Measurement and calibration

Water measurement

Measurement of surface water flow is an important component of most water quality monitoring projects. Flooding, stream geomorphology, and aquatic life support are all directly influenced by streamflow, and runoff and streamflow drive the generation, transport, and delivery of many nonpoint source pollutants. Calculation of pollutant loads requires knowledge of water flow. Healthy water bodies significantly affect the underwater flora and fauna and the overall health of the environment. Numerous physical, chemical, and biological factors affect the quality of water in the ponds, the lakes, the streams, the rivers, the oceans, and the groundwater. Effective and pre-emptive water-quality monitoring strategies can help environmentalists determine the natural and human factors that affect the water bodies. The results can be used to plan restoration projects to ensure that the water bodies meet the environmental standards.

Here are ways to measure and monitor the water quality, encouraging a clean and healthy aquatic ecosystem.

1. Coloured or chromophoric dissolved organic matter (CDOM)

Coloured or chromophoric dissolved organic matter occurs naturally in water bodies. This organic matter absorbs the ultraviolet light and decomposes to release tannin, an organic pollutant that causes the water to turn murky. Moreover, tannin contributes to reducing the pH (acidic) of the water and depleting the oxygen levels. A portion of the CDOM fluoresces and is referred to as fluorescent dissolved organic matter (FDOM) further making the water look cloudy. CDOM/ levels can be measured using electrical optical sensors that use fluorometers and sapphire lens. These sensors gauge the light availability in water bodies depending on the water level and indicate the concentration of dissolved organic matter.

2. Chlorophyll Fluorescence Analysis

When the surface water in ponds and lakes is rich in minerals, namely phosphorus and nitrogen, algae flourish. Disproportionate growth of algae leads to oxygen depletion and increased levels of nitrogen and phosphorus which can be toxic to the flora and fauna. Chlorophyll fluorescence, measured using algae measurement tool, indicates the percentage of wet-chemical chlorophyll and active chlorophyll in the water sample under illumination. This is an effective method to keep a check on the excessive algal growth and monitor the water quality.

3. Conductivity, Salinity, and total dissolved solid Monitoring

The conductivity of a water body is an early indicator of the water quality. Conductivity affects the salinity and total dissolved solids content, which in turn affects the concentration of oxygen in the water. Certain ecological (temperature, excessive rainfall, and increased organic matter content) and man-made (pollution) factors can increase or decrease the water bodies' conductivity, severely impacting the water quality. For instance, an oil spill or increased levels of organic substances in an ocean can decrease its conductivity, indicating water pollution. Conductivity, salinity, and total dissolved solids content meters analyze the water quality by measuring the specific electrical conductance of electrolytes dissolved in the water. Though each of these instruments measures a separate parameter, the results are correlated and indicative of pollution.

4. Recording the Water Temperature

Temperature is a crucial factor that affects the other water quality parameters such as, the rate of photosynthesis and metabolism, the dissolved gas concentrations, the conductivity and salinity, the pH, and the water density amongst other factors. For instance, ammonia at a high pH is toxic to plants and aquatic animals, however, a sudden change in temperature can double the impact. Several devices such as thermometers, thermistors, thermocouples, and digital temperature sensors are used to obtain temperature readings at varying depths, time, and locations.

5. Measuring the Dissolved Oxygen Levels

The dissolved oxygen (DO) is a measure of the amount of oxygen available to the flora and fauna and is reported as percent saturation or mg/L. The oxygen levels in water go down owing to the decomposition of organic material such as dead plants and animals and human wastes. A dissolved oxygen level of less than 6 mg/L can be harmful to the ecosystem of water bodies. The dissolved oxygen concentration can be measured using the electrochemical or optical sensor, the colorimetric method, the Winkler titration method, and the optical dissolved oxygen sensors.

6. pH and carbonate hardness Testing

An increasing pH level is dangerous to the ecosystem of the water body. A safe pH range for a pond or a lake is between 6.0 to 8.0; however, certain factors such as overgrowth of algae and pollution alter the pH of the water and increase the levels of toxic ammonia. pH can be tested using water test kits that are color-coded and offer a wide range of pH measurement. These kits work best to give you an idea of the pH range the water falls into. However, for accurate pH measurements, electronic pH sensors offer measurement values up to two decimal points. The carbonate hardness (a measure of carbonate and bicarbonate levels) is another factor that needs to be monitored as it significantly impacts the pH of the water. Therefore, to readjust the pH, you may often have to stabilize the water carbonate hardness.

7. Assessing the Turbidity, total suspended solids and Clarity

The solar radiation provides light, heat, and energy to all living being on earth. Low or high levels of ultraviolet radiations can halt the photosynthetic process, causing permanent damage to the aquatic ecosystem. Suspended solids, decaying vegetation, and other dissolved coloured material cause the water to appear cloudy and murky, impacting the penetration of sunlight on water and the aquatic life. A sudden increase in the turbidity and the total suspended solids (TSS) is an indicator of soil erosion and point-source pollution adding heavy metals and effluents into the water. A nephelometer is used to measure the scattered light at an angle of 90◦. The total suspended solids are measured by filtering and weighing the sample and are measured in milligrams of solids per litre of water. The Secchi disk is often lowered in a water body to measure the depth until which it is no longer visible (also referred to as the Secchi depth). This is a measure of the cloudiness of the water. These devices help measure the water clarity and photosynthetically active radiation, promoting a healthy environment for the plants and animals residing in the water body. By measuring and monitoring the key indicators of the quality of water, researchers and environmentalists can plan and execute strategies to conserve the water bodies and encourage biodiversity.

Applications of water measurements

Water measurement is designed to provide suitable for data analysis procedures that will allow the future generation benefit from the priceless resource. A wide range of objectives are possible, including:

1. Determine basic hydrology of any water body

2. Characterize water quantity problems for the water body in study and evaluate efforts to restore natural flow regimes

3. Identify major sources of pollutant loads for the water body

4. Characterize habitat problems in stream channels

5. Collect habitat data in support of aquatic life monitoring

6. Calibrate water body models such as streams

7. Collect design information for water quantity, water quality, or stream restoration practices

8. Quantify pollutant loads before and after implementation of practices to determine cleanup project effectiveness

Sampling and measurement

The complexity of water quality as a subject is reflected in the many types of measurements of water quality indicators. Some measurements of water quality are most accurately made on-site, because water exists in equilibrium with its surroundings.

Sample collection

More complex measurements are often made in a laboratory requiring a water sample to be collected, preserved, transported, and analysed at another location. The process of water sampling introduces two significant problems:

- The first problem is the extent to which the sample may be representative of the water source of interest. Water sources vary with time and with location. The measurement of interest may vary seasonally or from day to night or in response to some activity of man or natural populations of aquatic plants and animals. The measurement of interest may vary with distances from the water boundary with overlying atmosphere and underlying or confining soil. The sampler must determine if a single time and location meets the needs of the investigation, or if the water use of interest can be satisfactorily assessed by averaged values of sampling over time and location, or if critical maxima and minima require individual measurements over a range of times, locations or events. The sample collection procedure must assure correct weighting of individual sampling times and locations where averaging is appropriate. Where critical maximum or minimum values exist, statistical methods must be applied to observed variation to determine an adequate number of samples to assess the probability of exceeding those critical values.

- The second problem occurs as the sample is removed from the water source and begins to establish chemical equilibrium with its new surroundings – the sample container. Sample containers must be made of materials with minimal reactivity with substances to be measured; and pre-cleaning of sample containers is important. The water sample may dissolve part of the sample container and any residue on that container, and chemicals dissolved in the water sample may sorb onto the sample container and remain there when the water is poured out for analysis. Similar physical and chemical interactions may take place with any pumps, piping, or intermediate devices used to transfer the water sample into the sample container. Water collected from depths below the surface will normally be held at the reduced pressure of the atmosphere; so, gas dissolved in the water will collect at the top of the container. Atmospheric gas above the water may also dissolve into the water sample. Other chemical reaction equilibria may change if the water sample changes temperature. Finely divided solid particles formerly suspended by water turbulence may settle to the bottom of the sample container, or a solid phase may form from biological growth or chemical precipitation. Microorganisms within the water sample may biochemically alter concentrations of oxygen, carbon dioxide, and organic compounds. Changing carbon dioxide concentrations may alter pH and change solubility of chemicals of interest. These problems are of special concern during measurement of chemicals assumed to be significant at very low concentrations.

Sample preservation may partially resolve the second problem. A common procedure is keeping samples cold to slow the rate of chemical reactions and phase change, and analysing the sample as soon as possible; but this merely minimizes the changes rather than preventing them. A useful procedure for determining influence of sample containers during delay between sample collection and analysis involves preparation for two artificial samples in advance of the sampling event. One sample container is filled with water known from previous analysis to contain no detectable amount of the chemical of interest. This sample, called a "blank", is opened for exposure to the atmosphere when the sample of interest is collected, then resealed and transported to the laboratory with the sample for analysis to determine if sample collection or holding procedures introduced any measurable amount of the chemical of interest. The second artificial sample is collected with the sample of interest, but then "spiked" with a measured additional amount of the chemical of interest at the time of collection. The blank (negative control) and spiked sample (positive control) are carried with the sample of interest and analysed by the same methods at the same times to determine any changes indicating gains or losses during the elapsed time between collection and analysis.

Testing in response to natural disasters and other emergencies

After events such as earthquakes and tsunamis, there is an immediate response by the aid agencies as relief operations get underway to try and restore basic infrastructure and provide the basic fundamental items that are necessary for survival and subsequent recovery. The threat of disease increases hugely due to the large numbers of people living close together, often in squalid conditions, and without proper sanitation. After a natural disaster, as far as water quality testing is concerned, there are widespread views on the best course of action to take and a variety of methods can be employed. The key basic water quality parameters that need to be addressed in an emergency are bacteriological indicators of faecal contamination, free chlorine residual, pH, turbidity and possibly conductivity/total dissolved solids. There are many decontamination methods. After major natural disasters, a considerable length of time might pass before water quality returns to pre-disaster levels.

Chemical analysis

The simplest methods of chemical analysis are those measuring chemical elements without respect to their form. Elemental analysis for oxygen, as an example, would indicate a concentration of 890 g/L (grams per litre) of water sample because oxygen (O) has 89% mass of the water molecule (H_2O). The method selected to measure dissolved oxygen should differentiate between diatomic oxygen and oxygen combined with other elements. The comparative simplicity of elemental analysis has produced a large amount of sample data and water quality criteria for elements sometimes identified as heavy metals. Water analysis for heavy metals must consider soil particles suspended in the water sample. These suspended soil particles may contain measurable amounts of metal. Although the particles are not dissolved in the water, they may be consumed by people drinking the water. Adding acid to a water sample to prevent loss of dissolved metals onto the sample container may dissolve more metals from suspended soil particles. Filtration of soil particles from the water sample before acid addition, however, may cause loss of dissolved metals onto the filter. The complexities of differentiating similar organic molecules are even more challenging. Making these complex measurements can be expensive.

Drinking water indicators

The following is a list of indicators often measured by situational category:

- Alkalinity
- Colour of water
- pH
- Taste and odour
- Dissolved metals and salts (e.g., sodium, chloride, potassium, calcium, manganese, magnesium)
- Microorganisms such as faecal coliform bacteria (*Escherichia coli*), Cryptosporidium etc.
- Dissolved metals and metalloids (lead, mercury, etc.)
- Dissolved organics: coloured dissolved organic matter (CDOM), dissolved organic carbon (DOC)
- Pharmaceuticals
- Hormone analogs

Physical indicators (as discussed above)

- Water temperature
- Specific conductance or electrical conductance (EC) or conductivity
- Total dissolved solids (TDS)
- Odour of water
- Colour of water

- Total suspended solids (TSS)
- Transparency or turbidity
- Taste of water

Chemical indicators

- pH
- Biochemical oxygen demand (BOD)
- Chemical oxygen demand (COD)
- Dissolved oxygen (DO)
- Total hardness (TH)
- Heavy metals
- Nitrate
- Orthophosphates
- Pesticides
- Surfactants

Biological indicators

- Ephemeroptera
- Plecoptera
- Mollusca
- Trichoptera
- *Escherichia coli* (E. coli)
- Coliform bacteria
- *Pimephales promelas* (fathead minnow)
- *Americamysis bahia* (Mysid shrimp)
- sea urchin

Water calibration: Calibration is a comparison between a known **measurement** (the standard) and the **measurement** using your instrument. Typically, the accuracy of the standard should be ten times the accuracy of the **measuring** device being tested. However, an accuracy ratio of 3:1 is acceptable by most standards organizations. It is important to have tools that calibrate water usage in order to monitor usage in terms of supply and demand. Flow measurement is integrated into every aspect of modern life, from the measurement of water flow in power plants to the metering of household water. Accurate measurement is vital in both these examples, as well as in other scenarios. Specifically, the power plant must measure correctly for safety, efficiency, and revenue, while the homeowner is interested in being charged correctly. With water supplies being affected by global weather, water measurement is integral to conservation plans. Accurate flow measurement has a positive impact on energy conservation. One of the most expensive problems in environmental control is the handling and treating of potable water distribution. Flow meters need to be calibrated when a defensible accuracy is required. Sometimes, as in the case of the petroleum industry, meters may be calibrated every day against a built-in calibration device.

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