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Physico-Chemical Parameters for Checking Drinking Water Quality: A Review

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ABSTRACT

Water plays a crucial role in sustaining human life, as it is required for a variety of essential daily activities. However, water sources are increasingly polluted due to factors such as population growth, industrial expansion, modern agricultural techniques, and various human activities. Contaminated water becomes unsafe for consumption and other uses, making access to clean water critical for both public health and environmental preservation. The quality of water is typically evaluated through several physico-chemical parameters, including characteristics such as colour, temperature, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), water hardness, acidity, alkalinity, and concentrations of substances like sulphate, chloride, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), and Biological Oxygen Demand (BOD). This study aims to provide an overview of the assessment of drinking water quality across various regions of India, employing a combination of these physico-chemical factors as well as the Water Quality Index (WQI) for a comprehensive evaluation.

Keywords: *Drinking Water; pH; Total Dissolved Solids; Water Hardness; Water Quality Index;* Water Quality Parameters

Introduction

Water is the most important natural resource for human survival. Not all water sources are suitable for drinking purposes. Water sources, particularly unimproved sources, are unhygienic not only due to contamination of heavy metals and other pollutants but also due to anthropogenic factors and natural factors such as climate, topography, flooding, weathering of parent material, and others that are also responsible for water pollution (Addisie, 2022). Water pollutants such as fertilisers and pesticides that are drained into rivers as agricultural run-off harm water resources. The water quality has affected tap water as well as groundwater due to inappropriate waste discarding and overutilization of resources (Nigam, Behl & Kanchan, 2013). The demand for fresh water remarkably increases due to population growth as well as the accelerated pace of industrialization. The availability of clean drinking water has become one of the most important necessities for human health. A little portion of water in the earth can be used for drinking purposes. Drinking water is now a global issue, as most of the fresh water bodies all over the world are getting contaminated, declining the portability of water.

Surface water, which is supplied in most of the cities in India by municipalities is unfit for direct consumption; more treatments are necessary for making surface water potable. According to the World Health Organisation, approximately 80% of human diseases are linked to contaminated or unsafe water (Dohare, Deshpande & Kotiya, 2014). Poor drinking water is responsible for some of the diseases, such as diarrhea, dysentery, polio typhoid, and cholera. In India, the presence of high fluoride concentrations in drinking water is a significant health concern, as prolonged consumption can lead to fluorosis, affecting both dental and skeletal systems. In India, different research teams are actively investigating water quality across different regions, using a range of instruments to analyse parameters like colour, temperature, pH, water hardness, alkalinity, acidity, chloride, sulphate, dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD) (Jangamwar & Gahalod, 2025). This study provides a comprehensive review of physico-chemical parameters such as colour, temperature, pH, electrical conductivity, total dissolved solids (TDS), hardness, turbidity, total alkalinity, DO, BOD, and COD examined across different regions in India, along with an in-depth look into their testing methods, relevance, measurement techniques, and practical applications.

Literature Review

The Water Quality Index (WQI) is an effective tool used to evaluate the overall water quality in a specific region. It plays a crucial role in identifying potential pollution risks and provides a simplified representation of complex water quality data in the form of a single, easily understandable value. By integrating multiple water quality parameters into one comprehensive index, WQI offers insight into the suitability of water for various purposes such as drinking, agriculture, recreation, and industrial use. It serves as a clear indicator of the overall condition of water in a given area. In a study conducted by Kothari *et al*. (2021) the WQI was utilised to assess water quality across five districts in the Garhwal and Kumaon regions of Uttarakhand, India and they observed that the water quality was suitable for drinking purposes as the physico-chemical parameters were as per BIS standards. Dutta *et al*. (2022) reported WQI to evaluate water quality parameters in the South Sikkim district of India, located in the Eastern Himalayan region. Water scarcity has emerged as a significant concern in certain areas of South Sikkim, primarily due to the rapid development of the tourism industry. As a result, local residents are struggling to access sufficient spring water and are increasingly relying on alternative sources such as surface water and rainwater. The study analysed various physico-chemical parameters, including pH, hardness, turbidity, alkalinity, iron, fluoride, chloride, and nitrate using standard methods. The results indicated that the water is generally safe for drinking. Surface water in the study area was classified into two categories based on WQI values: "excellent" and "good" quality (Dutta *et al.*, 2022). Similarly, Gaur *et al.* (2022) collected water samples from 31 sites in Tawang, Arunachal Pradesh, India, to evaluate the suitability of water for drinking during the winter season. Their study employed WQI estimation, considering key parameters such as pH, conductivity, TDS, salinity and hardness, as well as major cations and anions. The findings revealed that geogenic factors significantly influence water quality in the Tawang region. Based on WQI values, 61% of the water samples were deemed suitable for drinking, while the remaining 39% were classified as unfit for consumption. (Gaur *et al*., 2022). Prasad *et al.* (2019) conducted an assessment of drinking water quality in Obulavaripalli Mandal, located in YSR District, Andhra Pradesh, using the Water Quality Index (WQI) approach. The evaluation of groundwater samples revealed that the overall quality of the groundwater in the area falls below the acceptable standards for safe drinking purposes, with only 30% of the samples classified as "excellent", 40% as "good", and the remaining 30% falling into the "poor" category (Prasad *et al*., 2019). Tetali, Salomi and Gope, (2024) carried out an in-depth evaluation of key water quality parameters, including pH, total dissolved solids (TDS), turbidity, acidity, and hardness, across a range of water sources such as ponds, canals, borewells, lakes, rivers, seawater, and tap water. The study identified considerable variations among the samples, with several values diverging from the recommended standards. For example, pH levels were found to range between 6.81 and 8.33, TDS values spanned from 93 ppm in rainwater to 815 ppm in borewell water, and water hardness levels ranged from soft to extreme. Additionally, turbidity in all samples surpassed the acceptable limit of 0.3 NTU. These results demonstrate the value of implementing tailored water treatment solutions for different sources to safeguard drinking water quality and mitigate potential health hazards (Tetali, Salomi & Gope, 2024). Singh and Yadav reviewed the key physico-chemical parameters used in water quality assessments, discussing their definitions and explaining their effects on human and plant life. They also described the methodologies used to measure each parameter, emphasizing their importance in determining water quality (Singh & Yadav, 2022). Jangamwar and Gahalod provided a detailed review of various parameters for assessment of drinking water by the key tests of physical characteristics such as colour, temperature, pH, TDS, electrical conductivity, COD, and BOD, with providing a comprehensive understanding of their significance, test procedures, measurement techniques, and applications (Jangamwar & Gahalod, 2025).

Physico-Chemical Parameters

The presence of clean and high-quality water plays a crucial role in reducing the risk of disease and improving overall health and living standards. To effectively evaluate water quality, it is important to analyse key physico-chemical parameters such as colour, temperature, pH, hardness, alkalinity, acidity, chloride, sulphate, dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD). Preliminary information, including temperature, colour, odour, pH, and turbidity, can be obtained through physical testing, while chemical analyses are required to determine parameters such as dissolved oxygen, alkalinity, hardness, BOD, COD, and other characteristics. This review provides a detailed description of these parameters, and the methods used to determine them are summarised in Table 1.

Parameters	Methods Employed	Bureau of Indian Standard (BIS)	World Health Organization (WHO)
p^H	p^H metery	6.5-8.5	6.5-9.5
Electrical Conductivity	Conductometry	300	-
Total Dissolved Solid	Conductometry	500	-
Total Hardness	Complexometry	300 ppm	200 ppm
Turbidity	Turbiditimetry	5 NTU	-
Total Alkalinity	Titrimetry	200 ppm	-
Chloride	Argentometry	250	250
DissolvedOxygen	Winkler method	4 mg/l	-
Biochemical Oxygen Demand	Incubation followed by titration	30	6
Chemical Oxygen Demand	COD digester	-	10

Discussion

Temperature

Water temperature is a key physical parameter that influences chemical reaction rates and biological processes such as growth, reproduction, decay, mineralisation, and production (Nigam, Behl & Kanchan, 2013). It also affects the health of aquatic ecosystems and drives seasonal and diurnal variations. The BOD, sedimentation and chlorination processes are temperature dependent. Typically, normal water source temperature is influenced by geographic position and water depth whereas temperature may be affected by chemical discharges in industrial or urban water sources. The temperature is measured using a thermometer (Jangamwar & Gahalod, 2025).

Colour

The color of the water is primarily caused by the presence of inorganic substances such as soil, stones, and rocks, organic matter, namely, vegetation as well as industrial waste also contributes to colour of water. This colour is classified into two categories, viz., true colour and apparent colour. True colour is measured after filtering all the suspended components in water whereas apparent colour is colour due to reflection of sky or trees. Colours are graded from 0 (pure water) to 70 colour units. Pure water is colourless.

pH

pH is a key parameter in evaluating water quality, as it reflects the concentration of hydrogen ions in the water, which determines its acidity or alkalinity. The pH scale spans from 0 to 14: values under 7 indicate acidic conditions, values above 7 suggest alkalinity, and a pH of 7 signifies neutral water. As the pH increases, conditions become more basic; as it decreases, the water becomes more acidic. The acceptable pH range for drinking water is between 6.5 and 8.5, as recommended by BIS. The higher pH value can cause scale build up on pipes while lower pH can release metals like lead or copper into the water due to corrosion of pipes. Both acidic and alkaline water conditions can influence the taste and appearance of water and may have significant health implications. The pH is measured using a pH meter (Jangamwar & Gahalod, 2025).

Electrical Conductivity (EC)

Electrical Conductivity (EC) is an important indicator of water quality, as it measures an aqueous solution's ability to conduct electrical current. This conductivity is directly influenced by the presence and concentration of dissolved ions, which act as carriers of electric charge in the solution. The recommended maximum limit for EC in drinking water is 300 µS/cm. It is measured using a conductivity meter calibrated with a standard KCl solution, providing insight into the concentration of soluble salts in the water. The conductivity of distilled water is typically less than 1 µS/cm, due to the very low concentration of dissolved ions (Nigam, Behl & Kanchan, 2013).

Total Dissolved Solid (TDS)

Total Dissolved Solids (TDS) are closely linked to both the purity and overall quality of water. TDS gives information about minerals, salts, and organic compounds that are dissolved in water and it reflects the sum of all ions present, giving a sense of the mineral and chemical composition of the water. Salty or metallic taste refers to high TDS levels in drinking water. Very high TDS levels can be undesirable or even unsafe, as they affect water's suitability for industrial, agricultural, and personal uses. TDS is commonly measured in mg/L or parts per million (ppm) with the help of a TDS meter, which indirectly measures the electrical conductivity of the water and then calculates an approximate TDS value. TDS can also be measured using gravimetric methods, which involve evaporating the water sample and weighing the residual solids left behind in the laboratory. According to IS: 10500-2012 standards, the acceptable limit for TDS in drinking water is 500 mg/l, while the maximum permissible limit is 2000 mg/l (BIS, 2012).

Total Hardness

Hardness is commonly used as an indicator of water quality. In groundwater, hardness is primarily caused by the presence of calcium and magnesium salts in the form of carbonates, bicarbonates, sulphates, and chlorides. It is typically measured using the complexometric titration method with EDTA, which binds to calcium and magnesium ions responsible for hardness. According to drinking water standards, the total hardness should not exceed 300 mg/l expressed as $CaCO_3$. Based on the classification by Durfor and Becker (1964), water hardness levels are categorised as follows: soft (0–60 mg/l), moderately hard (60–120 mg/l), hard (120–180 mg/l), and very hard (above 180 mg/l).

Turbidity

Turbidity is the cloudiness of water in which suspended particles interfere with the route of light. Turbidity refers to the clarity of water and is influenced by the presence of suspended particles like clay, silt, organic substances, plankton, and other materials that scatter or absorb light, reducing its ability to pass through the water. The greater the concentration of these particles, the higher the turbidity, as light transmission becomes more difficult. Turbidity is measured using Turbidimetry (based on light transmission) or Nephelometry (based on light scattering). According to IS: 10500-2012 standards, the recommended turbidity level for drinking water is 1 NTU, while the maximum allowable limit is 5 NTU (Dohare, Deshpande & Kotiya, 2014).

Total Alkalinity

Alkalinity refers to the overall concentration of compounds in water that raise its pH and indicate its ability to neutralise acids. It mainly reflects the presence of carbonate, bicarbonate, and hydroxide ions, which serve as natural buffers by reducing excess hydrogen (H^+) ions, thereby making the water more alkaline. Alkalinity is commonly determined through titration using a standard acid until the pH reaches 4.5, and the results are typically reported in milligrams per litre as calcium carbonate (mg/L as $CaCO_3$). For drinking water, the acceptable alkalinity limit is 120 mg/L.

Chloride

Chloride is a key parameter in evaluating drinking water quality, as elevated levels can indicate a higher degree of organic pollution. While chloride naturally occurs in groundwater, streams, and lakes, concentrations above 250 mg/L in freshwater may signal contamination from industrial or domestic sources. Chloride levels in water are usually determined using a precipitation titration method, where standard silver nitrate is used along with potassium chromate as an indicator. The highest allowable concentration of chloride in drinking water is 250 mg/L, as levels above this threshold may lead to a laxative effect (Nigam, Behl & Kanchan, 2013).

Dissolved Oxygen (DO)

Dissolved oxygen (DO) is a crucial parameter for assessing water quality, as it is necessary for the respiration and survival of fish and other aquatic life. DO levels are influenced by both natural factors (such as water temperature, stream flow, and photosynthesis) and human activities within the catchment area. Warmer water holds less oxygen than cooler water, making temperature a key factor in DO availability. DO concentration indicates the quantity of oxygen gas present in water, usually measured in milligrams per litre (mg/L) or parts per million (ppm).

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) quantifies the amount of oxygen utilised by microorganisms to decompose organic materials in water. Elevated BOD levels are a sign of degraded water quality, indicating substantial organic contamination that can reduce oxygen availability and negatively impact aquatic organisms (Singh & Yadav, 2022). The greater the BOD, the more organic material is present for microbes to decompose. For drinking water, a low BOD is desirable, as it reflects minimal organic contamination. BOD is determined by measuring the dissolved oxygen in a freshwater sample and comparing it to that in a duplicate sample, which is incubated under controlled conditions for several days. The difference in oxygen levels is expressed in milligrams per litre (mg/L).

Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) quantifies the amount of oxygen required to chemically oxidise both organic and inorganic substances in a water sample. It serves as an important indicator of water pollution. High COD values suggest a high concentration of oxidisable pollutants such as organic matter and certain inorganic compounds, indicating significant contamination. COD measures the total oxygen needed to break down all organic matter into carbon dioxide and water. While COD values are generally higher than BOD values, the COD test is much quicker, taking only a few hours, compared to the five days needed for BOD measurement.

Conclusion

Physico-chemical parameters such as colour, temperature, pH, hardness, alkalinity, acidity, chloride, sulphate, dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) play a crucial role in assessing drinking water quality, as they are vital for ensuring its safety and suitability for consumption. This study provides a comprehensive review of the evaluation of these parameters in drinking water across India. Most of the results were found to be within the recommended limits set by the Bureau of Indian Standards (BIS), particularly in the Eastern Himalayan region and Uttarakhand, where the water was deemed suitable for drinking.

However, 39% of the samples collected from Arunachal Pradesh were found to be unfit for consumption. In some instances, electrical conductivity, turbidity, and total dissolved solids either exceeded or were close to exceeding the BIS recommended limits, suggesting the presence of suspended particles and elevated ion concentrations. The Water Quality Index (WQI) has been used to classify the overall water quality in most cases. This review also demonstrates the importance, measurement techniques, procedures and applications of the above-mentioned physico-chemical parameters as due to increasing urbanisation and population growth, surface water as well as groundwater is getting over contaminated and more stringent treatments would be required to get drinking water.

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