A Comprehensive Overview of Vital Water Quality Parameters

Bishnu Kant Shukla, Mudasir Ahmad Teeli, Shubham Kumar Shukla, Rishabh Chandra, Nitish Bharti, and Utkarsh Singh

Abstract Water is the furthermost significant component in the terrestrial foundation and regulating the climate. It is one of the chemicals that affects life the most significantly. Typically, the characteristics of water's physical, biological, chemical, and constitution are utilized to define it. Groundwater resources are being depleted and are becoming significantly and diversely contaminated as a result of rapid economic development and the unrestrained use of chemical pesticides and fertilizers in agriculture. In-place sewage systems, landfill leachate, wastewater treatment plant effluent, leaking sewers, hydraulic fracturing, gas stations, or excessive fertilizer use in agriculture are the usual causes of groundwater adulteration. Pollution can also be brought on by natural contaminants like fluoride and arsenic. Use of tainted groundwater exposes the entire public to illness or injury. Poor water quality can lead to a range of negative effects, including subpar goods, low earnings, and serious risks to human health. This document provides detailed information on underground water quality characteristics, including pH, temperature, biological oxygen demand, dissolved oxygen, alkalinity, chemical oxygen demand, nitrite, hardness, ammonia, nitrate, sulfate, and phosphate.

Keywords Water quality index (WQI) · Dissolved oxygen (D.O.) · Biochemical oxygen demand (BOD) · Alkalinity · Eutrophication · Heavy metal

1 Introduction

The lack of access to clean water is a global issue that affects all countries. The strong human desire to improve living standards has inevitably resulted in water pollution, with cumulative efforts and activities establishing as heavy industrial development and incessant urbanization, leading to progressive pollution of aquatic system [1–4].

B. K. Shukla (✉) · M. A. Teeli · S. K. Shukla · R. Chandra · N. Bharti · U. Singh
Department of Civil Engineering, JSS Academy of Technical Education, Noida 201301, India
e-mail: bishnukantshukla@gmail.com

S. Saxena et al. (eds.), *Emerging Materials and Technologies in Water Remediation and Sensing*, Lecture Notes in Civil Engineering 439,
https://doi.org/10.1007/978-981-99-6762-9_1

When it comes to drinking, irrigation of crops, waste disposal, transportation, recreation, irrigation of crops, and industrial production, humans are utterly dependent on renewable resources of freshwater. The quality and quantity of water that can be used to placate human necessities are already threatened in many parts of the biosphere due to rising water usage, growing population, climate change and a rising water usage, the gap between freshwater availability and demand will worsen over the next century. About 80% contamination of Indian water resources, according to estimates by WHO, is caused by inhabited refuse. Water system management issues could have a substantial impact on the supply of drinking water [5, 6]. Industrial waste is the main basis of water contamination. Wastewater from various industries is disposed of in the water without being properly treated [2]. Monitoring water quality is a vital component of environmental research and public health. It entails evaluating a range of physical, chemical, and biological factors to make sure that water is suitable for diverse uses, from supporting aquatic life to safe human consumption [7]. Temperature, turbidity, and color are some examples of the physical parameters. Aquatic creatures' biological activity and growth are directly influenced by temperature. Water clarity, or turbidity, can influence how aquatic plants synthesize their food and also reveal the presence of microbes. Minerals and organic debris that are dissolved in the water can be identified by looking at the color of the water. pH, conductivity, dissolved oxygen, hardness, and the presence of specific ions like nitrates, phosphates, and heavy metals are examples of chemical parameters. The solubility and toxicity of substances in the water can be influenced by the pH of the water, which is a measurement of its acidity or alkalinity [8]. Water's conductivity, a metric of how well it conducts electricity, is inversely proportional to its ion concentration. The life of aquatic species depends on the presence of dissolved oxygen. The usefulness of water for home and industrial usage can be influenced by its water hardness, which is determined by the amount of calcium and magnesium ions present. Heavy metals, phosphates, and nitrates can all be signs of pollution and provide health dangers [9].

A change in the underlying sediments' and aquifers' chemical makeup also affects the variation in water quality. Surface sources like canals, lakes, dams, and rivers provide around one-third of the world's drinking water needs. Water is used in some way or another by an organism's chemical and physiological processes. In numerous aspects of existence, water is crucial. In order to research numerous physicochemical water characteristics including B.O.D. (biochemical oxygen demand), WQI (water quality index), D.O. (dissolved oxygen), Eutrophication, heavy metal, alkalinity, etc., water samples from rivers and lakes provide an appropriate platform. Many scientists have occasionally studied the physicochemical properties of water bodies. The physicochemical features will also aid in the continuation of eco-biological impact research, the detection of pollution sources, and the beginning of remedial action procedures for polluted water bodies [10]. Numerous scholars in India have studied the physicochemical and biological properties of reservoirs and rivers. Since a variety of physical and chemical elements can combine to affect primary production levels, which in turn affect total biomass and trophy structure across the aquatic food web, water quality must be taken into account when evaluating wetland habitat.

Gaining a deeper understanding of these factors will help us manage our water resources more effectively, reduce risks, and guarantee the well-being and security of our communities and ecosystems. The function each of these parameters plays in determining the quality of the water, the variables that affect them, and the effects of their imbalance will all be covered in more detail in the sections that follow.

2 Analysis of Water Quality

Before using water for drinking, residential, industrial, or agricultural purposes, it must first be tested. Different biological, physical, and chemical factors must be used to test water. The only factors considered when selecting water testing parameters are the envisioned use of the water and the level to which its purity and quality are required [11–14]. Different kinds of microbiological, dissolving, suspended, floating, and bacteriological pollutants are present in water. Physical tests should be conducted to evaluate the substance's odor, color, temperature, pH, TDS, turbidity, and further physical characteristics. Chemical tests should be conducted to evaluate the substance's COD, BOD, alkalinity, hardness, DO, and other characteristics [15]. Water must be verified for heavy metal trace, organic, and metal contaminants like pesticide scum in order to obtain more and more pure, high-quality water. It goes without saying that potable water must satisfy all of the required parameters during tests and contain the necessary amount of minerals [16, 17]. Only in wealthy nations are all these requirements properly checked because there are very few organic and heavy metal pesticide contaminants in water, necessitating extremely analytical equipment and skilled labor. To monitor the water quality, a variety of physical–chemical parameters must be used.

2.1 Temperature Measurement

Using a digital thermometer, the temperature is determined by dipping the thermometer in the sample and recording the result [18]. Temperature is the degree of heat or cold in an aquatic organism's body, whether it is in water or on land. Despite having cold blood, fish experience body temperature changes in response to their environment. These changes have an impact on the fish's physiology and metabolism as well as its production. The microbiota's rate of metabolic activity as well as their rate of respiration both increase with temperature because of the rise in oxygen demand. It also results in increased ammonia levels in water and decreased oxygen solubility. However, with prolonged ice cover, chemicals such as carbon dioxide, methane, and hydrogen sulfide can build up to dangerous levels and affect the health of fish [19].

The accumulation of dangerous gases such carbon dioxide, methane, and hydrogen sulfide under varied lengths of ice cover is shown in Figs. 1 and 2. Figure 1

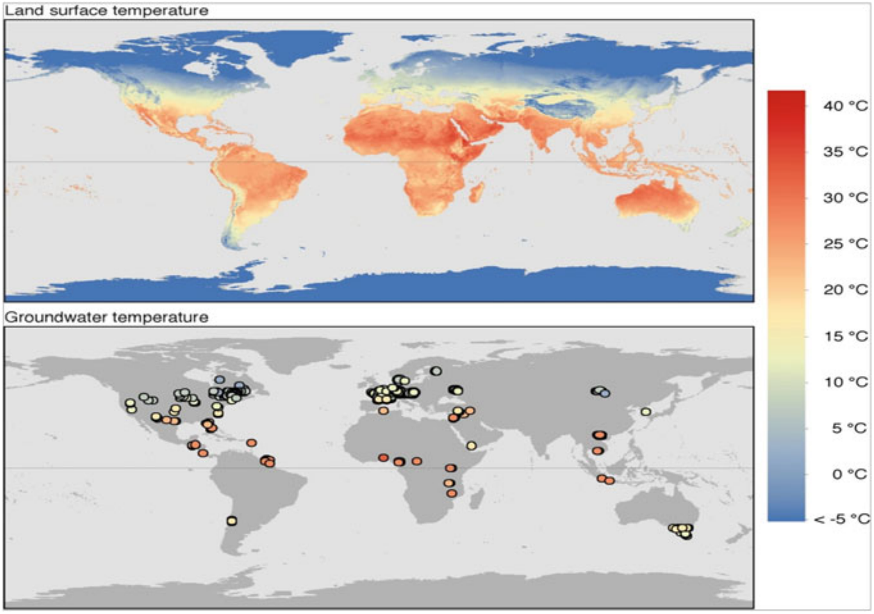

Fig. 1 Decadal average (2005–2014) of global shallow groundwater and land surface temperatures [19]

shows how chemical concentrations alter as ice cover duration lengthens. As seen in the image, there is a definite positive association between the quantity of these dangerous substances and the length of the ice cover. In particular, the data points point to a significant rise in chemical concentration following a specific critical period of ice cover. This suggests that a protracted ice cover may eventually cause a buildup of these compounds to levels that are harmful to aquatic life. Figure 2, on the other hand, depicts the condition of fish populations under various chemical concentrations brought on by various ice cover durations. The graph clearly shows that fish health drastically declines when chemical concentrations increase, a scenario brought on by prolonged ice cover. The need of preventing protracted ice cover scenarios is highlighted by this research in order to protect aquatic biodiversity and fish health.

2.2 pH Measurement

The pH scale, which determines how acidic or alkaline a solution is, fluctuates depending on the geology, contaminants, and climate of the area. For instance, locations with granite bedrock may have more acidic water than those with carbonate bedrock. Additionally, pollutants and dissolved gases can affect pH. Although drinking water is frequently supplemented with minerals and has a pH of 7, pure water

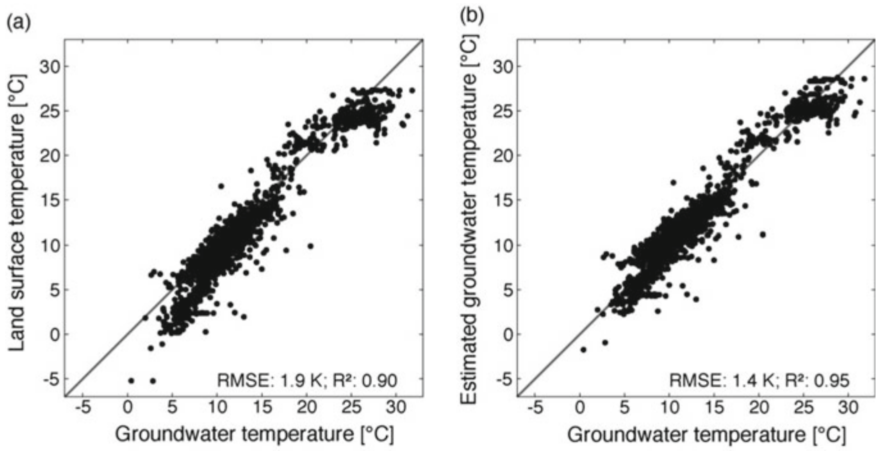

Fig. 2 **a** Correlation between land surface and groundwater temperatures; **b** Comparison of estimated and measured groundwater temperatures [19]

is inherently more alkaline. The World Health Organization recommends drinking water with a pH of 6.5–8.5. Beyond this range, water may provide health problems because extremely low pH can lead to corrosion and the release of metal ions from pipes, while extremely high pH can occasionally result in skin and eye irritation [20]. Due to the inclusion of minerals, bottled mineral water like Bisleri may have a pH slightly higher than 7. It's generally accepted that keeping a balanced pH in drinking water is essential for health, despite occasional claims to the contrary.

A key indicator of water quality, pH, is regulated by a variety of environmental conditions [21]. The regulation of pH is significantly influenced by dissolved materials, especially minerals and gases. For instance, the water frequently contains significant levels of calcium and magnesium in areas with limestone or dolomite bedrock, resulting in a more alkaline pH [22]. Similar to this, regions with a lot of organic matter that produces CO_2 or with volcanic activity may have more acidic water because dissolved CO_2 causes carbonic acid to develop [23]. Water pH is impacted by pollutants as well. Water's pH can be dramatically lowered by acid rain, which is caused by the atmospheric deposition of pollutants including sulfur dioxide and nitrogen oxides [24]. Heavy metals and other compounds that might change water pH and potentially damage aquatic life as well as degrade water quality are frequently present in industrial effluents [25]. Understanding the variables that affect water pH and keeping an eye on them are therefore essential for maintaining the highest possible level of water quality. This intricacy highlights the necessity for thorough water evaluation methods that can take these various factors into account.

2.3 DO Measurement

Determining the amount of dissolved oxygen in a river is crucial since aquatic life there depends on it and needs at least 4 ppm of DO to survive [8, 18, 26]. DO tests are carried out to confirm this. The Digital Dissolve Oxygen Meter is used to measure the DO test at the location of the sample collection. When measuring DO on-site, the results are correct, but if DO is measured later, the results will alter due to changes in the atmosphere and temperature [10, 14].

2.4 BOD Measurement

The BOD is a measurement of how much total dissolved oxygen is used by microorganisms during the biodegradation of organic materials, such as sewage or food particles. Rural ponds may have an excessive amount of phosphate, cow waste, and domestic sewage from non-point sources, which all contribute to a high organic load and a higher BOD level [27].

2.5 COD Measurement

Chemical oxygen demand, which is typically combined with biological oxygen demand, is a measure of the amount of organics in water (BOD). The COD is a measurement of the amount of organic matter in a sample that can be oxidized by a potent chemical oxidant [28–31]. The COD is frequently employed as a gauge of the organic and inorganic materials' susceptibility to oxidation in water bodies, industrial plant effluents, and sewage discharges [32]. As a result, the COD is an accurate indicator for determining the degree of water pollution (Fig. 3). As organic and inorganic matter concentrations rise, so does the COD of water [33, 34]. According to Garg [35], the COD concentration in Ramsagar reservoir ranged from 3.600 to 17.400 mg/l.

2.6 Carbon Dioxide Measurement

Unrestricted carbon dioxide, an exceedingly soluble gas in water generated by animal respiration, serves as nature's primary source of carbon. It can exist in water as dissolved or bound bicarbonate or carbonates in coral reef habitats, the earth's crust, and limestone. The pH of any system, especially those with inadequate buffering, is reduced when carbon dioxide is dissolved in water. This pH decrease can be harmful to aquatic life [37].

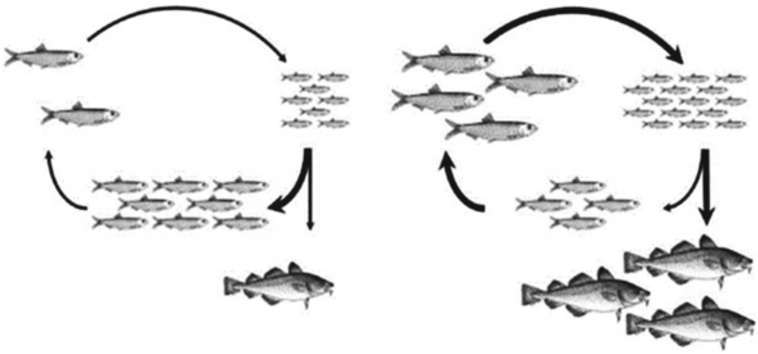

Fig. 3 Community conditions resulting in cod Allee effect: influence of predation on sprat population stages [36]

2.7 Alkalinity Measurement

Alkalinity, a measurement of the inclusive concentration of bases in pond water that includes dissolved calcium, magnesium, and other compounds as well as, bicarbonates, hydroxides, borates, phosphates, and carbonates, is the volume of water to engross variations in pH. Alkalinity is primarily increased by lime leaching from cement ponds or calcareous rocks, photosynthesis, sulfate reduction, and denitrification and it is primarily decreased or consumed by sulfide, respiration, and nitrification [38], as well as to a lesser extent by evaporation and decomposing organic matter. However, in case of insufficient alkalinity, even minor bit of acid might source a large pH change.

2.8 Nitrite-N (NO_2-N) Measurement

An intermediate in the transformation of NH_4^+ or NH_3 into NO_3, nitrite, is a by-product of oxidized NH_3 or NH_4^+. Nitrification, which is carried out by the system's naturally occurring highly chemo-autotrophic bacteria, aerobic, gram-negative, completes this process. Due to the rapid nature of the dialogue, large nitrite amounts are not frequently seen. The "brown blood illness" is a condition where high amounts of the substance do, however, result in hypoxia brought on by the hemoglobin in fish blood becoming inactive [39]. Boyd [40] asserts that less than 0.3 mg/l of nitrite is the ideal level for aquaculture. The concentration of nitrite at cage stations was greater than the standard permitted value due to the influence from fish waste and more feed, according to research [41–47] that found the concentration of nitrite-N lay in the range of 0.001–0.28 mg/l in cage culture systems. It has been discovered that a higher less dissolved oxygen, more ammonia, and pH can make it more poisonous.

2.9 Nitrate–N (NO_3-N) Determination

Nitrate is created via the process of nitrification, which is the oxidation of NO_2 to NO_3 by aerobic bacteria. De-nitrification of nitrate that aquatic plants cannot directly absorb occurs in anaerobic sediments [48]. According to Garg et al. [35], the ideal nitrate content for aquaculture is between 0.2 and 10 mg/l. Sewage and other pollutants high in nitrates can also contaminate surface water. Drinking water with higher nitrate content is harmful [49]. The Environmental Protection Agency (EPA) has determined that 10.00 mg/l of nitrate is the maximum contamination level (MCL) for water to be used for drinking purpose [50]. The concentration of nitrate in receiving waters is significantly impacted by runoff from farming operations and waste disposal sites. The usage of fertilizers on farms may have contributed to receiving streams' elevated nitrate levels through leaching and surface runoff during heavy rains [34].

2.10 Ammonia (NH_3) Determination

Ammonia is a consequence of the protein metabolism that fish harvest, as well as the breakdown of bacterial of biological waste like dead planktons, food scraps, and manure. Both ionized or unionized and ammonia are referred to as "total ammonia," yet only the unionized form (NH_3) is extremely toxic [36].

2.11 TSS Measurement

Total suspended solids, also known as non-filterable solids, are those solids that are retained by a filter with 1-micron holes. By running a known volume of sewage sample through a glass fiber filter equipment and weighing the dry residue that remains, their amount may be calculated [51].

2.12 Total Dissolved Solids (TDS) Measurement

Total dissolved solids, also known as filterable solids, are those solids that are not retained by a filter with 1-micron holes. By running a known amount of sewage sample through a glass fiber filter equipment and weighing the dry residue that remains after boiling the filtrate sewage, their quantity may be calculated. TDS is made up of organic and inorganic materials that are suspended in water [52]. The taste and potability of water can be impacted by high TDS [53]. TDS levels in drinking water should be measured using a conductivity metre and should be between 500 and 1000 mg/l according to WHO. TDS levels can be managed with treatments like reverse osmosis [54].

2.13 Measurement of Turbidity

As soon as you can after the sample is taken, determine the turbidity. Before examination, gently stir all samples to achieve a representative measurement. If sample preservation is not possible, start the analysis right away. If storage is necessary, refrigerate or cool to 4 °C to reduce the amount of microbial degradation of solids. For the best outcomes, test the turbidity right away without changing the pH or temperature of the original sample. A digital turbidity meter is used to measure turbidity. This was calibrated using a standard NTU [51, 55].

2.14 Heavy Metals Measurement

Each sample of acid-digested water weighed 100 cm^3 and was placed in a beaker. The beaker was then placed in a 70 °C oven to condense the water to 50 cm^3. Using an atomic absorption spectrometer, the concentrations of Co, Cu, Cr, CD, Zn, PB, and Ni in each sample of water were measured (AAS: AAS: LABINDIA: AA-7000) Prior to analysis, AAS required phase of acid digestion, which was accomplished by exposing the samples to concentrated HNO_3 [34]. Samples are digested using the methods endorsed by the American Public Health Association (APHA). The suggestions in the instruction manual were used to determine the instrument settings (IO).

2.15 Chlorides Measurement

Chlorides, which are often present as sodium chloride, alter the flavour of water [53]. Both pipes and vegetation may be harmed by presence of excess chlorides [56]. Titration techniques or ion chromatography are frequently used to determine the concentration of chloride [52]. A 250 mg/l limit is advised by the WHO [53]. Chloride levels can be controlled by reducing industrial effluents and recycling [54].

2.16 Biological Indicators

The presence of specific microbes, algae, and other lifeforms can reveal information about the quality of the water. E. coli is frequently tested for because its presence suggests fecal contamination [53]. Eutrophication can result from an algae bloom, which is frequently brought on by too many nutrients (such phosphates) [57]. Chemical and biological testing work together to offer a complete picture of the water quality [4, 6].

2.17 Index of Water Quality (WQI) Measurement

The WQI is premeditated in three steps. Each criterion was given a weight (W_i) in the first phase based on its relative significance to the overall quality of water intended for consumption. Nitrate has been given a maximum weight of 5 due to its significant role in determining the water quality [58]. The relative weight is computed using Eq. 1 in the second step.

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{1}$$

where n is the number of parameters, relative weight is denoted by W_i, and w_i represents the weight of each parameter. The parameter's calculated W_i values are provided in Table 1.

In the third stage, by dividing each parameter's concentration in each water sample by the relevant standard, according to the BIS specifications, and multiplying the result by 100, a quality rating scale (q_i) is obtained for each parameter (Eq. 2)

$$q_i = \left(\frac{C_i - C_{io}}{S_i - C_{io}}\right) \times 100 \tag{2}$$

where S_i is the BIS-recommended standard for Indian drinking water in mg/l for each chemical parameter and C_i is the concentration of each chemical parameter in every single water sample in mg/l. The parameter's optimal value in clear water is C_{io}. With pH, q_i is equal to $(C_i - 7)/(S_i - 7)100$ and C_{io} is equal to 7. For the remaining parameters, the optimal value is 0.

Table 1 Chemical parameters and their relative weight [59]

Chemical indicators	Weight	Indian standard	Relative weight (W_i)
Magnesium	2.00	30.00	0.091
Total hardness	2.00	300.00	0.091
Calcium	2.00	75.00	0.091
TDS	4.00	500.00	0.182
Chloride	3.00	250.00	0.136
pH	4.00	6.50–8.50	0.182
Nitrate	5.00	45.00	0.227

Table 2 Classification of water quality based on WQI value [59]

Water quality index	Quality of water
>300.00	Unsuitable
200.00–300.00	Very poor
100.00–200.00	Poor
50.00–100.00	Good
<50.00	Excellent

Each parameter's sub-index (SI), which is utilized to calculate the WQI in accordance with Eqs. 3 and 4, is first determined in order to calculate the WQI.

$$\mathrm{SI}_i = W_i \times q_i \tag{3}$$

$$\mathrm{WQI} = \sum_{i=1}^{n} \mathrm{SI}_i \tag{4}$$

The *i*th parameter's subindex is SI_i. The estimated WQI values are classified into five categories in Table 2.

The five categories range from "good water" to "unfit for drinking water," according to the computed WQI values (Table 2). The WQI has an inter-seasonal range of 28–267, with 24% of water bodies rated outstanding in the pre- and post-monsoon seasons and 18% rated excellent during the monsoon season. Approximately 62%, 58%, and 60% of water bodies are in good quality during the monsoon, pre-monsoon, and post-monsoon seasons, respectively in pre-monsoon, monsoon, and post-monsoon seasons, respectively. 14, 16, and 12% of water bodies were found to be poor water bodies in the respective seasons. The remaining 6, 2, and 4% of water bodies were very poor water bodies in aforesaid seasons. 16 and 48% of water bodies are in excellent and good water bodies throughout the monsoon and post-monsoon seasons. Limits for the physicochemical properties of lake water in India are shown in Table 3.

3 Advantageous and Limitations of Water Quality Evaluation and Treatment Methods

Numerous evaluation and treatment techniques have been created throughout the years in the quest to monitor and manage water quality. While each of these approaches has its own advantages and drawbacks, it is important to be aware of both in order to choose the approach that will work best in a certain circumstance. The biological, chemical, and physical testing approaches that are frequently employed in water quality evaluation and treatment are examined in this section along with their benefits and limitations [61]. By doing this, we intend to provide a thorough

Table 3 Physical and chemical features of Indian lake water [60]

Sr.	Parameter	BIS specification
1	PH	6.50–8.50
2	Color	5 Hazena max
3	Appearance	Clear
4	Turbidity	5 NTU max
5	Alkalinity	200 mg/L max
6	EC	Lacking mention
7	Chloride	250 mg/L max
8	Florid	1 mg/L max
9	Sulfate	200 mg/L max
10	Phosphate	Lacking mention
11	Ca H	75 mg/L max
12	T H	300 mg/L max
13	TDS	500 mg/L max
14	Mg H	30 mg/L
15	FRC	0.25 mg/L
16	Silica	Lacking mention
17	COD	Lacking mention
18	Hydrazine	Lacking mention
19	DO	Lacking mention
20	BOD	Lacking mention
21	NO_3	50 g/L
22	SO_3	Lacking mention

grasp of these techniques, permitting more informed choices about the management of water quality.

3.1 Physical Testing Methods: Benefits and Limitations

Advantages:

1. Physical tests can frequently be performed on-site and offer fast findings.
2. These tests can often be carried out more easily and affordably than chemical or biological ones.

Disadvantages:

1. Limited Information: Physical examinations can’t tell you anything about particular chemical or biological pollutants.

2. Subjectivity: Some physical tests, such as smell and color, can be a little subjective and may not give accurate quantitative information.

In order to obtain a thorough understanding of water quality, each of these techniques should preferably be utilized in combination.

3.2 Chemical Testing Methods: Benefits and Limitations

Advantages:

1. Specificity: Chemical analyses can locate particular contaminants, enabling focused responses to contamination.
2. Quantitative Information: These tests offer quantitative information that can be used to determine conformity with rules and specifications.

Disadvantages:

1. Expensive: Testing for a wide range of potential contaminants can be expensive when doing chemical analyses.
2. Point-in-Time Data: These tests offer a snapshot at a particular moment in time, and it's possible that they don't accurately capture changes in water quality over time.

3.3 Biological Testing Methods: Benefits and Limitations

Advantages:

1. Sensitive Indicators: Some species may be exceptionally sensitive to particular pollutants, making them reliable markers of harmful chemicals.
2. Long-term monitoring: Biological testing is helpful for long-term monitoring since it offers a snapshot of water quality across time rather than only at one particular instant.
3. Threats other than chemical pollutants can be found through biological testing: These include threats like temperature fluctuations, habitat damage, and more.

Disadvantages:

1. Requires professional expertise: Accurate identification and interpretation of biological indicators can be time-consuming and require professional expertise.
2. Seasonal variations make it challenging to compare results obtained at various times of the year since biological indicators can alter with the seasons.

3.4 Water Quality Index (WQI) Method: Benefits and Limitations

Advantages:

1. Simpleness: The WQI method's biggest benefit is the straightforward nature of the procedure. It reduces complicated water data to a single, simple number. With the use of this one number, the general public and decision-makers can be properly informed on the water quality.
2. Comprehensive: The WQI approach provides a comprehensive snapshot of the water quality by accounting for a wide range of characteristics. When assessing the effects of particular actions or tracking changes over time, this can be helpful.
3. Comparative Evaluation: WQI enables users to compare the water quality of one body of water to another or to the same body over time. This can assist in locating issue regions or water quality trends.

Disadvantages:

1. Lack of Specificity: Despite offering a helpful overall evaluation, the WQI does not draw attention to particular contaminants or characteristics. Even in the presence of high levels of a particular pollutant pollution, a location may still have a positive WQI if all other factors fall below permissible limits.
2. Equal Weight: WQI anticipates that all parameters will be given equal weight. This can be a drawback because some criteria might be worse for the environment and human health than others.
3. Variation in Standards: It is difficult to apply a global WQI since different countries and regions have different acceptable limitations for the criteria they utilize.

4 Physicochemical Review of Some Water Samples from India

The study of physical–chemical parameters is crucial to obtaining a precise understanding of the water quality, and it allows us to compare the results of various chemical and physical parameter values with reference values (Table 3). Here is a brief summary of some previous research studies. Pulp and paper sector effluents are one of India's most polluting industries, according to Tripathi et al. [62]. Small and large pulp and paper mills use several procedures that produce effluents with drastically varying physical–chemical characteristics due to their disparate production capacities and raw material sources. To diminish the impact of various pollutants on the environment, before being released into the drainage channel, such contaminated effluents must undergo sufficient treatment. Based on the findings presented here, it can be stated that the effluent emitted from both paper industries is extremely contaminated and exceeds the limits set by Indian regulatory agency norms. Furthermore, it is claimed that the pollutants produced at various stages of the paper manufacturing process can be reduced either by replacement of some current bleaching and pulping techniques with ECF (Elemental Chlorine Free bleaching), bio-pulping, TCF (Total Chlorine Free bleaching), bio-bleaching, and ozone bleaching or by treating the effluent with physical, biological, or chemical methods. This monitoring research of pulp and paper mill effluent collected from wood-based and agro-based sources resulted in the creation of a data bank that may be used to successfully anticipate their toxicity and implement appropriate management. Agrawal et al. [63] concluded that the water in the Bihar River can perform as a good habitat, provide educational data, and aid in understanding water features. The pH value suggests that the alkaline water in May have resulted from the high temperature, which suggests that CO_2 is soluble in the water. The Bihar River's Baba Ghat's water quality metrics, including alkalinity, total hardness, chloride ion, pH, BOD, COD are all well within the acceptable range, according to the analysis. Consequently, appropriate methods should be developed. According to research by Kaur et al. [64], the majority of freshwater bodies worldwide are becoming contaminated by human waste, industrial waste, sewage, agricultural waste, and religious practices like idol immersion. The Central Pollution Control Board [65] has created a thorough set of regulations regarding the act of immersing idols in oceans, lakes, and rivers (Guidelines for Idol Immersion, CPCB 2006). These regulations outline and define the function of state pollution control boards in evaluating the water quality of aquatic bodies and categorizing them according to specific physiochemical parameters. If these recommendations are followed and put into practices, the quality of the river's water after idol immersion could significantly improve. Khan et al. [66] assert that the most crucial metric for determining the water quality is DO, which was discovered to be Nil at seven places despite being necessary for all aquatic creatures' metabolism. Altaf and Saltanat [67] came to the conclusion that water temperature and water chemistry are the primary influences on phytoplankton dispersal, chloride, transparency, dissolved oxygen, alkalinity, TDS, and CO_2. Hardness and Conductivity, on the other hand, have less of an impact on the distribution of phytoplankton groups. Rani Lake water displays low high COD, BOD, DO, hardness, turbidity, alkalinity, chloride, TDS, nitrate, and phosphate during 2008 and 2009, according to evaluations done by Mishra et al. [68]. These parameters' values were discovered to be over the allowable limit (IS: 10500). A higher pH number implies that the water is slightly alkaline. The results unambiguously show that sewage discharge and other anthropogenic activities have caused this lake to become contaminated and entropic in character. The amount of oxygen utilized during aerobic processes of organic material degradation brought on by microorganisms is measured by biological oxygen demand. Therefore, the BOD provides details on the proportion of an organic substance in a sample of water that can be converted biologically. As a result, it is necessary to take into account how susceptible certain materials are to oxygen oxidation. The pre- during and post-immersion activities yielded the ranges of 1.4–35, 4–55, and 3.3–38 mg/L. At Site-7, the immersion period produced the highest BOD value (Majnu Ka Tila). Analysis was also done on the COD, which is frequently used to estimate indirectly how many organic chemicals are present in water. COD is a helpful indicator of water quality because the majority of its applications estimate the volume of organic contaminants present in wastewater or surface water (such as lakes and rivers). As indicated by a number of researchers [69–73], the value of COD in conjugation with BOD is beneficial in determining the hazardous circumstances and existence of physiologically resistant organic compounds.

5 Conclusions and Recommendations

The water quality of rivers and lakes has declined as a result of all the aforementioned effects. It provides a hint for municipal authorities to create effective management plans. The main factors influencing temperature variation are atmospheric temperature and weather. The industrial effluents that were released may have contributed to the pH decrease in Indian water bodies. This outcome is consistent with prior scientists' reports. The decrease in water volume due to rapid evaporation at high temperatures, high loadings of organic compounds, chlorides, detergent, and other pollutants are all responsible for the increase in hardness. Low levels of DO as a result of wastewater discharge from enterprises that were discharging some biological wastes that demanded a lot of oxygen. An important factor that is frequently used to estimate the pollutant load of wastewater is biological oxygen demand. The purpose of the BOD test is to quantify the quantity of carbonaceous matter that is biochemically oxidized. Values of BOD were caused by a faster rate of organic matter decomposition with turbidity, at a higher temperature and slower water current. A test called chemical oxygen demand is used to gauge how polluting household and industrial waste is. This provides important information regarding the possibility for pollution from home sewage and industrial effluents. Many aquatic zones in India have high COD value, which shows that industrial effluents released by industrial units are mostly to blame for the pollution there. Therefore, it is crucial to check the water's purity using the several criteria listed above before utilizing it.

References

1. Shukla, B.K., Bhowmik, A.R., Raj, R.B., Sharma, P.K.: Physico-chemical parameters and status of ground water pollution in Jalandhar-Phagwara region. J. Green Eng. **9**(2), 212–223 (2019)
2. Shenoy, A., Shukla, B.K., Bansal, V.: Sustainable design of textile industry effluent treatment plant with constructed wetland. Mater. Today: Proc. **61**(02), 537–542 (2022)
3. Shenoy, A., Bansal, V., Shukla, B.K.: Treatability of effluent from small scale dye shop using water hyacinth. Mater. Today: Proc. **61**(02), 579–586 (2022)
4. Shukla, B.K., Bashir, M., Sharma, P.K.: An analytical investigation of surface water quality and pollution status in Srinagar, Jammu and Kashmir, India. J. Green Eng. **11**, 952–962 (2021)
5. Madhuri, T.U., Subhashini, B.: A study on groundwater quality in residential colonies of Visakhapatnam. Ecobiol. Polluted Waters, 102 (2006)

6. Shukla, B.K., Gupta, A., Sharma, P.K., Bhowmik, A.R.: Pollution status and water quality assessment in pre-monsoon season: a case study of rural villages in Allahabad district, Uttar Pradesh, India. Mater. Today: Proc. **32**, 824–830 (2020)
7. Periyasamy, S., Temesgen, T.: Application of biochar for wastewater treatment. In: Biochar and its Application in Bioremediation, pp. 363–380. Springer, Singapore (2021)
8. Shukla, B.K., Goel, A.: Study on oxygen transfer by solid jet aerator with multiple openings. Eng. Sci. Technol. Int. J. **21**(2), 255–260 (2018)
9. Patil, P.N., Sawant, D.V., Deshmukh, R.N.: Physico-chemical parameters for testing of water-a review. Int. J. Environ. Sci. **3**(3), 1194 (2012)
10. Shukla, B.K., Khan, A., Saikiran, G., Sriram, M.: Comparative study on effect of variation in opening shape on oxygenation performance of surface jet aerators used in water and wastewater treatment. J. Green Eng. **9**(3), 427–440 (2019)
11. Adebowale, K.O., Agunbiade, F.O., Olu-Owolabi, B.I.: Impacts of natural and anthropogenic multiple sources of pollution on the environmental conditions of Ondo State coastal water, Nigeria. Electron. J. Environ., Agric. Food Chem. **7**(4), 2797–2881 (2008)
12. Edema, M.O., Omemu, A.M., Fapetu, O.M.: Microbiology and Physicochemical Analysis of different sources of drinking water in Abeokuta, Nigeria. Niger. J. Microbiol. **15**(1), 57–61 (2001)
13. Rim-Rukeh, A., Ikhifa, O.G., Okokoyo, A.P.: Effects of agricultural activities on the water quality of Orogodo River, Agbor Nigeria. J. Appl. Sci. Res. **2**(5), 256–259 (2006)
14. Shukla, B.K., Goel, A., Sharma, P.K.: An experimental study on oxygenation performance of rectangular shaped solid jet aerator having rounded edges. J. Green Eng. **10**, 2728–2745 (2020)
15. Dhakyanaika, K., Kumara, P.: Effects of pollution in River Krishni on hand pump water quality. J. Eng. Sci. Technol. Rev. **3**(1), 14–22 (2010)
16. Rajagopal, T., Thangamani, A., Sevarkodiyone, S.P., Sekar, M., Archunan, G.: Zooplankton diversity and physico-chemical conditions in three perennial ponds of Virudhunagar district, Tamil Nadu. J. Environ. Biol. **31**(3), 265–272 (2010)
17. Eruola, A.O., Ufoegbune, G.C., Eruola, A.O., Awomeso, J.A., Adeofun, C.O., Idowu, O.A.: An assessment of the effect of industrial pollution on Ibese River, Lagos, Nigeria. Afr. J. Environ. Sci. Technol. **5**(8), 608–661 (2011)
18. Shukla, B.K., Rajesh Kumar, V., Goel, A.: Experimental studies on the effect of variation in jet length on oxygenation performance of elliptical shaped solid jet aerator. J. Adv. Res. Dyn. Control Syst. **10**(08-Special issue), 1037–1044 (2018)
19. Koirala, S., Jung, M., Reichstein, M., de Graaf, I.E., Camps-Valls, G., Ichii, K., Papale, D., Ráduly, B., Schwalm, C.R., Tramontana, G., Carvalhais, N.: Global distribution of groundwater-vegetation spatial covariation. Geophys. Res. Lett. **44**(9), 4134–4142 (2017)
20. Agarwal, A., Saxena, M.: Assessment of pollution by physicochemical water parameters using regression analysis: a case study of Gagan river at Moradabad-India. Adv. Appl. Sci. Res. **2**(2), 185–189 (2011)
21. Srinivasamoorthy, K., Chidambaram, S., Prasanna, M.V., Vasanthavihar, M., Peter, J., Anandhan, P.: Identification of major sources controlling groundwater chemistry from a hard rock terrain—a case study from Mettur taluk, Salem district, Tamil Nadu, India. J. Earth Syst. Sci. **117**, 49–58 (2008)
22. Schulte, P., Van Geldern, R., Freitag, H., Karim, A., Négrel, P., Petelet-Giraud, E., Probst, A., Probst, J.L., Telmer, K., Veizer, J., Barth, J.A.: Applications of stable water and carbon isotopes in watershed research: weathering, carbon cycling, and water balances. Earth Sci. Rev. **109**(1–2), 20–31 (2011)
23. Smedley, P.L., Kinniburgh, D.G.: A review of the source, behaviour and distribution of arsenic in natural waters. Appl. Geochem. **17**(5), 517–568 (2002)
24. Likens, G.E., Driscoll, C.T., Buso, D.C.: Long-term effects of acid rain: response and recovery of a forest ecosystem. Science **272**(5259), 244–246 (1996)
25. Zheng, N., Liu, J., Wang, Q., Liang, Z.: Health risk assessment of heavy metal exposure to street dust in the zinc smelting district, Northeast of China. Sci. Total Environ. **408**(4), 726–733 (2010)

26. Gupta, S., Bhatnagar, M., Jain, R.: Physico-chemical characteristics and analysis of Fe and Zn in tubewell water and sewage water of Bikaner City. Asian J. Chem. **15**(2), 727 (2003)
27. Dan'Azumi, S., Bichi, M.H.: Industrial pollution and heavy metals profile of Challawa River in Kano, Nigeria. J. Appl. Sci. Environ. Sanit.Ion **5**(1), 23–29 (2010)
28. Sanap, R.R., Mohite, A.K., Pingle, S.D., Gunale, V.R.: Evaluation of water qualities of Godawari River with reference to physico-chemical parameters, Dist. Nasik (MS), India. Pollut. Res. **25**(4), 775 (2006)
29. Pande, K.S., Sharma, S.D.: Natural purification capacity for Ramganga River at Moradabad (UP). Pollut. Res. **17**, 409–415 (1998)
30. Murhekar, M.V., Murhekar, K.M., Das, D., Arankalle, V.A., Sehgal, S.C.: Prevalence of hepatitis B infection among the primitive tribes of Andaman & Nicobar Islands. Indian J. Med. Res. **111**, 199–203 (2000)
31. American Public Health Association: APHA Standard Methods for the Examination of Water and Wastewater. Standard Methods for the Examination of Water & Wastewater. American Public Health Association, Washington, DC (2005)
32. Chapman, D.: Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring. CRC Press (2021)
33. Boyd, C.E.: Water Quality in Warmwater Fish Ponds. Craftmaster Printers. Inc., Opelika, Alabama (1979)
34. Sharma, P.K., Ayub, S., Shukla, B.K.: Cost and feasibility analysis of chromium removal from water using Agro and horticultural wastes as adsorbents. In: 3rd International Conference on Innovative Technologies for Clean and Sustainable Development: ITCSD 2020 3, pp. 449–463. Springer International Publishing (2021)
35. Garg, R.K., Rao, R.J., Uchchariya, D., Shukla, G., Saksena, D.N.: Seasonal variations in water quality and major threats to Ramsagar reservoir, India. Afr. J. Environ. Sci. Technol. **4**(2), 61–76 (2010)
36. Van Leeuwen, A., De Roos, A.M., Persson, L.: How cod shapes its world. J. Sea Res. **60**(1–2), 89–104 (2008)
37. Verma, D.K., Satyaveer, N.K.M., Kumar, P., Jayaswa, R.: Important water quality parameters in aquaculture: an overview. Agric. Environ. **3**(3), 24–29 (2022)
38. Butler, J.N.: Aquatic chemistry: an introduction emphasizing chemical equilibria in natural waters (Stumm, Werner) (1971)
39. Lawson, T.B. (Ed.): Fundamentals of Aquacultural Engineering. Springer Science and Business Media (1994)
40. Diana, J.S., Szyper, J.P., Batterson, T.R., Boyd, C.E., Piedrahita, R.H.: Water quality in ponds. Dyn. Pond Aquac., 53–71 (2017)
41. Siti-Zahrah, A., Padilah, B., Azila, A., Rimatulhana, R., Shahidan, H.: Multiple streptococcal species infection in cage-cultured red tilapia but showing similar clinical signs. In: Diseases in Asian Aquaculture VI. Manila: Fish Health Section, Asian Fisheries Society, 2008, pp. 313–320 (2008)
42. Eglal, A.O., Nour, A.M., Essa, M.A., Zaki, M.A., Mabrouk, H.A.: Technical and economical evaluation of small-scale fish cage culture for youth in the River Nile for Egypt: 1. Effect of stocking density of mono-sex Nile Tilapia (Oreochromis niloticus) fingerlings. In: Cage Aquaculture in Asia: Proceeding of the International Symposium on Cage Aquaculture in Asia, pp. 107–114 (2009)
43. Mondal, M.N., Shahin, J., Wahab, M.A., Asaduzzaman, M., Yang, Y.: Comparison between cage and pond production of Thai Climbing Perch (Anabas testudineus) and Tilapia (Oreochromis niloticus) under three management systems. J. Bangladesh Agric. Univ. **8**(2), 313–322 (2010)
44. Jiwyam, W.: Extensive net cage culture of Nile Tilapia (Oreochromis niloticus) fingerlings in nutrient-enriched pond. Our Nat. **10**(1), 61–70 (2012)
45. Nyanti, L., Hii, K.M., Sow, A., Norhadi, I., Ling, T.Y.: Impacts of aquaculture at different depths and distances from cage culture sites in Batang Ai Hydroelectric Dam Reservoir, Sarawak, Malaysia. World Appl. Sci. J. **19**(4), 451–456 (2012)

46. Gorlach-Lira, K., Pacheco, C., Carvalho, L.C.T., Melo Júnior, H.N., Crispim, M.C.: The influence of fish culture in floating net cages on microbial indicators of water quality. Braz. J. Biol. **73**, 457–463 (2013)
47. Yee, L.T., Paka, D.D., Nyanti, L., Ismail, N., Emang, J.J.: Water quality at Batang Ai hydroelectric reservoir (Sarawak, Malaysia) and implications for aquaculture. Int. J. Appl. **2**(6), 23–30 (2012)
48. Furnas, M.J.: The behavior of nutrients in tropical aquatic ecosystems. In: Pollution in Tropical Aquatic Systems, pp. 29–65. CRC Press (2018)
49. Manickam, N., Bhavan, P.S., Santhanam, P., Bhuvaneswari, R., Muralisankar, T., Srinivasan, V., Asaikkutti, A., Rajkumar, G., Udayasuriyan, R., Karthik, M.: Impact of seasonal changes in zooplankton biodiversity in Ukkadam Lake, Coimbatore, Tamil Nadu, India, and potential future implications of climate change. J. Basic Appl. Zool. **79**(1), 1–10 (2018)
50. Self, J.R., Waskom, R.M.: Nitrates in Drinking Water. Service in Action, no. 0.517 (2008)
51. Gorde, S.P., Jadhav, M.V.: Assessment of water quality parameters: a review. J. Eng. Res. Appl. **3**(6), 2029–2035 (2013)
52. Rice, E.W., Bridgewater, L., American Public Health Association (eds.): Standard Methods for the Examination of Water and Wastewater, vol. 10. American Public Health Association, Washington, DC (2012)
53. Gordon, B., Ahmed, F., Chorus, I., Cotruvo, J., Cunliffe, D., de Roda Husman, A.: Guidelines for drinking-water quality: World Health Organization (2011)
54. Xu, P., Drewes, J.E.: Viability of nanofiltration and ultra-low pressure reverse osmosis membranes for multi-beneficial use of methane produced water. Sep. Purif. Technol. **52**(1), 67–76 (2006)
55. Sawant, R., Chavan, N.: Water quality status of Mahagaon reservoir from Gadhinglaj Tahsil from Maharashtra. Int. J. Sci. Environ. Technol. **2**(6), 1196–1204 (2013)
56. Yahya, S.M., Rahman, A., Chughtai, M.O.: Study on environmental impact of chemical pollutants & interpretation of characteristics using statistical technique in water quality of Keenjhar Lake located in Sindh Pakistan. J. Mater. Environ. Sci. **7**(2), 648–659 (2016)
57. Conley, D.J., Paerl, H.W., Howarth, R.W., Boesch, D.F., Seitzinger, S.P., Havens, K.E., Lancelot, C., Likens, G.E.: Controlling eutrophication: nitrogen and phosphorus. Science **323**(5917), 1014–1015 (2009)
58. Ramakrishnaiah, C.R., Sadashivaiah, C., Ranganna, G.: Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. E-J. Chem. **6**(2), 523–530 (2009)
59. Rao, G.S., Nageswararao, G.: Assessment of ground water quality using water quality index. Arch. Environ. Sci. **7**(1), 1–5 (2013)
60. Manjare, S.A., Vhanalakar, S.A., Muley, D.V.: Analysis of water quality using physicochemical parameters Tamdalge tank in Kolhapur district, Maharashtra. Int. J. Adv. Biotechnol. Res. **1**(2), 115–119 (2010)
61. Bhateria, R., Jain, D.: Water quality assessment of lake water: a review. Sustain. Water Resour. Manag. **2**, 161–173 (2016)
62. Tripathi, P., Kumar, V., Joshi, G., Singh, S.P., Panwar, S., Naithani, S., Nautiyal, R.: A comparative study on physico-chemical properties of pulp and paper mill effluent. Int. J. Eng. Res. Appl. **3**(6), 811–818 (2013)
63. Agrawal, N., Choubey, P.M., Pandey, J.P.: Water quality assessment of Baba Ghat of Bihar River Rewa (MP) India. Int. J. Sci. Res. Publ. **4**(10), 306–308 (2014)
64. Kaur, B.J., George, M.P., Mishra, S.: Water quality assessment of river Yamuna in Delhi stretch during Idol immersion. Int. J. Environ. Sci. **3**(6), 2122 (2013)
65. Bhawan, P., Nagar, E.A.: Central Pollution Control Board (2020)
66. Khan, A.A., Shammi, Q.J., Hussain, S.D., Gulam, N.N.: Seasonal variations in physico-chemical parameters in upper lake of Bhopal (MP). Int. J. Appl. Univers. Res. **2**(2), 1–7 (2015)
67. Altaf, H.G., Saltanat, P.: Effect of physico-chemical conditions on the structure and composition of the phytoplankton community in Wular Lake at Lankrishipora, Kashmir. Int. J. Biodivers. Conserv. **6**(1), 71–84 (2014)

68. Mishra, R., Prajapati, R.K., Dwivedi, V.K., Mishra, A.: Water quality assessment of Rani Lake of Rewa (MP), India. GERF Bull. Biosci. **2**(2), 11–17 (2011)
69. Rajurkar, N.S., Nongbri, B., Patwardhan, A.M.: Physico-chemical and microbial analysis of Umiam (Barapani) lake water. Indian J. Environ. Prot. **23**, 633–639 (2003)
70. Shukla, B.K., Sharma, P.K., Goel, A.: Study on oxygenation performance of solid jet aerator having circular opening corresponding to variable jet length and flow area. In: Journal of Physics: Conference Series, vol. 1531, no. 1, p. 012117. IOP Publishing (2020)
71. Gupta, A.K., Kavita, M., Pramod, K., Chandrasekhar, S., Sumita, S.: Impact of religious activities on the water characteristics of prominent ponds at Varanasi (UP), India. Plant Arch. **11**(1), 297–300 (2011)
72. Singh, S., Singh, V.P., Garg, P., Shukla, B.K.: Physico-chemical analysis of groundwater in Noida-Ghaziabad region. In: IOP Conference Series: Earth and Environmental Science, vol. 1110, no. 1, p. 012028. IOP Publishing (2023)
73. Imtiyaz, I., Krishnakant, Shukla, B. K., Varadharajan, S., Bharti, G.: A comprehensive review of mass transfer phenomenon in gas-liquid phase flow during aeration in wastewater treatment. In: Proceedings of Indian Geotechnical and Geoenvironmental Engineering Conference (IGGEC) 2021, vol. 2, pp. 127–135. Springer Nature Singapore, Singapore (2022)