Impact of Temperature, pH, Turbidity, and Dissolved Oxygen on Water Quality Parameters

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***Abstract*—Water is a vital component for all living organisms. Water quality guidelines establish permissible limits for various parameters concerning drinking water. Regular monitoring of drinking water quality is essential, as the consumption of contaminated water can lead to a range of waterborne diseases affecting the human population. Access to high-quality water is crucial for disease prevention and enhancing overall quality of life. Key physico-chemical parameters used to assess water quality include color, temperature, hardness, turbidity, pH, sulfate, chloride, dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD). Additionally, heavy metals such as lead (Pb), chromium (Cr), iron (Fe), and mercury (Hg) pose significant risks of chronic poisoning in aquatic life. This paper highlights the importance of monitoring parameters such as temperature, turbidity, pH, and dissolved oxygen in drinking water and their potential negative impacts. The World Health Organization (WHO) outlines numerous drinking water quality parameters, providing guidelines that allow for the comparison of actual water samples to determine their quality.**

***Index Terms*—Drinking water, Parameters, Temperature, Dissolved Oxygen, Turbidity, pH.**

I. INTRODUCTION

Three main sources are employed for water collection across different regions worldwide:

1.Groundwater: The characteristics of groundwater, including its depth and quality, vary considerably based on geographical location. It is estimated that around fifty percent of the global drinking water supply is derived from these underground reserves, making it a crucial resource for many communities.
2. Surface water: This category encompasses water sourced directly from natural bodies, including streams, rivers, lakes, ponds, and springs. Generally, the quality of surface water is not suitable for direct consumption and requires appropriate treatment processes to ensure it is safe for human use.
3. Rainwater: Rainwater is collected and stored through various methods, such as rooftop collection systems, ground surfaces, or rock catchments. This practice allows for the utilization of precipitation as a valuable water resource, particularly in areas where other sources may be limited.

The quality of rainwater harvested from a rooftop is generally superior to that collected from ground surfaces or rock catchments. Water is in a constant state of movement, circulating on, above, and beneath the Earth's surface. As it travels through the environment, water undergoes a natural recycling process, during which it absorbs various substances along its route. The quality of water can differ significantly depending on geographical location, seasonal changes, and the types of rock and soil it encounters. While water covers 70% of the Earth's surface, the majority is saline, with only 3% classified as freshwater. This freshwater has become a scarce resource due to over-exploitation and pollution. The contamination of both surface and groundwater has emerged as a significant issue, exacerbated by rapid urbanization and industrial growth. The increasing range of human activities has progressively accelerated the degradation and pollution of freshwater resources.

Assessing water safety requires evaluating three key qualities:

- Microbiological factors, including bacteria, viruses, protozoa, and worms
- Chemical components, such as minerals, metals, and various chemicals
- Physical characteristics, encompassing temperature, color, odor, taste, and turbidity

"Pure" water does not exist in its entirety within the natural world, as all water sources contain a variety of naturally occurring chemicals that have leached from their surrounding environments. Generally, the levels of these natural substances are either beneficial or minimal, presenting little to no risk to health or safety. In contrast, a significant concern arises from the presence of numerous synthetic chemicals that can contaminate water supplies, thereby affecting their usability for consumption and other purposes. These chemical pollutants can originate from a range of sources, including naturally occurring materials, agricultural runoff, waste from human settlements, industrial discharges, and even substances introduced during the processes of water treatment and distribution.

The provision of high-quality drinking water is essential for enhancing public health and preventing diseases. Regular monitoring of drinking water quality is crucial, as the consumption of contaminated water can lead to a variety of waterborne illnesses. It is important to understand the various physicochemical parameters used to assess water quality, including color, temperature, hardness, pH, turbidity, sulfate, chloride, dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD). Additionally, heavy metals such as lead (Pb), chromium (Cr), iron (Fe), and mercury (Hg) are particularly concerning due to their potential to cause acute or chronic poisoning in aquatic life. Numerous parameters for assessing drinking water quality are outlined by organizations such as the World Health Organization (WHO), the Indian Standard IS 12500:2012, the Environmental Protection Agency (EPA), and the Environmental Quality Standards (EQA).

Water is referred to as the "universal solvent" due to its ability to dissolve a greater variety of substances than any other liquid. This characteristic allows water to transport essential chemicals, minerals, and nutrients as it moves through the soil or within living organisms. Pure water maintains a neutral pH of 7 and exhibits strong cohesive properties, making it quite adhesive. In its pure form, water does not conduct electricity; however, it becomes a conductor when it begins to dissolve other substances. Additionally, water has a high specific heat capacity, meaning it can absorb significant amounts of heat before its temperature rises. This property is what makes water indispensable in various industries and as a coolant in automobile radiators.

A guideline value for drinking water quality indicates the concentration of a substance that poses no significant health risk to consumers over a lifetime of use. If this guideline value is surpassed, it is essential to investigate the cause and implement corrective measures. The extent and duration for which any guideline value can be exceeded without compromising human health vary depending on the specific substance in question. When establishing national drinking water quality standards, it is crucial to consider various local, geographical, socioeconomic, and cultural factors. Consequently, national standards may significantly differ from the World Health Organization's guideline values. Monitoring and evaluating water quality is vital for the sustainability of water resources and has garnered considerable attention in research and development. The permissible limits for different parameters set by various agencies lack uniformity. This article provides a summary of two physical parameters (Temperature, Turbidity) and two chemical parameters (pH, Dissolved Oxygen) related to water quality, along with guidelines for these physicochemical parameters to facilitate the comparison of actual water samples.

II. PHYSICAL WATER QUALITY PARAMETERS

Two physical parameters, namely temperature and turbidity, are discussed.

A. Temperature

Temperature indicates the level of heat or coldness and is measured in degrees Celsius. It is essential to regularly monitor water temperature, as deviations from the acceptable temperature range can lead to increased disease and stress levels. Changes in temperature can affect various factors, including photosynthetic activity, gas diffusion rates, and the solubility of oxygen. The recommended aesthetic standard for water temperature is set at 15 degrees Celsius or lower, as outlined in the 'Guidelines for Canadian Drinking Water,' which has been endorsed by the Ministry of Health Services for use in British Columbia.

Objectives are established based on specific criteria that take into account local water quality, various water uses, water flow dynamics, waste discharges, and socioeconomic conditions. Temperature plays a crucial role due to its impact on water chemistry.

Typically, the rate of chemical reactions rises with increasing temperature. Warmer water, especially groundwater, has a greater capacity to dissolve minerals from surrounding rocks, resulting in higher electrical conductivity. Additionally, temperature significantly affects biological activity and growth, determining the types of organisms that can thrive in rivers and lakes.

From the perspective of users, cool drinking water is favored over warm water, with a temperature of 10°C generally being considered acceptable. The commonly referenced threshold of 19°C, above which many consumers express dissatisfaction, is founded on empirical research conducted approximately 60 years ago. Pangborn and Bertolero demonstrated that the taste intensity of water is highest at room temperature and is notably diminished when the water is either chilled or heated, using distilled water, mineral salt solutions in distilled water, and samples of drinking water in their studies.

Turbidity and color are influenced by temperature in an indirect manner, as temperature plays a significant role in the coagulation process. The effectiveness of coagulation is highly dependent on temperature, with the optimal pH for coagulation decreasing as temperature rises. Due to the intricate chemical equilibria involved in coagulation, it is advisable to conduct jar tests at the temperature of the water being treated rather than at room temperature to ensure the most cost-effective use of coagulants. Additionally, the rate of corrosion is affected by the concentration of dissolved oxygen in the water. As temperature increases, the solubility of oxygen diminishes (from 10.15 mg/L at 15°C to 7.1 mg/L at 35°C). Although the variation in dissolved oxygen with temperature is relatively minor, it is overshadowed by the more significant changes in corrosion rates. Warmer water retains less dissolved oxygen compared to cooler water, which may not provide sufficient oxygen levels for the survival of various aquatic species. Furthermore, certain compounds exhibit increased toxicity to aquatic life at elevated temperatures.

Factors influencing water temperature include:

- Ambient air temperature
- Degree of shading
- Soil erosion leading to increased turbidity
- Thermal pollution resulting from human activities
- Unidentified chemical reactions that were not previously present in the water.

Impacts of Water Temperature:

- *Dissolved Oxygen Solubility*: Cold water can hold a greater amount of dissolved oxygen compared to warm water.
- *Plant Growth Rate*: Elevated water temperatures can enhance the photosynthetic activity of aquatic plants and algae, potentially resulting in accelerated plant growth and algal blooms, which may negatively affect local ecosystems.
- *Organism Resilience*: Extreme water temperatures, whether excessively high or low, can induce stress in organisms, diminishing their ability to withstand pollutants, diseases, and parasites.

B. Turbidity

Turbidity refers to the degree of cloudiness or clarity in water. This cloudiness is primarily caused by suspended solids, including soil particles such as sand, silt, and clay, as well as microscopic organisms. Moderate turbidity levels can suggest a healthy ecosystem, where a balanced presence of microscopic plants and animals supports the food chain. Conversely, elevated turbidity levels can lead to various issues within stream systems. Increased turbidity is often linked to higher concentrations of viruses, parasites, and certain bacteria, as these pathogens can adhere to the particles in the water. Consequently, it is important to exercise caution with turbid water, as it typically contains a greater number of pathogens, increasing the risk of illness if consumed. Additionally, turbidity can obstruct light penetration necessary for submerged aquatic plants and may elevate surface water temperatures, as the suspended particles near the surface enhance heat absorption from sunlight.

Nephelometers are instruments that quantify the intensity of light scattered by particles suspended in a liquid. This measurement is expressed in Nephelometric Turbidity Units (NTU). According to the World Health Organization (WHO), the recommended turbidity level for drinking water should be below 5 NTU. Levels exceeding 5 NTU or 5 JTU can be perceptible and may be deemed unacceptable by consumers. High turbidity in water diminishes light penetration, which adversely impacts photosynthesis, increases heat absorption from sunlight, and is generally considered visually unappealing. These suspended particles obstruct the transmission of light through the water. A turbidity sensor assesses the cloudiness of water by measuring the amount of light scattered at a 90-degree angle. Typically, turbidity sensors utilize a Light Dependent Resistor (LDR) and a Light Emitting Diode (LED).

Excessive turbidity or cloudiness in drinking water is not only visually unappealing but may also pose health risks. Turbidity can create an environment conducive to the growth of pathogens. If left unaddressed, it can facilitate the regrowth of these harmful microorganisms within the distribution system, potentially leading to waterborne illnesses, including significant instances of gastroenteritis. While turbidity itself is not a direct measure of health risk, numerous studies indicate a strong correlation between the removal of turbidity and the elimination of protozoa. The particles that contribute to turbidity can provide a protective habitat for microbes, shielding them from disinfectants. Fortunately, conventional water treatment methods are capable of effectively eliminating turbidity when implemented correctly.

Factors Contributing to Turbidity:

- Soil erosion leading to the deposition of silt and clay
- Urban runoff containing contaminants from roads, rooftops, and parking lots
- Industrial discharges, including effluent from sewage treatment and various particulates
- Organic materials such as microorganisms, decomposing flora and fauna, and hydrocarbons from vehicles

Consequences of Turbidity:

- Diminishes the clarity of water
- Creates an unattractive appearance
- Reduces the efficiency of photosynthesis
- Raises the temperature of the water

III. CHEMICAL WATER QUALITY PARAMETERS

Two chemical parameters, namely pH and dissolved oxygen, are discussed:

A. *pH*

The pH level indicates the concentration of hydrogen ions in water, reflecting its acidity or basicity, and is mathematically expressed as –log[H+]. The pH scale ranges from 0 to 14, with a pH of 7 representing neutrality; values below 7 indicate acidity, while values above 7 signify basicity. pH serves as a measure of the relative concentrations of free hydrogen and hydroxyl ions present in water. Water with a higher concentration of free hydrogen ions is classified as acidic, whereas water with a greater concentration of free hydroxyl ions is considered basic. Given that pH can be influenced by various chemicals in the water, it serves as a crucial indicator of chemical changes occurring within the water. The pH level of water plays a significant role in determining the solubility of chemical constituents, such as nutrients (including phosphorus, nitrogen, and carbon) and heavy metals (like lead, copper, and cadmium), as well as their biological availability for aquatic organisms. For heavy metals, their solubility directly impacts their toxicity; lower pH levels generally increase solubility, thereby enhancing toxicity. Additionally, pH is a key factor in assessing the corrosive properties of water.

A lower pH value indicates a greater corrosive potential of water. There is a positive correlation between pH, electrical conductivity, and total alkalinity. During the summer months, a decrease in photosynthetic activity, along with the assimilation of carbon dioxide and bicarbonates—which ultimately lead to an increase in pH—was observed alongside low oxygen levels and elevated temperatures. Karanth (1987) noted that the elevated pH values suggest that the equilibrium between carbon dioxide and carbonate-bicarbonate is more significantly influenced by changes in physico-chemical conditions. Extremely high pH levels (above 9.5) or very low pH levels (below 4.5) are detrimental to most aquatic life. Aquatic organisms are particularly vulnerable to pH levels below 5, which can be lethal. Additionally, high pH levels (ranging from 9 to 14) can be harmful to fish, as ammonia can convert to its toxic form at pH levels exceeding 9.

The pH level of drinking water typically ranges from 6.5 to 8.0 at a temperature of 25°C (80°F). The pH of water found in streams, rivers, lakes, or underground sources can fluctuate based on various factors, including the water's origin, the type of soil and bedrock, and the contaminants it encounters along its journey. The impact of specific water pollutants on aquatic plants and animals can differ significantly. The World Health Organization (WHO) does not recommend a health-based guideline value for pH. While pH generally does not have a direct effect on consumers, it remains a crucial parameter for assessing water quality. For instance, effective chlorine disinfection requires a pH level below 8, with the ideal range being between 5.5 and 7.5. Elevated pH levels can lead to a bitter taste, cause the buildup of deposits in water pipes and appliances, and reduce the efficacy of chlorine disinfection, necessitating the use of additional chlorine. Conversely, low pH levels can lead to the corrosion or dissolution of metals and other materials.

Factors Influencing pH Levels:

- Acidic precipitation may have minimal impact in areas abundant in minerals that contribute to high alkalinity, such as elevated levels of carbonate, bicarbonate, and hydroxide ions derived from limestone. These minerals can offer a natural buffering capacity that neutralizes a significant portion of the hydrogen ions ($H+$) present in the acid. Conversely, regions with low concentrations of alkalinity ions may experience more pronounced effects from acidic rainfall.
- Concentration of hard-water minerals
- Emissions from industrial activities, which vary based on whether they release acids or bases
- Introduction of detergents into aquatic systems
- Carbonic acid produced from organic decomposition
- Oxidation of sulfides in sediments, which can lead to increased acidity

B. Dissolved oxygen (DO)

The concentration of dissolved oxygen (DO) in water is influenced by both the water temperature and the biological demands of the ecosystem. Dissolved oxygen enters the water through various mechanisms, including direct diffusion from the atmosphere, the effects of wind and wave action, and the process of photosynthesis. It plays a crucial role in the aerobic decomposition of organic materials, the respiration of aquatic organisms, and the chemical oxidation of minerals. Due to its consumption by numerous aquatic organisms, the levels of dissolved oxygen can fluctuate significantly.

The capacity of water to retain oxygen is influenced by its temperature, salinity, and pressure. As salinity decreases, the solubility of gases increases. Freshwater can contain more oxygen compared to saltwater. Conversely, gas solubility diminishes with a reduction in pressure. The concentration of oxygen dissolved in water declines with increasing altitude due to the drop in relative pressure. Various factors, such as water temperature, time of day, season, depth, altitude, and flow rate, affect the levels of dissolved oxygen. Water at elevated temperatures and altitudes tends to have lower levels of dissolved oxygen. Dissolved oxygen levels peak during daylight hours and decrease at night when photosynthesis ceases.

Flowing water, like that found in mountain streams or large rivers, typically has a high concentration of dissolved oxygen, in contrast to stagnant water, which has lower levels. The presence of bacteria in water can lead to oxygen depletion as they break down organic matter. Consequently, an abundance of organic material in lakes and rivers can lead to eutrophic conditions. Aquatic organisms often struggle to survive in stagnant water rich in decaying organic matter, particularly during the summer months. The situation can worsen during prolonged periods of hot, calm weather, potentially resulting in significant fish mortality. Human activities that influence dissolved oxygen levels in streams include the introduction of oxygen-consuming organic waste, such as sewage, the addition of nutrients, alterations to water flow, increases in water temperature, and the introduction of chemicals.

Sources of dissolved oxygen include the following:

- Diffusion from the atmosphere into the water at the surface
- Aeration resulting from water flowing over rocks and irregular surfaces
- Aeration caused by the turbulent action of wind and waves
- Photosynthesis carried out by aquatic plants

The levels of dissolved oxygen are influenced by several factors, including:

- *Plant activity*: Dissolved oxygen (DO) levels vary throughout the day, typically rising in the morning and reaching their highest point in the afternoon. At night, these levels decrease as photosynthesis halts.

- *Temperature*: The capacity of water to hold oxygen is impacted by temperature, with cooler water being able to dissolve more oxygen compared to warmer water.
- *Decomposing organic matter*: The process of decomposition generates heat, which raises the temperature of the water and subsequently reduces its ability to hold dissolved oxygen.
- *Stream flow*: Increased water movement and turbulence enhance the dissolution of oxygen in the water.
- *Altitude and atmospheric pressure*: Higher altitudes and reduced atmospheric pressure lead to a decrease in the capacity of water to retain dissolved oxygen.
- *Human activities*: Actions such as removing vegetation that provides shade or discharging warm water from industrial processes can elevate water temperatures, thereby diminishing the dissolved oxygen levels.

IV. CONCLUSION

It is crucial to conduct water testing prior to its use for drinking, domestic, agricultural, or industrial purposes. Various physico-chemical parameters should be assessed based on the intended use of the water and the required standards of quality and purity. Water can contain a range of impurities, including floating, dissolved, suspended, microbiological, and bacteriological contaminants. Groundwater serves as a vital source for drinking, irrigation, and industrial activities. However, the growing population and its demands have led to the degradation of both surface and subsurface water sources. This pollution of groundwater poses significant health risks. Once contaminated, the quality of groundwater cannot be restored merely by halting the pollutants at their source, making it essential to regularly monitor groundwater quality and implement protective measures. Therefore, prior to utilizing water, it is important to conduct a qualitative analysis of specific physico-chemical parameters. This serves as a reference for society to remain vigilant about the potential decline in their environmental and health conditions.

The physical properties of water are typically those that can be assessed through our senses, including turbidity, color, taste, odor, and temperature. Generally, water is considered to possess good physical qualities if it is clear, palatable, odorless, and cool. While physical contaminants do not usually pose direct health risks, their presence may indicate an increased likelihood of microbiological and chemical contamination, which can be detrimental to human health. The significance of temperature in determining water quality primarily stems from its connection to other quality parameters. Many of these connections pertain to the aesthetic qualities of water, with some having indirect implications for health. The palatability of drinking water is somewhat influenced by temperature, with 19°C often referenced as a threshold above which most consumers express dissatisfaction (WHO). When temperatures exceed 15°C, issues may arise within the distribution system, potentially resulting in undesirable tastes and odors. The impact of low temperatures on water treatment processes is managed by adjusting the quantities of chemicals used; low temperatures do not prevent the production of water that meets acceptable quality standards. Turbidity refers to the cloudiness of water caused by suspended particles such as sand, silt, and clay, which are not harmful in small quantities. However, elevated turbidity levels are frequently linked to increased concentrations of viruses, parasites, and certain bacteria. Given that pathogens are the primary cause of waterborne diseases, caution is warranted when dealing with turbid water. The WHO guideline for turbidity in drinking water is set at less than 5 NTU.

pH plays a crucial role in assessing the corrosive properties of water. A lower pH value indicates a greater corrosive potential. Extremely high pH levels (above 9.5) or very low pH levels (below 4.5) are generally detrimental to most aquatic life. Aquatic organisms are particularly vulnerable to pH levels below 5, which can lead to mortality. Elevated pH levels (ranging from 9 to 14) can be harmful to fish, as ammonia can convert into toxic forms at pH levels exceeding 9. For drinking water, the pH typically ranges from 6.5 to 8.0 at a temperature of 25°C. Dissolved oxygen (DO) enters the water through various means, including direct diffusion from the atmosphere, the effects of wind and wave action, and the process of photosynthesis. The concentration of dissolved oxygen is influenced by factors such as plant activity, temperature, the presence of decaying organic matter, stream flow, altitude or atmospheric pressure, and human activities.

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