Introduction to water quality instruments and measurements

Water quality

Water quality is commonly defined by its physical, chemical, biological and aesthetic (appearance and smell) characteristics. Water may be used for drinking, irrigating crops and watering stock, industrial processes, production of fish, shellfish and crustaceans, wildlife habitats, protection of aquatic ecosystems, navigation and shipping, recreation (swimming, boating), and scientific study and education.

Factors influencing water quality

Water quality is closely linked to the surrounding environment and land use. Liquid water is never pure and is affected by agriculture, urban, industrial and recreation uses. The modification of natural stream flows and the weather can also have a major impact on water quality. Groundwater is a major source of water and, when close to urban or industrial development, is vulnerable to contamination. Generally, water quality of rivers is best in the headwaters, where rainfall is often abundant, declining as rivers flow through regions where land use and water use are intense and pollution from intensive agriculture, large towns, industry and recreation areas increases. There are of course exceptions to the rule and water quality may improve downstream, behind dams and weirs, at points where tributaries or better-quality groundwater enter the mainstream, and in wetlands. Rivers frequently act as conduits for pollutants by collecting and carrying wastewater from catchments and, ultimately, discharging it into the ocean. Storm water, which can also be rich in nutrients, organic matter and pollutants, finds its way into rivers and oceans mostly via the storm water drain network.

Water quality and ecosystems

An ecosystem is a community of organisms - plants, animals, fungi and bacteria - interacting with one another and with the environment in which they live. Protecting aquatic ecosystems is in many ways as important as maintaining water quality, for the following reasons:

•Aquatic ecosystems are an integral part of our environment. They need to be maintained if the environment is to continue to support people. World conservation strategies stress the importance of maintaining healthy ecosystems and genetic diversity.

•Aquatic ecosystems play an important role in maintaining water quality and are a valuable indicator of water quality and the suitability of the water for other uses.

•Aquatic ecosystems are valuable resources. Aquatic life is a major source of protein for humans. In most countries, commercial and domestic fishing is economically important.

Water quality assessment

The presence of contaminants and the characteristics of water are used to indicate the quality of water. These water quality indicators can be categorized as:

- Biological: algae, bacteria

Physical temperature, turbidity (Turbidity: The clearness of the water, as affected by suspended solids. Measured in nephelometric turbidity units (NTU). Nephelometric means that the measurement has been arrived at through the estimation of light absorption. The more turbid a water, the less light there is available for photosynthesis) and clarity, Colour: The presence of colour in water. Ideal colour is colourless for drinking water. Affected by suspended solids, usually organic constituents–Taste: The presence of a taste in water. Drinking water quality measurement is affected by the presence of dissolved inorganic substances (i.e. Mg, Ca, Na, Cu, Fe and Zn)–Odour: The presence of odour in water. Often Affected by the presence of organic constituents–Temperature: The temp. of surface waters at their respected depths which can also affect the level of dissolved oxygen and metabolic rate of aquatic fauna. Most fish species require a temp. range of 5-20°C and a DO concentration of 5 g m-3, salinity, suspended solids, dissolved solids, sediment

- Chemical: pH, dissolved oxygen, biological oxygen demand, nutrients (including nitrogen and phosphorus), organic and inorganic compounds (including toxicants)
  Aesthetic: odors, taints, color, floating matter
- Radioactive: alpha, beta and gamma radiation emitters.

Measurements of these indicators can be used to determine and monitor changes in water quality and to determine whether the quality of the water is suitable for the health of the natural environment and the uses for which the water is required. The design of water quality monitoring systems is a complex and specialized field. The range of indicators that can be measured is wide and other indicators may be adopted in the future. The cost of a monitoring system to assess them all would be prohibitive, so resources are usually directed towards assessing contaminants that are important for the local environment or for a specific use of the water.

Why Monitor Water Quality?

1. Characterize waters and identify changes or trends in water quality over time.

2. Identify specific existing or emerging water quality problems.
3. Gather information to design specific pollution prevention or remediation programs.
4. Determine whether program goals such as compliance with pollution regulations or implementation of effective pollution control actions are being met.
5. Respond to emergencies, such as spills and floods

The Aquatic Environment

• The quality of the aquatic environment is a broader issue which can be described in terms of–water quality, the composition and state of the biological life present in the water body, the nature of the particulate matter present, and the physical description of the water body (hydrology, dimensions, nature of lake bottom or river bed, etc.).

Sampling types

1. Grab sampling
2. Composite sampling
3. Automated sampling

What determines water quality?

The water of even the healthiest rivers and lakes is not absolutely pure. All water (even if it is distilled) contains many naturally occurring substances–mainly bicarbonates, sulphates, sodium, chlorides, calcium, magnesium, and potassium. They reach the surface and groundwater from the soil, geologic formations and terrain in the catchment area (river basin); surrounding vegetation and wildlife; precipitation and runoff from adjacent land; biological, physical and chemical processes in the water; human activities in the region.

Water quality parameters and measuring techniques

Temperature

Temperature is an important water parameter because it is an influence quantity for the generality of other water parameters and also because it determines many physical characteristics of a water body. In the winter, water's temperature-dependent density allows aquatic life to survive. Ice is formed at 0 ºC and thus remains at the top of the water body. Sun shining through the ice will serve to warm the water below slightly, keeping the temperature just above freezing. Water at 4 ºC is the densest, and will sink to the bottom and be replaced by lighter 1 - 3.9 ºC water. The continual process of heating and sinking keeps the water body from freezing entirely. In addition, temperate lakes stratify during the summer because of water's temperature-dependent density. Stratification prevents the mixing of oxygen and nutrients in the water body, and often encourages dissolved oxygen depletion. During the spring, stratification will break down allowing mixing of oxygen and nutrients. During the fall, the water body loses heat until its temperature is uniform at 4 ºC. Wind creates circulation, which distributes oxygen and nutrients throughout the water body (fall overturn). Eventually, the surface water layer falls below 4 ºC, becomes less dense, and remains at the surface. Ice will form if temperatures are low enough; otherwise, this upper layer will remain just above 0 ºC. Deeper water will remain roughly at 4 ºC until spring. Higher temperatures often exacerbate low dissolved oxygen level problems in lakes and reservoirs. High temperatures encourage the microbial breakdown of organic matter, a process that requires dissolved oxygen. Unfortunately, warm water naturally holds less dissolved oxygen. Thus, persistent warm conditions may lead to a depletion of dissolved oxygen in the water body.

Temperature probes: Temperature range is usually from 0 to 30 ºC. Thus thermistor, platinum or even electronic based probes are adequate.

Turbidity

Turbidity is a quantity quantifying the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles. Light scattering increases with the quantity of solids suspended in water. Turbidity is commonly measured in Nephelometric Turbidity Units (NTU).

Salinity

The total dissolved solids in water consist of inorganic salts and dissolved materials. In natural waters, salts are chemical compounds comprised of anions such as carbonates, chlorides, sulphates, and nitrates (primarily in ground water), and cations such as potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na). In ambient conditions, these compounds are present in proportions that create a balanced solution. If there are additional inputs of dissolved solids to the system, the balance is altered and detrimental effects may be seen. Inputs include both natural and anthropogenic sources.

Total dissolved solids and conductivity

The presence in water of different anions and cations in different proportions leads to different values of water electric conductivity. However, even if it exists almost a linear relation between salinity and conductivity, that relation depends on the type of the dissolved salt. Moreover, conductivity is a non-selective measurement because instead of salinity, it gives the contribution of all charge carriers and not of a specific one. Notwithstanding, commonly, salinity is indirectly measured using conductivity meters.

Sediment

Sediment is composed of organic and inorganic particles of various sizes. The major classes of sediment, from largest to smallest, are boulders, cobbles, pebbles, sand, silt, and clay Sediments are classified into four broad categories, according to their origin in relation to the basin of water in which they are deposited: extrabasinal, carbonaceous, pyroclastic, and intrabasinal.

1. **Extrabasinal** (terrigenous) particles: Terrigenous particles have been eroded from the land outside the body of water experiencing the deposition. The particles either retain their chemical make-up, or become chemically altered to clays and iron oxides.
2. **Carbonaceous** particles: These particles are organic in nature and are derived from either solid carbonaceous material (coal, amber, wax, and kerogen), reworked from other geologic formations, or from modern plant detritus.
3. **Pyroclastic** particles: These particles are derived during the explosive action of a volcano. Particles include rock fragment, single crystals, or bits of volcanic glass.
4. **Intrabasinal** particles: These particles grow biochemically or chemically in the waters experiencing deposition. These particles include carbonate biocrystals, silica biocrystals, particles composed of evaporated minerals, and minerals that grow at the water/sediment interface. Sediment introduced into surface water is either deposited on the bed of the stream or lake or suspended in the water column (suspended load). Bed load is large sediment particles that move by bouncing along the bottom. Generally, the suspended loads in lotic (flowing) water consist of grains less than 0.5 mm in diameter. A water body's suspended load is a component of the total turbidity. Any sediment transported by water is subject to deposition as flow velocity decreases. The amount of sediment deposited on a rocky substrate can be quantitatively defined by an estimation of the percent embeddedness. The percent embeddedness is the

degree to which fine sediments such as sand, silt, and clay fill the interstitial spaces between rocks on a substrate.

Dissolved oxygen.

Dissolved oxygen (DO) refers to the volume of oxygen that is contained in water. Oxygen enters the water by photosynthesis of aquatic biota and by the transfer of oxygen across the air-water interface. The amount of oxygen that can be held by the water depends on the water temperature, salinity, and pressure. Gas solubility increases with decreasing temperature (colder water holds more oxygen). Gas solubility increases with decreasing salinity (freshwater holds more oxygen than does saltwater). Both the partial pressure and the degree of saturation of oxygen will change with altitude. Finally, gas solubility decreases as pressure decreases. Thus, the amount of oxygen absorbed in water decreases as altitude increases because the atmospheric pressure decreases. Microbes play a key role in the loss of oxygen from surface waters because they use oxygen as energy to break down long-chained organic molecules into simpler, more stable end-products such as carbon dioxide, water, phosphate and nitrate. If high levels of organic matter are present in water, microbes may use all available oxygen.

Nitrogen.

Nitrogen makes up 78% of the atmosphere as gaseous molecular nitrogen, but most plants can use it only in the fixed forms of nitrate and ammonium. Nitrate and nitrite are inorganic ions occurring naturally as part of the nitrogen cycle. The nitrogen cycle is composed of four processes. Three of the processes - *fixation, ammonification*, and *nitrification* - convert gaseous nitrogen into usable chemical forms. The fourth process, *denitrification,* converts fixed nitrogen back to the unusable gaseous nitrogen state

•Nitrogen fixation is the conversion of nitrogen in its gaseous state to ammonia or nitrate. Nitrate is the product of high-energy fixation of atmospheric nitrogen and oxygen. High-energy fixation accounts for little (10%) of the nitrate entering the nitrogen cycle. In contrast, biological fixation accounts for 90% of the fixed nitrogen in the cycle. In biological fixation, molecular nitrogen (N2) is split into two free N molecules. The N molecules combine with hydrogen (H) molecules to yield ammonia (NH3).

•Ammonification is a one-way reaction in which organisms break down amino acids and produce ammonia (NH3).

•Nitrification is the process in which ammonia is oxidized to nitrite and nitrate, yielding energy for decomposer organisms.
•Denitrification is the process in which nitrates are reduced to gaseous nitrogen. This process is used by facultative anaerobes. In temperate zones, soil nitrate concentrations will vary seasonally with temperature and moisture levels. Fall and winter rains thoroughly remove all nitrates from the soil. During the spring and summer, the increased nitrogen-fixing activity of organisms and the addition of fertilizer cause the concentration of nitrates in the soil to steadily increase. Most of this nitrate is absorbed by plants. Thus, the removal of crops in the fall increases the chances for large flushes of nitrate from the soil to water bodies. Some leaching may occur in the spring if crops are not well- established enough to absorb the nitrogen.

Phosphorus.
Phosphorus (P) is an essential nutrient for all life forms. It plays a role in deoxyribonucleic acid (DNA), ribonucleic acid (RNA), adenosine diphosphate (ADP), and adenosine triphosphate (ATP). Phosphorus is required for these necessary components of life to occur. Phosphorus does not exist in a gaseous state. Natural inorganic phosphorus deposits occur primarily as phosphate in the mineral apatite. Apatite is found in igneous and metamorphic rocks, and sedimentary rocks. When released into the environment, phosphates will speciate as orthophosphate according to the pH of the surrounding soil. Phosphate is usually not readily available for uptake in soils. Phosphate is only freely soluble in acid solutions and under reducing conditions. In the soil it is rapidly immobilized as calcium or iron phosphates. Most of the phosphorus in soils is adsorbed to soil particles or incorporated into organic matter.

Heavy metals.
Heavy metals are elements having atomic weights between 63.546 and 200.590, and a specific gravity greater than 4.0. Living organisms require trace amounts of some heavy metals, including cobalt, copper, iron, manganese, molybdenum, vanadium, strontium, and zinc. Excessive levels of essential metals, however, can be detrimental to the organism. Non-essential heavy metals of particular concern to surface water systems are cadmium, chromium, mercury, lead, arsenic, and antimony. All heavy metals exist in surface waters in colloidal, particulate, and dissolved phases, although dissolved concentrations are generally low. The solubility of trace metals in surface waters is predominately controlled by the water

pH, the type and concentration of ligands on which the metal could adsorb, and the oxidation state of the mineral components and the REDOX environment of the system. The behaviour of metals in natural waters is a function of the substrate sediment composition, the suspended sediment composition, and the water chemistry. Sediment composed of fine sand and silt will generally have higher levels of adsorbed metal than will quartz, feldspar, and detrital carbonate-rich sediment. Metals also have a high affinity for humic acids, organo-clays, and oxides coated with organic matter. Heavy metals in surface water systems can be from natural or anthropogenic sources. Currently, anthropogenic inputs of metals exceed natural inputs.

Water quality monitoring is a complex issue because there are a large number of parameters that can be used to access its quality. Understanding the meaning of each parameter requires a good knowledge of different areas, namely electrical, electrochemical and biological engineering, among others. Measuring techniques is still an open field for some variables, particularly in which concerns in-situ and on-line measurement systems.

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