplitude response of the equipment

3.2.5 Recorders

3.2.5.1 Graphic Level Recorder

If the sound level meter has a logarithmic DC output facility, common graphic recorders can be used to obtain a permanent record of the evolution of the sound level, providing that their writing speed is compatible with the characteristics of the sound level meter.

Many different types are available and it is not intended to review them. The essential characteristics for this type of equipment are:

a. the detection capabilities;

b. the frequency response;

c. the writing speeds, that should at least correspond to the slow and fast characteristics of the sound level meter. For reverberation time measurements, however, much faster writing speeds are needed;

d. the dynamic range of the graph (often 25 or 50 dB) and of the instrument.

It is usually not practical to record graphically the instantaneous noise level at a workplace for extended periods of time. The graph allows only the determination of maximum and minimum levels and cannot be used to define any average level. The use of this technique should be restricted to special cases such as:

a. the characterisation of short events of noise;
b. the determination of the intermittency of a noise;
c. the study of the reverberation time;
d. the recording of frequency analysis

3.2.6 Microphones

3.2.6.1 The different types

The microphone is the interface between the acoustic field and the measuring system. It responds to sound pressure and transforms it into an electric signal which can be interpreted by the measuring instrument (e.g. the sound level meter). The best instrument cannot give a result better than the output from the microphone. Therefore, its selection and use must be carefully carried out to avoid errors.

When selecting a microphone, its characteristics must be known so that its technical performance (e.g. frequency response, dynamic range, directivity, stability), in terms of accuracy and precision, meets the requirements of the measurement in question, taking into account the expected conditions of use (e.g. ambient temperature, humidity, wind, pollution). The microphone can be of the following types: piezoelectric, condenser, electret or dynamic.

In a piezoelectric microphone, the membrane is attached to a piezoelectric crystal which generates an electric current when submitted to mechanical tension. The vibrations in the air, resulting from the sound waves, are picked up by the microphone membrane and the resulting pressure on the piezoelectric crystal transforms the vibration into an electric signal. These microphones are stable, mechanically robust and not appreciably influenced by ambient climatic conditions. They are often used in sound survey meters.
In a condenser microphone, the microphone membrane is built parallel to a fixed plate and forms with it a condenser. A potential differential is applied between the two plates using a DC voltage supply (the polarisation voltage). The movements, which the sound waves provoke

in the membrane, give origin to variations in the electrical capacitance and therefore in a small electric current. These microphones are more accurate than the other types and are mostly used in precision sound level meters. However, they are more prone to being affected by dirt and moisture.

A variation on the condenser microphone which is currently very popular is the electret. In this case the potential difference is provided by a permanent electrostatic charge on the condenser plates and no external polarising voltage. This type of microphone is less sensitive to dirt and moisture than the condenser microphone with a polarisation voltage.

The last type is a microphone where the membrane is connected to a coil, centered in a magnetic field, and whose movements, triggered by the mechanical fluctuations of the membrane, give origin to a potential differential in the poles of the coil. The dynamic microphone is more mechanically resistant but its poor frequency response severely limits its use in the field of acoustics.

4.0 CONCLUSION

This Unit has discussed what you need to know about the basis of noise and sound measurements.

5.0 SUMMARY

Noise and sound probing equipment have been discussed. These include microphone calibrators, recorders, noise dosimeters, sound level meters and tape recorders. The distinguishing features of these instruments were described. Earlier in the unit, the composition of a typical sound level meter has been discussed. Let’s see if you understand what you have read by answering the following questions.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe 5 instruments for measuring noise and sound.
2. Mention 5 components of a typical measuring system.

7.0 REFERENCE/FURTHER READING

Harris, C. M. (1991). (Ed.) *Handbook of Acoustical Measurements and Noise Control* (3rd ed.). New York: McGraw-Hill, Inc.

UNIT 4 METEOROLOGICAL VARIABLES AND THEIR OBSERVATIONS

CONTENTS

1.0 INTRODUCTION

Meteorology is concerned with every aspect of local and regional climates and the causes of their variations, thus making standard observation of climatic variables a fundamental necessity. It is also concerned with any climatic modifications which may be introduced by human management of land use.

Physical variables of climate are observed to assist the management of agricultural activities, land use planning and adaptation to weather variability and climate change. Parameters pertaining to energy and water balance are thus very important, such as precipitation, humidity, temperature, solar radiation and air motion. Further, certain physical and chemical characteristics of the atmosphere, precipitation and soil are also important in meteorology, e.g. pollutants such as CO_2, SO_2, dissolved and suspended matter in precipitation, thermal, hydrological contents and salinity of soil. These require specialised equipment which is available only at a few selected stations.

2.0 OBJECTIVES

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

- describe the types of meteorological stations
- mention some climate/weather elements and instruments for their measurements.

3.0 MAIN CONTENT

3.1 Types of Meteorological Stations

Two types of meteorological stations can be described; these are fixed and mobile stations.

3.1.1 Fixed Stations

Fixed stations are those stations that are seen as operating for an extended period at a fixed place, and may be:

a) Minimum Equipment Stations

Small portable screen, minimum and maximum thermometers, dry and wet-bulb thermometers, totalizing anemometer at a convenient height, and rain gauge. For screens which are not standard, the radiation error should be determined;

b) Standard Equipment Stations

Standard screen instruments and rain gauge as in a) above, thermohygrograph, wind vane, windrun and sunshine recorder. These permit determination of evaporation using empirical methods;

(c) Semi-Automatic Stations

When trained personnel are not available, semiautomatic stations are required with uninterruptible power supply to provide the measurements. There is no automatic data communication;

(d) Automatic Stations

These stations require less supervision but installation, calibration and inspection must be of a high standard. Uninterruptible power supply is required. Data from these stations can be used for direct computer processing. Initial and maintenance costs as well as proper calibrations may be limiting factors. Data should preferably also be communicated automatically.

A minimum equipment station

An Automatic (fixed) Meteorological Station

3.1.2 Mobile stations

Mobile stations are used for surveys and research. Some mobile stations move continuously and others need equilibrium of sensors or certain periods for measurements, such as for local wind observations. When an extended but superficial survey of air temperature and humidity is required, the instruments are usually carried by vehicles. In these circumstances use is made of thermocouples and thermistors which have a rapid response (low “time constants”) and high sensitivity. When using motor vehicles, all mechanical instruments should have anti-shock mounts and should be mounted so that the recording movement is perpendicular to the direction of the most frequent vibrations, to reduce their effect on the instruments

An emergency mobile weather station used for the Beijing Olympic Sailing Competition

3.2 Meteorological variables and Their Techniques of Measurement

The following are some meteorological variables and their techniques of measurements

3.2.1 Radiation

Global solar radiation (direct and diffuse solar radiation) is measured with *pyranometers* containing thermocouple junctions in series as sensors. A pyranometer is an instrument used to measure the amount of solar radiation (power) the sun produces in a specific location. These devices are compact and easy to use for surveying solar radiation anywhere. Pyranometers are typically used in conjunction with a multimeter in order for a reading to be obtained.

The ability to measure the intensity of solar radiation for a certain area can be used to: design photovoltaic systems (solar panels), establish greenhouse locations, predict insulation requirements (for structures), etc. Essentially a pyranometer can be used whenever solar intensity data is required.

The three types of solar radiation are measured:

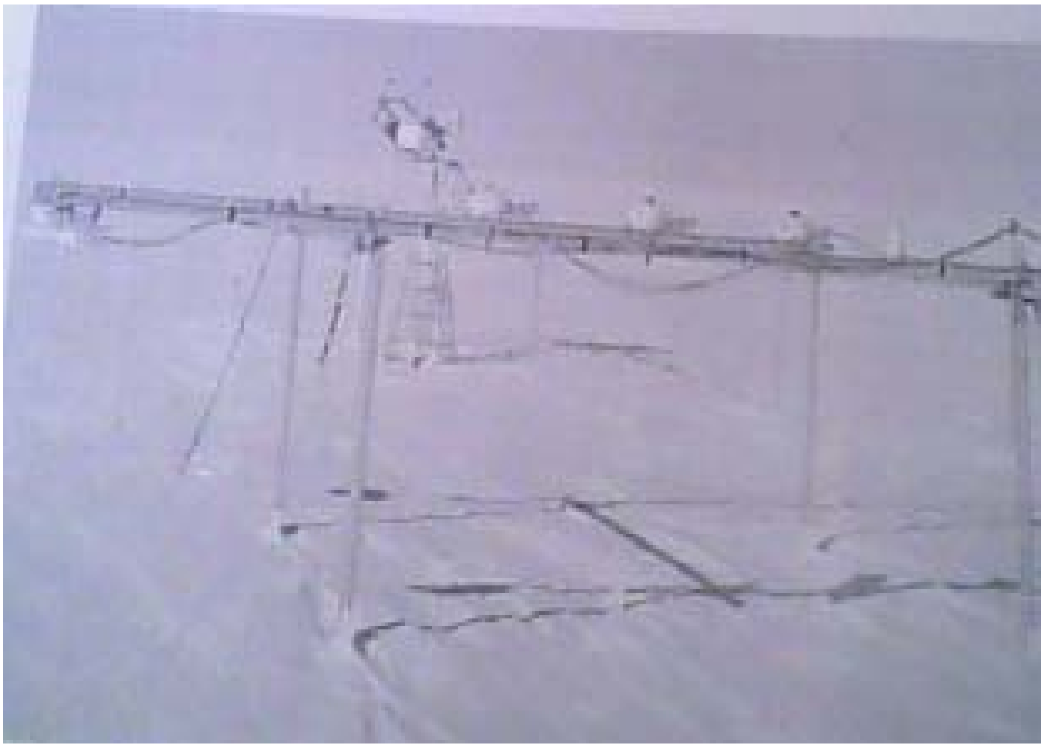
1. Direct
2. Diffuse horizontal
3. Global horizontal

Direct and diffuse radiation measurements combined should add up to the global horizontal measurement (total radiation). The pictures below refer to the typical set up of styles measuring these three components of solar intensity. A pyranometers output is in millivolts and each instrument is calibrated to measure the power emitted by the sun in Watts/meter^2. Each pyranometer is calibrated and a specific calibration constant (numerical value) is given to accurately calculate the output in watts. With this in mind a multimeter (set to 300Mv) is connected to the pyranometer and the reading is multiplied by the calibration value to give a final value in watts/m^2. Most solar panel designers assume a maximum average of 1000watts/m^2 which can be obtained anywhere on the planet.


Pyranometer with multimeter


Global horizontal reading **Diffuse horizontal reading**


Direct reading



A surface radiation measuring station

3.2.2 Sunshine

Standard meteorological stations usually measure only sunshine duration. The traditional instrument to observe this is the *Campbell-Stokes sunshine meter*. Sunshine duration has been defined as the time during which direct radiation (on a plane perpendicular to the Sun's beam) is larger than 120 Wm^{-2}. This definition makes it possible to now use automatic sunshine recorders.

Particular metadata of radiation measurements are

(1) wavelength transmission spectral window of pyranometer dome;
(2) sunshine recorder threshold radiation value;
(3) horizon mapping for each instrument measuring radiation or sunshine;
(4) procedures or means to keep radiometer domes clean and clear.

3.2.3 Temperature of Air

The most common thermometers for standard observations in air are those generally called *differential expansion thermometers*, which include liquid-in-glass, liquid-in-metal, and bimetallic sensors. Because of their sizes and characteristics many of these instruments are of limited use for other than conventional observations. However, spirit-in-glass, mercury-in-glass, and bimetallic sensors make useful *maximum and minimum* temperature measurements. When temperature observations are required in undisturbed and rather limited spaces, the most suitable sensors are electrical and electronic thermometers which permit remote readings to be made.

Thermocouples are excellent for measuring temperature differences between the two junctions, e.g. dry- and wet-bulb temperatures, or gradients. When they are used to measure single temperatures or spatial average temperatures (such as surface temperatures, using thermocouples in parallel), there is always need for one junction to be at a known steady reference temperature.

A ***black-globe thermometer*** is a blackened copper sphere commonly 15 cm in diameter, with a thermometer or thermocouple inserted. When a black globe thermometer is exposed in the open or under a ventilated shelter, the effects of different radiation fluxes are integrated with that of convective heat (wind and air temperature). Installed inside closed barns or stables, under still air conditions, it gives the average radiant temperature of soil, roof and walls at equilibrium.

3.2.4 Temperature of soil and other bodies

3.2.4.1 Soil

Mercury in glass type soil thermometers are frequently used. For measurements of the soil temperature at shallow depths these thermometers are bent in between angles 60^0 and 120^0 for convenience. At greater depths lagged thermometers are lowered into tubes. Care should be taken to see that water does not enter the tubes. Alternatively, shielded thermocouples or thermistors can be used. Temperature of deeper soil layers can be measured with glass thermometers, thermistors, thermocouples, diodes and platinum resistance thermometers when good contact is made with the soil.

3.3 Wind

Wind speed and direction measured with standard instruments under standard exposure are fundamental requirements of the science of meteorology. The most common routine observation is the wind run, providing an average over the measuring period. That period should be at least ten minutes for smoothing out typical gustiness, and at most an hour because surface wind has a very pronounced diurnal course. However, different instruments are used when it is necessary to observe the more detailed structure of air motion, e.g. in meso- and micrometeorological studies. In such cases wind speeds are measured with cup anemometers of high sensitivity at low velocities or with electrical thermo-anemometers or sonic anemometers.

Sensitive *cup anemometers* are the most common in routine and research use, measuring all wind components with an angle of attack with the horizontal smaller than about 45º. The best have a low stalling speed (threshold of wind speed below which the anemometers does not rotate) of about 0.1 m s^{-1}, because friction loads have been minimized. The rotation produces an electrical or phototransistor signal which is registered by a recorder or counter. Such transducers also allow separate recording of gustiness.

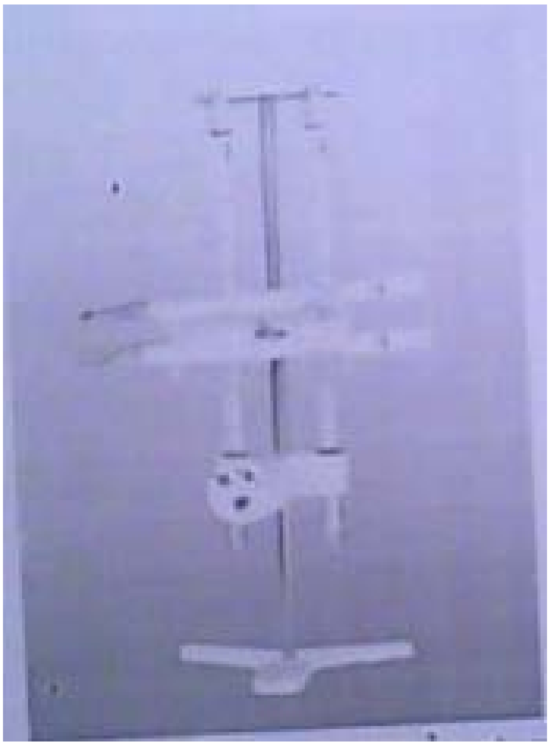
Sensitive *propellers*, if mounted on a vane, can be an alternative for cups but are these days mainly used in research instruments. *Pressure tube anemometers* on a vane are reliable, but so unwieldy that they are disappearing in favour of smaller instruments. A new instrument for horizontal wind speed and direction measurement is the *hot-disk anemometer*, which has the advantage that it has no moving parts. For steady wind direction measurement, wind vanes must have fins whose height exceeds their length.

Sonic anemometers, sensing the transport speed of sound pulses in opposite directions along a line, so being totally linear, respond quickly enough to measure turbulence and have become useful in flux measurements in research. However, they cannot be used in small spaces and their calibration shifts in wet weather.

3.3 Humidity

The most commonly used are hair hygrometers and hair hygrographs. They may however give acceptable values only if great care is taken in their use and maintenance. Besides standard *psychrometers equipped with mercury-in-glass thermometers, portable aspirated and shielded psychrometers and mechanical hygrometers*, many instruments have been developed to measure different aspects of air humidity. Since, the above-mentioned routine instruments are bulky and inadequate for remote reading; they are unsuitable for many meteorological observations. For observations in undisturbed and small spaces, electrical or electronic instruments are used.

The best method for measuring humidity distribution in the layers near the ground is also by using thermo-electric equipment, unventilated thermocouple psychrometers being most suitable in vegetation. Ventilated psychrometers may be used for levels at least 50 cm above bare soil or dense vegetation.



An image of a Psychrometer: used to measure the temperature and the temperature extremes, and to determine relative humidity; electrically driven aspirator with battery (rechargeable by charger unit) to ventilate both thermometers

For measuring relative humidity directly, use has been made of *lithium chloride or sulphonated polystyrene layers*, since the electrical resistance of these electrolytes changes with relative humidity. However, these electrolytic sensors become affected by air contamination and high relative humidity conditions and are therefore to be used with great care and frequent recalibration. For example *resistive polymer film* humidity sensors are increasingly used. Instruments are usually contaminant resistant and common solvents, dirt, oil, and other pollutants do not affect the stability or accuracy of the sensor.

Electrical dew-point hygrometers indicate dew point rather than relative humidity.

For example, the *lithium chloride dew-point hydrometer* measures the equilibrium temperature of a heated soft fiberglass wick impregnated with a saturated solution of lithium chloride. This temperature is linearly related to atmospheric dew point. However, the response of the instrument under low relative humidity conditions is not so good.

More expensive and complicated, but more accurate, instruments require that the air be sampled and delivered, without changing its water-vapour content, to a measuring unit. One such instrument, an illuminated condensation mirror, is alternately cooled and heated by a circuit energized by a photocell relay, which maintains the mirror at dewpoint temperature. *Infra-red gas analyzer hygrometers* (IRGAs) are based on the fact that water vapour absorbs energy at certain wavelengths and not others.

3.5 Soil and Grain Moisture

Several instruments have been constructed to measure soil-moisture variations at a single point but they avoid the variability of soils in space and depth. An indirect method of obtaining soil water content is the measurement of a property of some object placed in the soil, usually a porous absorber, which comes to water equilibrium with the soil. Blotting paper is popular here and they may be also useful for soil potential determinations, characterizing the water supplying power of the soil in representation of root hairs. Subjective methods of estimating soil moisture have been used with satisfactory results in some regions where regular observations in a dense network are necessary and suitable instruments lacking.

Skilled observers, trained to appreciate the plasticity of soil samples with any simple equipment, form the only requirement for this method. Periodic observations and simultaneous determinations of soil texture at depths, by competent technicians, allow approximate charts to be constructed. The direct methods of soil water measurement facilitate implementation of easy follow up methods at operational levels. Gravimetric observations of soil water content have been in use for a long time in many countries. An auger to obtain a soil sample, a scale for weighing it, and an oven for drying it at 100-105^{0}C are used for the purpose. Comparison of weights before and after drying permits evaluation of moisture content which is expressed as a percentage of dry soil or, where possible, by volume (in mm) per meter depth of soil sample. Because of large sampling errors and high soil variability the use of three or more replicates for each observational depth is recommended. The volumetric method is useful to measure the absolute amount of water in a given soil and it has known volumes of soil sampled.

Among *radioactive methods, the neutron probe* measures the degree to which high energy neutrons are thermalized in the soil by the hydrogen atoms in the water. It determines volumetric water content indirectly *in-situ* at specific soil depths using a pre-designed network of access tubes. The neutron scattering and slowing method was until recently most widely used, relatively safe and simple to operate. The total neutron count per unit time is proportional to the moisture content of a sphere of soil of which the diameter is larger when the soil is drier. Soil moisture is measured with the *gamma radiation probe* by evaluating differential attenuation of gamma rays as they pass through dry and natural soils. This method generally requires two probes introduced simultaneously into the soil a fixed distance apart, one carrying the gamma source and the other the receiver unit.

Time Domain Reflectometry (TDR) determines the soil water content through measuring the dielectric constant of the soil, which is a function of the volumetric water content. It is obtained by measuring the propagation speed of alternating current pulses of very high frequency (>300 MHz). The pulses are reflected as inhomogeneities, either in the soil or at the probe soil interface, and the travel time between the reflections is measured. From the travel time the dielectric constant is determined and in that way the volumetric water content of the soil. As with neutron scattering, this method can be used over a large range of water contents in the soil. It can be used directly within the soil or in access tubes. Compared to the neutron scattering method, the spatial resolution is better, calibration requirements are less severe and the cost is lower.

3.6 Precipitation (Clouds and Hydrometeors)

For some purposes for which no great precision in rainfall is needed, for example in classifying days as either “wet” or “dry” for insurance claims or when only rough ideas are wanted of accumulation of rainfall over agricultural fields over an ongoing season compared to the same period in earlier years, a topic most farmers will be interested in. The same applies in school (agricultural) environmental science teaching. In Mali the National Meteorological Directorate is of the opinion that farmers need to have a means of measuring rainfall if they wish to derive full profit from the meteorological information disseminated by rural radio, and farmer raingauges are now locally manufactured. A few additional remarks are appropriate here on a number of instruments used for specific work, and on their operation. Hailfall observations cannot be automated, because the only useful observation method so far is employment of a network of hail pads.

It should first be noted that since close to 150 years, wind, and therefore particularly height and shape of the rain gauge, have correctly been seen as by far the most important factors determining errors in rainfall measurement. When cost is important, including needs for high measuring densities, raingauges smaller in size than the normal standard are employed, but they are unsuitable for snow
Sometimes these are made of plastic and shaped like a wedge, sometimes they are plastic or other can like receptacles. Commercially the former are often called “raingauges according to Diem” or “farmer

raingauges", the latter, if from plastic, "clear view raingauges". Inexpensive rain gauges and small-size totalizer rain gauges are used for studying the small-scale distribution of precipitation, as in limited meso climates, forest or crop interception, shelterbelt effects, etc.

In addition to routine rainfall measurements, agricultural practices need the amount, duration and intensity of precipitation at the time of floods and related disasters. As the severe weather systems affecting coastal areas originate in seas and oceans the ocean based data collections through ships and buoys are necessary. Also, installation of automatic weather stations that meet the necessary criteria will help monitoring and early warning coastal zones about hazardous weather. However, capability for disseminating the weather data, topography and vulnerability of the coastal zone to severe weather, decide on the weather station network requirements. In vulnerable coastal zones a dense network of observations is required to diagnose and plan in advance the mitigation of weather related hazards.

Radar, sometimes together with satellite remote sensing, is increasingly used to estimate both point and area rainfall from characteristics of cloud structure and water content. These data complement the surface raingauge networks in monitoring and mapping rainfall distribution but it is essential that representative actual observations at the surface are used when taking decisions on the track of the storm for forecasting purposes. Such derived rainfall data need ongoing intensity calibration.

3.7 Evaporation and Water-Balance

Standard instruments used for measuring the different components of the water balance for climatological and hydrological purposes include screened and open pan evaporimeters, lysimeters.

While it is possible to estimate actual or potential evapotranspiration from observed values of screen or open pan evaporimeters or from integrated sets of meteorological observations, more accurate, direct observations are often preferred. Actual evapotranspiration is measured by using soil evaporimeters or lysimeters, which are field tanks of varying types and dimensions, containing natural soil and a vegetation cover (grass, crops or small shrubs). Potential evapotranspiration (PET) can be measured by lysimeters containing soil at field capacity and a growing plant cover. A surface at almost permanent field capacity is obtained by regular irrigation or by maintaining a stable water table close to the soil surface. A strict control must be kept of infiltration from rainfall of excess water supply. The reliability of observation by lysimeters depends upon the conditions at the instrumental surface and below it being very similar to the conditions of the surrounding soil.

Lysimeters are used for measurement of evaporation, transpiration, evapotranspiration (ET), effective rainfall, drainage, chemical contents of drainage water, to study climatic effects of ET on the performance of crops. Lysimetry is one of the most practical and accurate methods for short term ET measurements, but a number of factors cause a lysimeter to deviate from reality viz., changes in the hydrological boundaries, disturbance of soil during construction, conduction of heat by lateral walls, etc.

Devices for measuring net radiation, soil heat flux and sensible and advected heat are needed in energy budget methods, while continuous measurements of wind speed, temperature and water-vapour profiles are needed for the aerodynamic method. When adequate instrumentation facilities and personnel are available, it is possible to compute actual evapotranspiration using energy balance or mass-transfer methods. Certain semi-empirical methods which require relatively simple climatological measurements to provide estimates of PET are often of little value when evaporation is limited by water supply.

Microlysimeters are very small lysimeters, for soil evaporation measurements, which can be put into the ground and used for short times, such that disturbance of the soil boundary condition does not appreciably effect evaporation from the soil.

4.0 CONCLUSION

This marks the end of the 13 unit material to introduce you to instrumentation in Environmental Science. It is assumed that you will have read through all the units before you reach this last page. You are not expected to have missed any unit as each unit is mutually inclusive of another. Interestingly, each unit is characteristically important.

5.0 SUMMARY

This Unit has focused on some meteorological variables, and their measurements. The earlier part of the unit discussed the types of the meteorological stations, namely fixed and mobile stations. Within these stations is some equipment, ranging from electrically controlled to electromechanical and mechanically controlled. Instruments for measuring a number of meteorological variables, including wind, temperatures, precipitation, evaporation, etc. are also discussed. Please let’s have you assessed of this unit before I bid you bye to this course.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe 5 meteorological observation instrument and the corresponding variables they measure.
2. Compare fixed and mobile meteorological stations.

7.0 REFERENCES/FURTHER READING

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