

WATER QUALITY - AN INTRODUCTION

1.0 WATER QUALITY PARAMETERS

1.1 Physical parameters

This include turbidity, solids, electrical conductance, colour, odour and temperature etc. We expect water to be clear, colourless, and odourless. Most natural waters are at best cloudy; they are often coloured by tennin and other organic materials picked up from decaying plants. Temperature measurements are important for understanding the problem of density, viscosity, vapour pressure, oxygen saturation value and rates of bio-chemical degradation. The test for residue is of great importance in sewage treatment process to indicate the physical state of the principal constituent. The solid present in dissolved form are related to the electrical conductivity of the water. Common analysis used to assess the physical impurities in water and wastewater are Turbidity, solids, electrical conductance, colour, odour, and temperature.

Turbidity: The first thing that is noticed about water is its clarity. Very clear natural water allows images to be seen distinctly at considerable depths. Measurement of turbidity is accomplished by determining light transmission using standard light sources. The test has little meaning in relatively clear waters but is very useful in defining drinking water quality in water treatment.

Solids: All contaminants of water, other than dissolved gases, contribute to the solids load. Solids can be classified by their size and state, by their chemical characteristics, and by their size distribution. Solids are divided into two broad groupings: dissolved (including colloidal and small suspended particles) and suspended (including settleable). The distinction is made using a membrane filter with a pore size of about 1.2 micron. Any particle passing the filter is considered dissolved, and any particle retained on the filter is considered suspended. In some cases, the more accurate terms, filtrable and nonfiltrable, are now being used. The sum of dissolved and suspended (filtrable and nonfiltrable) solids is the total solids content.

Solids are also characterized as being nonvolatile or volatile (in some texts the terms "fixed" and "volatile" are used). Volatile solids are by definition those solids that volatilize at a temperature of 550 °C. In many cases volatile solids are considered to be organic, and thus the test is sometimes used to estimate the organic/inorganic characteristics of the solids.

Colour: Many of the colours associated with water are not true colours but the result of colloidal suspension; tea is an example of such coloration. True colours result from dissolved materials, most often organisms. Most colours in natural waters result from dissolved tannin extracted from decaying plant materials. The result is slightly brownish tint. Many industrial wastes are coloured and if not properly treated can impart colour to the receiving stream.

Odour: Odour associated with water usually result from the presence of decaying organic matter or, in the case of mineral springs, the reduction of sulfates by bacteria to hydrogen sulfide gas. Decaying organic matter may accumulate in bottom deposits large enough to provide suitable conditions for the anaerobic bacteria that produce noxious gases. Sources of the organics include plant debris washed into streams, dead animals, microorganisms, and wastewater discharge.

Temperature: Temperature affects a number of important water quality parameters. Chemical and biochemical reaction rates increase markedly with temperature. Gas solubility decreases and mineral solubility increases with temperature. Growth and respiration rates of aquatic organisms increases and decreases with temperature, and most organisms have distinct temperature ranges within which they

reproduce and compete.

Lakes vary in temperature from surface to bottom, and fish population vary accordingly. Cold-water species such as trout stay in the depths, while warm-water species such as bass found in shallow regions near the edges. Downstream populations can be modified by reservoir releases. Water released from the reservoir surface will be warmer and promote warm-water organisms downstream. Releasing water from the bottom will have the opposite effect. When the water is used for irrigation, its temperature must be high enough to induce germination of seeds.

1.2 Chemical parameters

Chemical characteristics of water can be classified into two categories, (a) inorganic matter, and (b) organic matter. The chemical characteristics of water quality include analysis for the presence of specific ions. Gross chemical measures such as alkalinity and hardness are also used to define water quality. Most of the common water quality parameters reflects combination of or interactions between ions.

(a) Inorganic matter

Major ionic species: All natural water contain dissolved ionic constituents. The following ionic species represent the principal chemical constituents present in most waters.

Cations	Anions
Calcium	Bicarbonate
Magnesium	Sulfate
Sodium	Chloride
Potassium	Nitrate

Typically these ionic species are derived from the contact of the water with various mineral deposits. The most abundant species are bicarbonates, sulfates, and chlorides of calcium, magnesium, and sodium. The distribution of these species vary with geographic location and the residence time history of the water. Potassium, usually present in small amounts, is derived from soil minerals, from decaying organic matter, and from the ashes of burned plants and trees. Nitrate is usually present in small amounts.

Minor ionic species: Minor ionic species found in water include the following:

Cations	Anions
Aluminium	Bisulfate
Ammonium	Bisulfate
Arsenic	Carbonate
Barium	Fluoride
Boron, as borate	Hydroxide
Copper	Phosphate, mono-
Iron, ferrous	Phosphate, di-
Iron, ferric	Phosphate, tri-
Manganese	Sulfide, Sulfite

As with the major ionic species, most of the minor ionic species are derived from the contact of water with various mineral deposits. In addition, some of the minor constituents such as ammonium, carbonate, and sulfide may be present because of bacterial and algal activity.

Nonionic species: The principal nonionic mineral found in all natural waters and groundwaters is silica, usually expressed as SiO_2 . When reference is made to silica it is assumed that the soluble form

is being considered, as opposed to the silica that may be present in the suspended solids. The presence of silica in water is troublesome, especially in industrial applications, where it causes severe scaling problems in boilers and heat exchangers.

Inorganic species added by humans: In addition to the major and minor ionic species found in natural waters, a variety of inorganic species (principally heavy metals) of anthropogenic origin may also be found. The more important of these are arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, zinc and cyanide.

These constituents are of concern primarily because of their toxicity to microorganisms, plants, and animals. Typically the presence of these constituents is due to the discharge of improperly processed industrial wastes, and high concentrations are often found in wastewater sludges.

Nutrients added by humans: Nitrogen and phosphorous are essential elements for the growth of plants and animals. For this reason these elements are often identified as nutrients. It may be noted that both organic and inorganic forms of these constituents are of importance. Nitrogen is a complex element that can exist in seven states of oxidation. From a water quality standpoint, the nitrogen-containing compounds that are of most interest are organic nitrogen, ammonia, nitrite and nitrate.

Phosphorous, like nitrogen, is of great importance in water supply systems and in the aquatic environments. Phosphorous compounds are used for corrosion control in water supply and industrial cooling water systems and in the production of synthetic detergents.

(b) Organic matter

Natural organic compounds: Most organic compounds are composed of various combinations of carbon, hydrogen, oxygen, nitrogen, phosphorous, and sulphur. The principal organic compounds found in wastewater, and to a much lesser degree in natural waters, include proteins, carbohydrates, and lipids.

Synthetic organic compounds: A large number of organic compounds have been synthesized whose presence in water is of concern from health, treatment, and ecological standpoint. Of greatest concern are those organic compounds that may be carcinogenic or that may cause mutation in humans and other living forms at extremely low concentrations, e.g. surfactants, pesticides and agricultural chemicals, organic solvents etc.

1.3 Biological parameters

The principal groups of microorganisms found in water may be classified as protists, plants, and animals. The most important microorganisms of concern in water and wastewater include bacteria, fungi, algae, protozoa, worms, rotifers, crustaceans, and viruses.

Bacteria: Bacteria are single cell protists. Although there are hundreds of bacteria, most bacteria can be grouped by form into four general categories: spheroid, rod, curved rod or spiral, and filamentous. Spherical bacteria, known as cocci (singular, coccus), are about 1 to 3 μm in diameter. The rod-shaped bacteria, known as bacilli (singular, bacillus) are quite variable in size, ranging from 0.3 to 1.5 μm in width (or diameter) and from 1.0 to 10.0 μm in length. *Escherichia coli*, a common organism found in human faeces, is described as being 0.5 μm in width by 2 μm in length. Curved rod-shaped bacteria are known as vibrios and typically vary in size from 0.6 to 1.0 μm in width (or diameter) and from 2 to 6 μm in length. Spiral bacteria known as spirilla (singular, spirillum) may be found in lengths up to 50 μm . Filamentous forms, known under a variety of names, can occur in

lengths of 100 μm and longer.

Fungi: Fungi are aerobic, multicellular, nonphotosynthetic, heterotrophic, eucaryotic protists. Most fungi obtain food from dead organic matter. Along with bacteria, fungi are the principal organisms responsible for the decomposition of carbon in the biosphere. Ecologically, fungi have two advantages over bacteria: They can grow in low-moisture areas and in low-pH environments. Because of the above characteristics, fungi play an important role in the breakdown of organic materials in both terrestrial and aquatic environments. As organic materials are decomposed, fungi release carbon dioxide to the atmosphere and nitrogen to the terrestrial environment. Without the presence of fungi to break down organic material, the carbon cycle would soon to exist and organic matter would start to accumulate.

Fungi vary in size from microscopic organisms to mushrooms and are often divided into following five classes :1. Myxomycetes, or slime fungi; 2. Phycomycetes, or aquatic fungi; 3. Ascomycetes, or sac fungi; 4. Basidiomycetes, or rusts, smuts, and mushrooms; and 5. Fungi imperfecti, or miscellaneous fungi. With respect to water quality, the first two classes are of greatest importance.

Algae: The name algae is applied to a diverse group of eucaryotic micro organisms that share some similar characteristics. Typically algae are autotrophic, photosynthetic, and contain chlorophyll. In addition to chlorophyll, other pigments encountered in algae include carotenes (orange), phycocyanin (blue), fucoxanthin (brown), and xanthophylls (yellow). Combinations of these pigments result in the various colours of algae in nature.

Metabolically, algae utilize the CO_2 present in water for synthesis of cell carbon. Chlorophylls, carotenoids and phycobilins are used to absorb light energy for photosynthetic cell reproduction and cell maintenance. Oxygen is produced during the photosynthetic process. At night algae utilise oxygen. Although respiration also occur in the presence of sunlight, the amount of oxygen released exceeds the amount used during day light.

Algae are very important microorganisms with respect to water quality. In an aquatic environment, algae forms a symbiotic relationship with bacteria. If allowed to predominate, they can affect the dissolved oxygen balance by causing anaerobic conditions to exist at night.

Protozoa: Protozoa are single-cell eucaryotic microorganisms without cell walls. Most protozoa are free-living in nature, although several species are parasitic, living on or in a host organism. Hosts can vary from primitive organisms such as algae to highly complex organisms, including human beings. The majority of protozoa are aerobic, although some anaerobic types have been reported. The four major groups of protozoa are ciliata, mastigophoran, sarcodina and sporozoa.

Worms: A number of worms are of importance with respect to water quality, primarily from the standpoint of human disease. Two important worm phyla are the Platyhelminthes and the Aschelminthes. The common name for the phylum Platyhelminthes is flatworms. Freelifing flatworms of the class Turbellarian are present in ponds and quietstreams. Two classes of flatworms, Trematoda (flukes) and Cestoda (tapeworms), are composed entirely of parasitic forms

The most important members of the phylum Aschelminthes are the nematodes. More than 10,000 species of nematodes have already been identified. Most nematodes are free-living. Of greater interest to humans are the parasitic forms. The most serious parasites forms are Trichinella, Necator, Ascaris, etc.

Rotifers: Rotifers are the simplest of the multicellular animals. The name is derived from the apparent rotating motion of the cilia located on the head of organism. The cilia are used for motility and for capturing food. Metabolically, rotifers can be classified as aerobic chemoheterotrophs. Bacteria are the principal food source for rotifers.

Crustaceans: Like rotifers, crustaceans are aerobic chemoheterotrophs that feed on bacteria and algae. These hard-shelled, multicellular animals are an important source of food for fish.

Viruses: Viruses are oligate parasitic particles consisting of a strand of genetic material - deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) - within the protein coat. The particles do not have the ability to synthesize new compounds. They invade living cells, where the viral genetic material redirects cell activities towards production of new viral cells at the expense of the host cell growth. When the host cell dies, large numbers of viruses are released to infect other cells. They cause several types of infections, e.g., common cold. A number of viral diseases are commonly transferred via water.

2.0 SAMPLING TECHNIQUES

Sampling is the first of a series of steps leading to the generation of water quality data and is an exceedingly important one. Care must always be taken to ensure obtaining a sample that is truly representative. Further, the integrity of the sample must be maintained from the time of collection to the time of analysis. If the sample is not representative of the system sampled or if the sample has changed in chemical composition between sampling and analysis, all care taken to provide an accurate analysis will be lost.

2.1 Sample containers

Chemically neutral plastic (polyethylene) or glass containers should be used, non-breakable plastic containers being more desirable than glass. However, when sampling for phosphorous, pesticides, and other similar type compounds, glass containers must be used because of their possible interference with plastic. When the sample is collected for analysis of metals, the sampler should be designed so that no metallic parts come into contact with the sample.

2.2 Sampling from surface water

Water samples for physical, chemical and biological analysis are taken in the same manner. For bacteriological analysis it is always necessary to use sterilized equipment and apparatus. One to two litres of sample is normally sufficient for most physical, chemical and bacteriological parameters. Before the sampling bottles are filled, they should be rinsed two to three times with the water to be sampled. Depending upon desired accuracy of the sample and local conditions, different type of sampling devices can be used.

Manual sampling : The simplest form of a water sampling device is a bottle attached to a string. To lower a plastic or glass into a body of water it is necessary to use a bracket or holder of sufficient weight to overcome the buoyancy of the bottle and allow it to sink as rapidly as desired (Fig.1). In this case, even if the bottle is lowered rapidly to the desired depth, a certain amount of water from the overlying layers will be included in the sample.

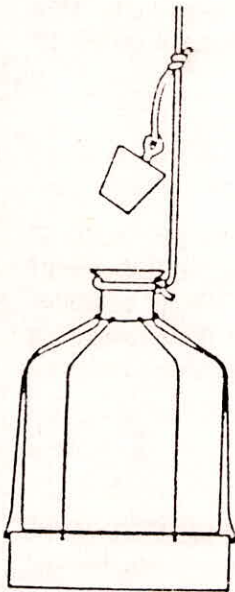


Fig. 2: Meyer's sampling bottle

When water from a particular depth is to be collected, Meyer's sampler bottle (Fig.2) or Dussart sampler (Fig. 3) may be used. In both of these devices, a closed container is lowered to the desired depth and then by means of a jerk of the suspending cord, the container is opened. In these samples, when the bottle is full it cannot be stoppered and must be pulled up in an open position. Thus, to some extent, admixtures with other layers of water cannot be avoided.

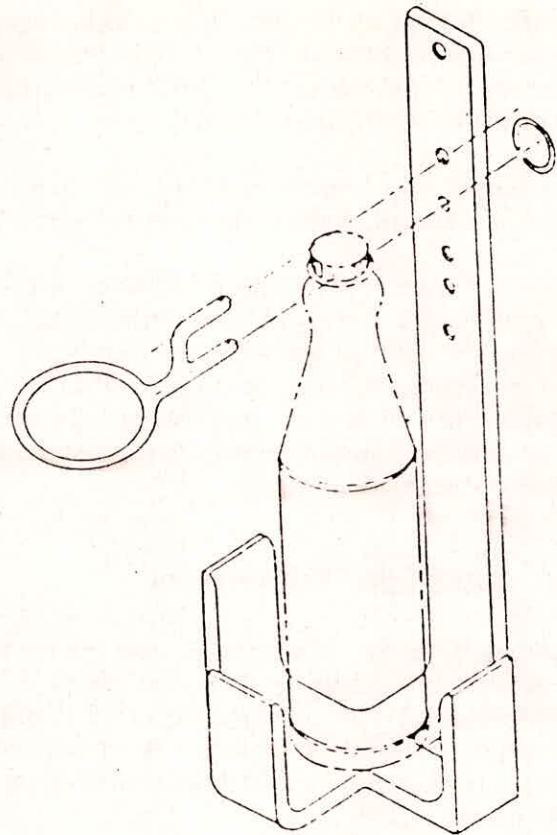


Fig. 1 : Sample bottle holder for manual sampling

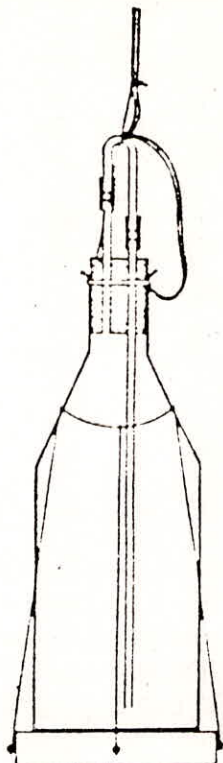


Fig. 3 : Dussart Sampler

For greater accuracy and for water depths greater than 50 m, special samplers such as Kemmerer (Fig. 4) may be used. This essentially consists of bottles, opened at both ends, which are lowered to desired depth in the open position in order to allow water to stream through the bottle. Closure is effected by a drop weight or a messenger which slides the supporting wire or cord. In this way, a sample of water is isolated and is not affected when the bottle is either lowered or pulled up.

Automatic sampling : Automatic sampling devices are used to collect composite samples over extended periods of time. Several types of automatic samplers are available in the market, such as vacuum type, pressure type and those which are operated by pumps. Automatic samplers are programmed by timing devices designed to collect small aliquots of samples at regular intervals during a prescribed period of time. These aliquots are either stored in separate containers in the sampling device or discharged into a common container thereby producing a composite sample. Automatic sampling devices are widely used for sampling waste discharges from municipal and industrial waste water treatment plants.

Sampling from shallow water : In shallow waters a simple glass tube may be used for sampling. For example, an integrated sample may be collected by immersing a tube, open at both ends. A sample from a particular depth may be collected by immersing a tube with both top and bottom closed. The top is then opened after the lower end has reached the desired depth. When the sample has been collected the top is closed again and the tube is withdrawn.

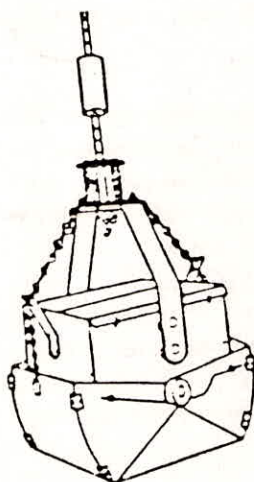


Fig. 5 : Eckman Dredge

2.3 Sediment sampling from surface water

Sediments are collected for performing chemical and biological analysis. There are several types of dredgers available for sampling sediments. Of these, the Eckman, Petersen and Surber dredges are used commonly for rivers and lakes. Eckman dredge (Fig. 5) is a fairly light, spring-triggered, brass dredge made in several sizes (about 15x15 cm, 24x24 cm and 30x30 cm, of which the 15x15 cm size is most common). After reaching the bottom, a messenger is sent down the line to trigger closure of the jaws and enclose a sample of bottom sediment.

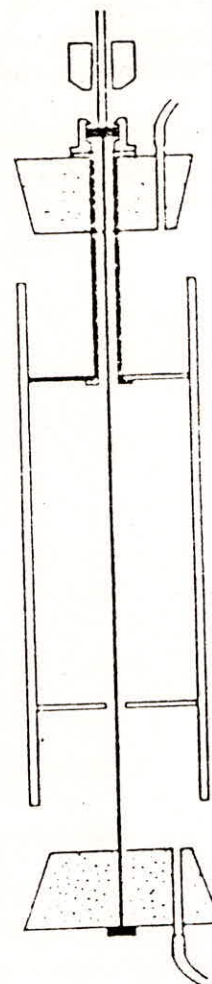


Fig. 4: Kemmerer Sampler

The Petersen dredge (Fig. 6) is made of steel and is quite heavier. This is not spring equipped, requires no messenger and its closing is induced by the release of tension in the line once the dredge has settled on the bottom. The dredge is quite heavier (30 kg or more) and require the use of a small winch or boat crane and has to be lowered carefully so as not to produce a shock wave ahead of the dredge as it reaches the bottom sediments. The heavier dredges collect samples from sediments which are too hard for an Eckman dredge.

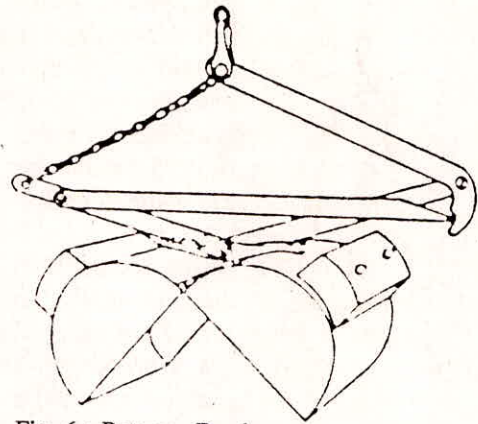


Fig. 6 : Petersen Dredge

The Surber sampler (Fig. 7) is a light weight device for collecting biological samples in water depths up to 0.75 m for fast flowing streams. It consists of strong close-woven fabric

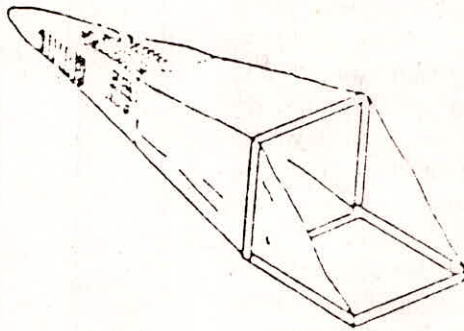


Fig. 7 : Surber Sampler

approximately 70 cm long. This net is held open by a one square foot metal frame hinged at one side to another frame of equal size. In operation, the frame which supports the net is in a vertical position while the other frame is locked into horizontal position against the other bottom deposits and are dug to a depth of at least 6 cm. The dissolved organisms then drift into the open net. In shallow water, semi-quantitative bottom samples may be obtained by bringing the bottom sediment into suspension by kicking the bed one or more times and collecting the dislodged organisms in a net.

2.4 Ground water sampling

Ground water sample collection involve sampling of drainage water, open well water and drilled well water.

The drainage water may be collected directly from the drainage outlet in the sample bottle. When open well water is to be collected, it should be pumped for about 5 min before the collection takes place/ If the well is only slightly used, water should be pumped for 20 min and longer, until a constant temperature or conductivity of the water is reached. The pumped water should be drained out of the well perimeter to prevent the infiltration of washed water back into the well.

Samples from drilled wells in which water is standing for a long time or where the upper opening is not adequately closed, should be collected only after the well has been pumped for a sufficient time to ensure that the sample represent the ground water which feeds the well. It is often necessary to collect a water sample from a particular depth without mixing it with water from other layers.

3.0 WATER ANALYSIS

3.1 Field analysis

Because of chemical changes that occur in water samples during transit and storage, certain parameters should be measured on-site immediately after the sample is taken. These are temperature, pH, dissolved oxygen and electrical conductance. These measurements are usually carried out using portable test kits.

Temperature may be measured on-site with a standard laboratory thermometer. Thermometers contained in metal protective casings are available commercially for field work and are calibrated in scales suitable for normal water temperatures.

The pH value of water may be determined potentiometrically by a wide variety of pH meters equipped with glass and reference electrode. Each pH meter requires standardization with standard buffer solutions before each measurement.

Electrical conductance is a measure of dissolved solid concentrations. This is usually measured in the field by Wheatstone bridge type instrument with a conductivity cell, which is immersed in the water sample or directly in the water body for measurement of electrical conductivity.

Dissolved oxygen can be measured either by well known Winkler method or by electrometric method. The electrometric method is more rapid and more versatile than the Winkler procedure because of its capability for direct measurement of dissolved oxygen.

3.2 Preservation techniques

In addition to on-site measurements discussed in previous section, colour, turbidity, nitrogen, phosphorous, silica, residue and other parameters should be determined within hours of sampling. These analyses are best carried out in a mobile laboratory. It is also desirable, though not essential, to measure acidity, alkalinity, total hardness, calcium and magnesium within hours after taking the sample(s). Some laboratories, however, measure these in a permanent laboratory within seven days of sample collection.

Once samples have been collected and treated as required, sample bottles should be tightly capped and forwarded to a laboratory for analysis in accordance with standard methods. The following are some of the guidelines on the handling and preparation of samples.

Colour: In natural waters, colour is due to mainly humic acid and organic matter leached from decaying vegetation, including tannin and vegetable dyes. Iron and manganese compounds also impart colour to natural waters. Sewage and industrial waters cause serious colour problems in local areas.

Turbidity: Turbidity is largely a value reflecting the particle size of suspended matter and is not a measure of the amount of material. Turbidity may be due in part or in total to suspended clay, silt, bacterial decomposition products, iron oxide, finely divided organic matter, microscopic organisms, and industrial and mining substances. Turbidity affects all uses of water and adds to the cost of water treatment for these uses. Turbidity should be measured as quickly as possible.

Residue: As part of the laboratory measurement technique, the sample is filtered through a standard glass fibre filter. The filterable residue is the material remaining in the dish after evaporating the

filtrate to dryness at 105°C to achieve a constant weight. The fixed filterable residue is the material remaining in the same dish after the filterable residue has been subjected to heat for 1 hour at 550°C. The nonfilterable residue is the material retained on the glass fibre filter after drying to constant weight at 105°C. The fixed nonfilterable residue is the material remaining on the same glass fibre filter after subjecting the nonfilterable residue to heat for 1 hour at 550°C.

Acidity: Sample should be collected in polyethylene bottles and stored at a low temperature and analysed as soon as possible after sampling. In the laboratory an electrometric titration method may be used where a sample aliquot is titrated with standard alkali such as NaOH to designated end points, usually pH 4.5 and pH 8.3.

Alkalinity: Alkalinity is a measure of the bicarbonate, carbonate and hydroxide ions. In most natural waters, the principal anion is bicarbonate with carbonate and/or hydroxyl ion being present only if the pH is greater than 8.3 (phenolphthalein alkalinity). Phenolphthalein alkalinity is usually due to carbonates and/or free hydroxides present in treated waters or waste waters. Most surface waters show no phenolphthalein alkalinity, since all alkalinity is due to the bicarbonates of alkali earth. Alkalinity may be determined by using sulphuric acid or by a potentiometric method.

Total hardness: Hardness of water is the property attributed to the presence of alkaline earths. Calcium and magnesium are the principal alkaline earths in natural waters. Hardness of water presents one of the greatest problem in the use of water contributing to dense scale formation on heating surfaces in boilers, cooling water equipment and industrial process systems. Total hardness may be determined by the standard titration method using the sodium salt of EDTA and Eriochrome black T as indicator.

Nitrogen: Nitrogen is an essential constituent of all living organisms. It occurs in various oxidation states ranging from N^{+3} (ammonia and amino group) to N^{5+} (nitrate). Most lake water analysis are restricted to ammonia, nitrate, nitrite and Kjeldahl nitrogen (ammonia nitrogen plus organic nitrogen). Sample should be preserved with 0.8 ml concentrated sulphuric acid per litre of sample. Then the sample should be stored at 4°C.

Oxygen: Sample collected for oxygen determination should be collected in narrow mouthed, BOD bottle. Other bottles may also be used but special care must be taken to avoid contamination with atmospheric oxygen. The sample should be immediately analysed by the Winkler titration method or by a dissolved oxygen meter using a membrane electrode.

The BOD test empirically measure the quantity of oxygen required for the biological oxidation of water-borne substances under specific test condition. It is generally based on a five day incubation method at 20°C which should be started immediately in the field, preferably within four hours after the sample has been taken. The composition of the dissolved oxygen content at the beginning and end of the incubation period provides a measure of the biochemical oxygen demand. The oxygen consumed is a measure of the oxidizable material in waters.

Chemical oxygen demand (COD) is the measure of oxygen equivalent of most organic matter in water. COD requires as complete an oxidation as possible with a very strong oxidant mixture such as potassium dichromate and sulphuric acid. If there is any delay before analysis for COD, the samples may be preserved by acidifying with sulphuric acid.

Carbon: Samples collected for organic carbon determination should be refrigerated and kept tightly capped. Sample may be preserved by adding 1 ml concentrated sulphuric acid per litre of sample. In

laboratory a combustion method using an infra-red carbon analyser would be suitable to determine the total organic carbon content.

Metals: Metals are usually measured under three different categories, depending upon the requirement and nature of the study. These are dissolved metals, suspended metals and total metals. Sample collected for dissolved metals should be filtered at the time of collection through a 0.45 μm membrane filter and the sample acidified with 2 ml concentrated nitric acid per litre after filtration. Samples collected for suspended metals should be filtered at the time of collection through a 0.45 μm membrane filter and analysis carried out on the portion of the sample retained on the filter. Total metal determination may be performed by calculating the sum of dissolved and suspended metal concentrations. Total metal may also be determined by conducting an analysis on an unfiltered sample, treated with nitric acid so as to dissolve all metals. Trace elements are treated with 2 ml concentrated nitric acid per litre of sample, to preserve the sample against changes in transportation and storage. Samples thus preserved can be stored for a period of six months.

3.3 Laboratory for testing

Basic layout planning is an exercise of packing laboratory benches in the most economical manner into a minimum space. The traditional method is to place benches around the walls and then, if more space is available, more benches may be placed in the middle of the room. The following items should be acquired in developing a basic water quality laboratory:

- Adequate space with essential services provided;
- Distilling apparatus and adequate supply of volumetric and other laboratory glassware;
- Supply of standard chemicals and reagents for the parameters to be measured;
- Analytical balance;
- Portable equipment like pH meter, conductivity meter, turbidity meter, water testing kit;
- UV-Visible spectrophotometer;
- General purpose equipment like oven, furnace, hot plate, autoclave, BOD incubator, bacteriological incubator;
- Bacteriological equipment.

As the requirement for more data develops and the need to measure constituents at low concentrations increases, consideration should be given to procuring more sophisticated instrumentation such as:

- Atomic absorption spectrophotometer;
- Deionizing equipment to purify distilled water for trace element analysis;
- Chromatographic equipment;
- Infra-red (IR) spectrophotometer;
- Auto analyzers
- Radioactivity measuring equipment

Because of the wide use and versatility of atomic absorption units, these may even be considered as a requirement for a basic laboratory. These units are relatively expensive but add materially to the efficiency of a laboratory operation.

Scientific instruments and equipment must be thoroughly checked and evaluated before final acquisition. A very important consideration in the procurement of equipment is the availability of service and spare parts.

In the development of laboratory facilities it is important to keep provision for expansion as needs arise and to keep abreast of the latest developments in this field.

