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Evaluating the Physicochemical and Microbiological Quality of Borehole Water Sources

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KEYWORDS

Borehole water, physicochemical parameters, microbiological quality,WHO.

ABSTRACT **:**

Borehole water serves as a significant source of potable water in numerous developing areas; however, its quality is frequently undermined by various pollutants. This research examines the physicochemical and microbiological quality of borehole water sources in Ain Temouchent, Algeria. Five water samples were collected and analysed according to standardised ISO methods. The mean physicochemical parameters measured were: pH 7.47, temperature 18.88 C°, conductivity 1125 µS/cm, turbidity 1.03 NTU, TDS 1012mg/l, nitrite 0.15 mg/L, nitrate 48.95 mg/L, calcium 58.04 mg/L, magnesium 50.15mg/L, sodium 157.24 mg/l, sulfates 129.06 mg/L, and potassium 3.16 mg/L. Microbiological analyses for total Coliforms, *E. coli*, *Streptococcus*, and anaerobic sulfate-reducing bacteria indicate the absence of bacterial contamination. The water quality is largely satisfactory, except for elevated mineral concentrations in specific samples according to WHO., necessitating monitoring or treatment prior to utilisation. Consequently, it is essential to establish regular water quality monitoring programs and enhance borehole protection measures, including appropriate sealing and sanitation practices surrounding the water sources. These measures will guarantee the delivery of safe and dependable drinking water to the local populace and mitigate the risk of waterborne illnesses.

1. INTRODUCTION

Water, both on the surface and subterranean, is the most vital and crucial natural resource for sustaining life on Earth and for the sustainable development of socioeconomic sectors, including irrigation and industrialization. Water, in all its forms, is a crucial element of hydro-geo-ecological and numerous metabolic, physiological, and ecological processes in living organisms **[1].**

Groundwater resources are substantial natural reservoirs situated beneath the Earth's surface. Desiccated regions frequently depend on subterranean water sources for hydration, agriculture, and industrial operations. Fifty percent of drinking water is sourced from groundwater, while irrigation constitutes approximately 43% **[2]**.

Groundwater serves as a significant source of freshwater for the global populace, utilized for domestic, agricultural, and industrial purposes. About one-third of the global population relies on groundwater for potable water. Groundwater is a crucial resource in arid and semi-arid regions where surface water and precipitation are scarce **[3]**.

Globally, 69% of extracted groundwater is allocated for agricultural use, while 31% is utilized by municipal, industrial, and commercial sectors **[4]**.

Connecting groundwater quality to health will render the invisible groundwater perceptible; however, existing knowledge gaps necessitate cross-disciplinary convergent research to comprehend this relationship. Groundwater substances essential for health can be categorized into five types based on their sources and characteristics: Geogenic substances, biogenic elements, anthropogenic pollutants, emerging contaminants, and pathogens **[5].**

Groundwater is typically regarded as safe for consumption. Nonetheless, its quality fluctuates geographically and is occasionally influenced by climatic variations, soil types, terrain, and the geological characteristics of the rocks that the water

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traverses. Human activities, including the disposal of chemicals and microbiological materials in landfills, subterranean burial, or direct injection of waste into groundwater, can alter the natural composition and quality of water. The inadequate construction of boreholes may lead to groundwater contamination. Agricultural practices, inadequate solid waste management, and animal excrement near boreholes may contaminate the water **[6].**

The quality of groundwater primarily depends on the constituents present during its infiltration. The quality of water is evaluated based on its physical, chemical, and biological characteristics, as well as its intended applications. For instance, despite distilled water being physically, chemically, and bacteriologically pure, its flavor is quite insipid and it exhibits high corrosiveness **[7].**

The risks associated with groundwater quality are significant for human health, especially in resource-limited environments, where groundwater sources are typically established without water treatment facilities or support services **[8].**

Contaminated water and inadequate sanitation are associated with the transmission of diseases including cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio. Deficient, insufficient, or improperly administered water and sanitation services subject individuals to avoidable health hazards. The insufficient management of urban, industrial, and agricultural wastewater results in the drinking water of hundreds of millions being perilously contaminated or chemically polluted. The natural occurrence of chemicals, especially in groundwater, can pose health risks, including arsenic and fluoride, while other substances, like lead, may be present in elevated levels in drinking water due to leaching from components in contact with the water supply **[9].**

The detection of total coliforms in water samples signifies the potential proliferation of opportunistic pathogenic bacteria, including *Enterobacter* and *Klebsiella*, as well as the possible presence of pathogenic organisms such as *Campylobacter jejuni, Campylobacter coli, Salmonella spp., Shigella spp., Vibrio cholerae, Escherichia coli, and Yersinia enterocolitica*. To achieve purer and higher-quality water, it must be evaluated physicochemically for its metal concentrations, temperature, color, odor, pH, nitrate levels, and organic residues **[10].** This study aimed to evaluate the overall physicochemical and bacteriological quality of potable water from selected boreholes in five densely populated areas of Ain Temouchent City during rainfall.

2. MATERIELS AND METHOD

2.1 Study Area Description

Ain Temouchent is situated in the northwest of Algeria, bordered to the north by the Mediterranean Sea, to the east by Oran, to the west by Tlemcen, and to the south by Sidi Bel Abbes, thereby possessing a significant strategic position. It encompasses an area of 35.2376 km² and is distinguished by its coastal stretch, measuring 80 km in length. Water samples were collected from five designated areas for this study: Sidi Ouriache (S1), Sidi Djelloul (S2), Ain Temouchent (S3), Ain Kihal (S4) , El Amir Abdelkader (S5).

2.2 Sample Collection

Water samples were collected from five Borehole separately for chemical and microbiological analysis. The sampling campaigns took place during the period from February to March 2025, which corresponds to the wet season.

Water samples were collected aseptically in 500-mL sterile Duran Schott bottles and transported in ice cooler boxes to the laboratory for analysis **[11].**

2.3 Physico-Chemical Analysis of the Water Samples

The following physico-chemical parameters were measured according to standard methods.The water samples were analysed for, Temperature, Turbidity, pH, Calcium, Sodium ,Nitrite, Nitrate, Chloride, Potassium ,Magnesium, Total dissolved solids (TDS) and Sulfates (Table N°1).The pH was determined using a pH meter (Model 300408-1, Denver Instruments Company, Bohemia, USA). The conductivity was measured using the Hach SensION 7 conductivity meter.

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Table N°1: Analytical Methods

Parameters	Analytical Methods	References
pH	Electrochemical with a glass electrode	NA .751/2013
Conductivity	Electrochemical with a glass electrode	NA 749 /1989
Turbidity	Electrochemical with a glass electrode	ISO 7027
Calcium	Titrimetric method with EDTA	ISO 6059:1984(fr)
Magnesium	Titrimetric method with EDTA	
		ISO 6059:1984(fr)
Nitrite	Molecular absorption spectrometry method	
Nitrate	Spectrometric Method Using Sulfosalicylic Acid	
		ISO 6777:1984
Sulfates	Colorimetric method	
		ISO 7890-3 : 1988
TDS	Gravimetric Method	
Sodium	Determination of sodium and potassium by flame emission spectrometry	[12]
		[12]
Potassium	Determination of sodium and potassium by flame emission spectrometry	ISO 9964-3: 1993(F)
		ISO 9964-3: 1993(F)

2.4.Microbiological Analysis of the Water Samples

Monitoring of bacteriological quality concentrated on the identification and quantification of indicator organisms indicative of faecal contamination. Subsequent to collection, the samples were preserved in a refrigerated container at approximately 4°C and promptly transported to the laboratory for analysis of bacteriological alterations.The employed technique was his membrane filtration method.

2.4.1 Detection and enumeration of Escherichia coli and coliform bacteria ISO 9308-1:2000(F)

The method is based on membrane filtration and consists of two parts: the standard reference test and the optional rapid test. The standard test involves incubating the membrane on a selective medium followed by biochemical characterization of typical lactose-positive colonies, which leads to the detection and enumeration of coliform bacteria and E. coli within two to three days. The rapid test consists of two incubation steps allowing the detection and enumeration of E. coli within approximately 21 ± 3 hours. If both tests are performed in parallel, the final *E. coli* result shall be the higher value obtained from the two methods. Filtration of sample test aliquots through membranes that retain bacteria.

2.4.2 Research and enumeration of enterococci in water ISO 7899-2:2000(F)

The enumeration of *enterococci* is based on the filtration of a specified volume of a water sample through a membrane filter with a pore size of 0.45 µm, sufficient to retain the bacteria. The filter is placed on a solid selective medium. Typical colonies appear convex, with a red, brown, or pink color, either at the center or over the entire colony.

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If typical colonies are observed, a confirmation step is required by transferring the membrane, with all colonies, onto bile esculin agar preheated to 44 °C.

2.4.3 Research and enumeration of spores of sulfite-reducing anaerobic microorganisms

(clostridia) ISO 6461-2 : 1986

Filtration of the water sample through a membrane filter whose pores have a size such that bacterial spores (0.2 µm) are retained inside or on the surface of the membrane filter.The filter is then placed on a specially selective culture medium (sulfite-iron agar), followed by incubation at 37 ±1°C for 20 ±4 h and then at 44 ± 4 hours, and enumeration of the black colonies.

3. RESULTS AND DISCUSSIONS

3.1 Physicochemical Parameters

The physicochemical analysis of the five borehole samples (S1, S2,S3,S4 and S5) provided significant insights into water quality and its appropriateness for diverse applications. The examination of Borehole water samples encompasses the identification of inorganic components and microbiological assessments.

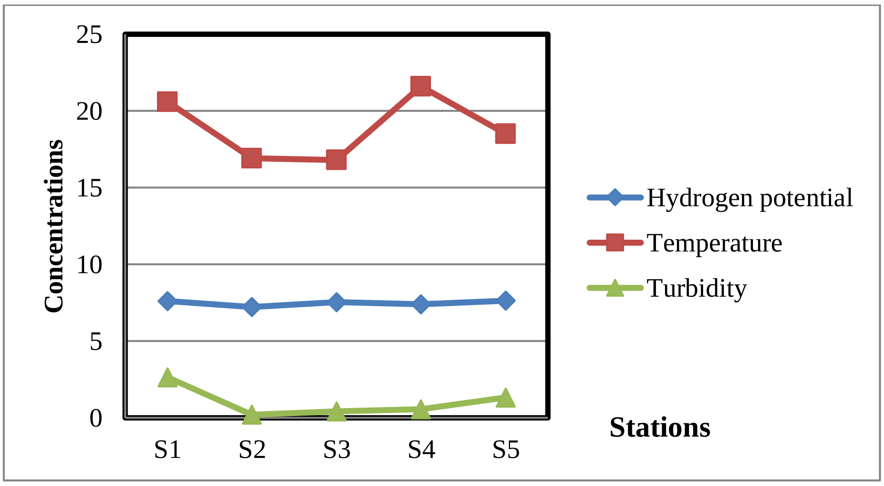

Fig .1: Variation of pH, temperature and turbidity from various sources

The pH values of the five analysed samples are 7.61, 7.22, 7.54, 7.39, and 7.63, respectively (Fig1). The results demonstrate that the water samples are marginally alkaline to neutral, with all values ranging from approximately 7.2 to 7.6. The World Health Organisation (WHO) guidelines stipulate that the acceptable pH range for drinking water is between 6.5 and 8. Our samples reside within the recommended range, indicating that the water is neither overly acidic nor excessively alkaline, which is advantageous for human consumption and mitigates the risk of corrosion or scaling in water distribution systems. Our samples, exhibiting pH values between 7.2 and 7.6, suggest favourable water quality regarding acidity and alkalinity balance. This pH range ensures the stability of numerous dissolved minerals and does not present immediate health hazards.

The temperatures recorded in the five groundwater samples are: 20.6°C, 16.9°C, 16.8°C, 21.6°C, and 18.5°C (Fig1).. These values are characteristic of groundwater and lie within the range typically observed in natural water sources. The World Health Organisation (WHO) states that there are no stringent health-based regulations regarding drinking water temperature; however, it is typically advised that water be cool and palatable, preferably below 15°C for optimal taste. Temperatures reaching 25°C are not deemed a health hazard and are commonly experienced, particularly in warm climate regions. The measured temperatures in our samples pose no health risks and are deemed acceptable for drinking water from a physico-chemical standpoint.

The turbidity of water is contingent upon the amount of solid matter present in suspension. This test quantifies the light-emitting characteristics of water and

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serves to assess the quality of waste discharge concerning colloidal substances **[12].** Turbidity is one of the indicators of poor water quality and can be considered as a proxy for microbial contamination **[13].** The turbidity values recorded in our samples are 2.64, 0.2, 0.43, 0.55, and 1.34 NTU, respectively (Fig1).The World Health Organisation (WHO) guidelines stipulate that drinking water turbidity should ideally be below 1 NTU and must not exceed 5 NTU to guarantee aesthetic quality and effective disinfection. Our results indicate that three samples (0.2, 0.43, and 0.55 NTU) fall within the optimal range, signifying excellent clarity and minimal suspended matter The two additional samples surpass 1 NTU yet remain compliant with WHO standards, which do not exceed 5 NTU. The rise in turbidity may result from soil contamination.

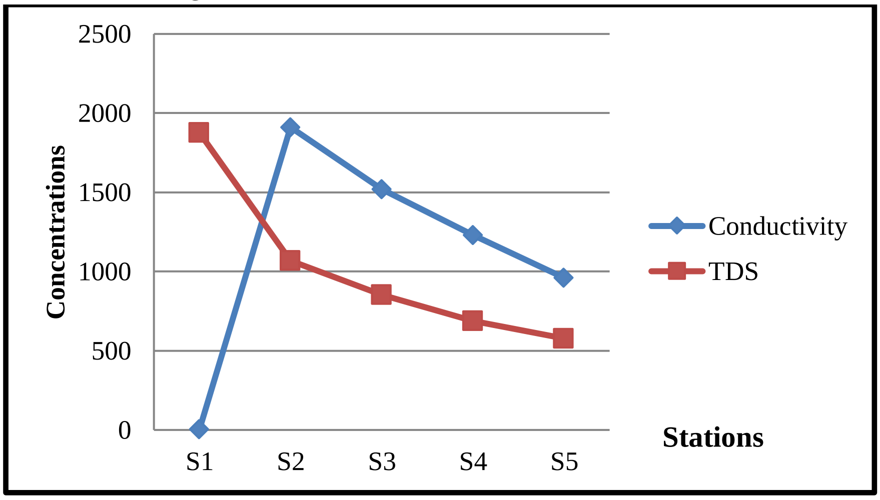

Fig .2: Variation of conductivity and Total dissolved solids from various sources

Conductivity, or electrical conductivity (EC), along with total dissolved solids (TDS), are commonly utilised as indicators of water quality, particularly in coastal regions. These two parameters serve as indicators of salinity levels. TDS concentration indicates the presence of inorganic salts and trace amounts of organic matter in water, while EC measures the water's ability to conduct electrical current **[14].**

The conductivity measurements obtained from our samples are 3.35, 1911, 1521, 1230, and 960 µS/cm, respectively (Fig .2). In accordance with WHO standards,EC value should not exceeded 400 µS/cm. In the current analysis, four out of five water samples demonstrated EC values exceeding the WHO recommended limit, whereas only one sample fell within the acceptable range. This finding indicates that most of the examined water sources fail to meet the WHO guideline for electrical conductivity, raising potential concerns about the salinity and overall quality of these water samples.

The Total Dissolved Solids (TDS) values measured in our samples are 1876, 1069.6 , 851.2 , 688.8 and 577.7 mg/L, respectively(Fig .2). The acceptable limit for Total Dissolved Solids (TDS) is 500 mg/l, while the maximum permissible limit is 1000 mg/l for potable water. The presence of elevated TDS levels in water may be undesirable to consumers due to the resultant taste and excessive scaling in plumbing systems **[15].**

Two samples (S1 and S2) surpassed the allowable TDS threshold, signifying that these water samples possess elevated levels of dissolved solids beyond the recommended limits for safe drinking water. This indicates possible concerns regarding water quality that could impact taste, safety, or appropriateness for consumption without treatment.Three samples did not surpass the permissible limit, indicating that their TDS levels are within the acceptable range for drinking water. These samples are deemed safe for consumption concerning TDS concentration.

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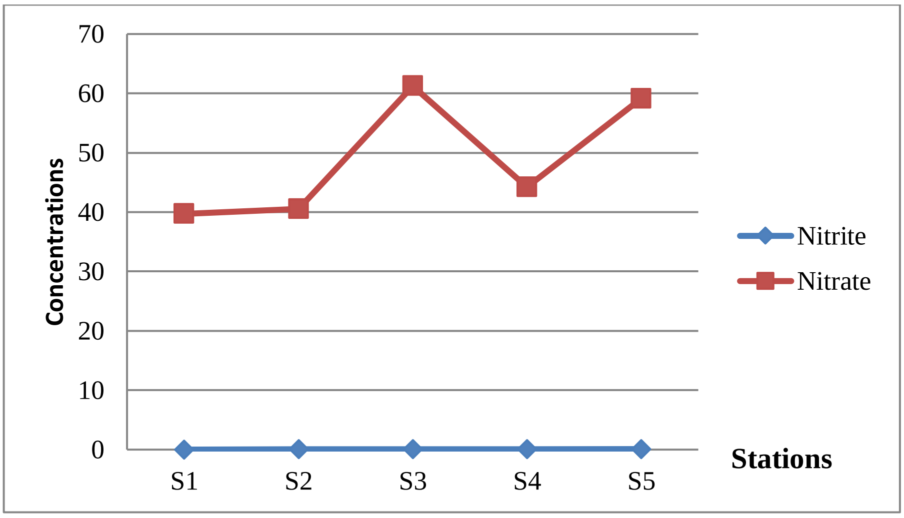

Fig .3: Variation of Nitrite and Nitrate and from various sources

In the analysis for Nitrite concentrations, the results were 0, 0.03, 0.02, 0,019 and 0.09 mg/L, respectively (Fig.3).The World Health Organisation (WHO) guidelines establish an acceptable limit for nitrite in drinking water at 0.9 mg/L to safeguard human health, particularly for vulnerable populations such as infants and pregnant women, owing to nitrite's potential to induce methemoglobinemia and its correlation with specific cancers. All our nitrite concentrations are below the WHO recommended threshold of 0.9 mg/L, signifying that the nitrite levels in our groundwater samples are within safe limits for human consumption.

The Nitrate concentrations measured in our samples are 39.7, 40.53, 61.23, 44.23, and 59.1mg/L, respectively (Fig.3).. The World Health Organisation (WHO) guidelines (2016) stipulate that the maximum permissible nitrate concentration in drinking water is 50 mg/L to mitigate health risks. In our results, three samples (39.7, 40.53, and 44.23 mg/L) fall below the WHO threshold, indicating that these waters are generally safe concerning nitrate content. Nevertheless, two samples at 59.1 and 61.23 mg/L surpass the recommended threshold, indicating possible health risks and necessitating treatment or dilution with lower nitrate water prior to consumption. The heightened nitrate concentration may signify localised pollution, potentially from fertilisers or sewage intrusion.

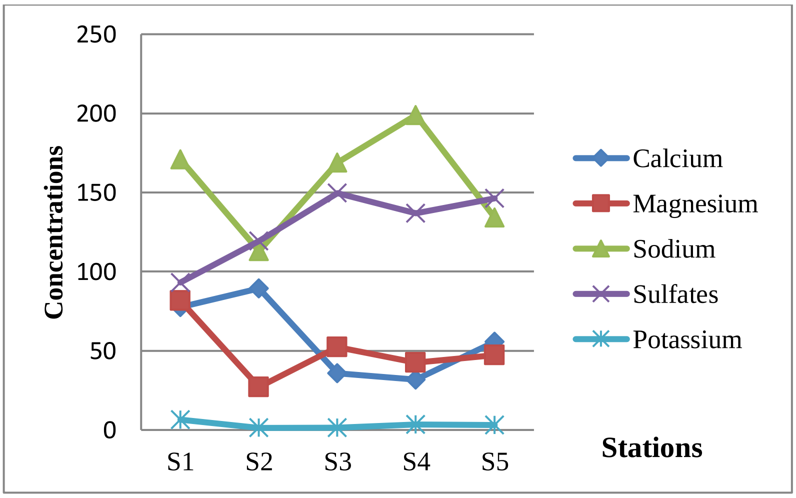

Fig .4: Variation of Calcium, Magnesium, Sodium, Sulfates and Potassiume from various sources

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The recorded calcium concentrations are 77.5, 89.41, 35.76, 31.8, and 55.6 mg/L, respectively (Fig .4). The World Health Organisation (WHO) guidelines (2011) stipulate that the maximum permissible concentration of calcium in drinking water is 75 mg/L. In comparison to the WHO guidelines, three of our samples (S3, S4 and S5) fall below the recommended threshold, demonstrating adherence to WHO standards. Nonetheless, two samples (S1 and S2) surpass the 75 mg/L limit.

The measured Magnesium concentrations are 81.63, 27.13, 52.2, 42.7, and 47.1 mg/L, respectively(Fig .4). The World Health Organisation (WHO) recommends a guideline value of 50 mg/L for magnesium in drinking water. This value is established primarily for operational purposes, as elevated magnesium levels contribute to water hardness and may result in scaling within pipes and appliances.Of our samples, two (S1 and S3) meet or surpass the WHO limit, whereas the remaining three (S2, S4, and S5) fall below this threshold. The sample containing 81.63 mg/L markedly exceeds the recommended threshold, potentially resulting in heightened water hardness and scaling complications.

The recorded sodium concentrations are 171, 113, 169, 198.9, and 134.3 mg/L, respectively (Fig .4).The World Health Organisation (WHO) guidelines for drinking water quality indicate that sodium concentrations are deemed acceptable if they do not surpass 200 mg/L; however, there is no health-based guideline value since sodium intake primarily derives from food rather than water. The sodium concentrations in our samples vary from 100 to 198 mg/L, remaining below the 200 mg/L limit. This indicates that our water samples exhibit moderately increased sodium levels, potentially attributable to natural geological sources or anthropogenic factors such as contamination from salt deposits or water softeners.When juxtaposing these findings with WHO guidelines, our samples fall within permissible thresholds for general consumption; however, they warrant monitoring, particularly for vulnerable populations.

The recorded sulfate concentrations are 93.16, 119.5, 149.6, 136.77, and 146.3 mg/L, respectively (Fig .4).The World Health Organisation (WHO) guidelines specify that the maximum allowable concentration of sulphate in drinking water is 250 mg/L. All analysed samples exhibit sulfate concentrations significantly beneath the WHO guideline threshold. The findings demonstrate that the water is appropriate for human consumption concerning sulfate levels, as none of the samples near the 250 mg/L threshold.

The potassium concentrations recorded in the samples are 6.5, 1.28, 1.43, 3.5, and 3.1 mg/L, respectively (Fig .4). The World Health Organisation (WHO) guidelines for drinking water quality indicate that potassium is not deemed a health risk at typical groundwater concentrations. Potassium levels in drinking water typically range from 1 to 12 mg/L, which are regarded as acceptable within this spectrum. In our samples, the potassium concentrations predominantly reside within the typical range, with one sample measuring 6.5 mg/L and the others ranging from 1.28 to 3.5 mg/L.

3.2 Microbiological Analysis:

In this study, none of the sampling sites exhibited the presence of *Escherichia coli*, total coliforms, sulfite-reducing anaerobes, or *Streptococci*.. In accordance with the World Health Organisation (WHO) Guidelines for Drinking-water Quality. *Escherichia coli* (*E. coli*) or thermotolerant coliform bacteria must be absent in any 100 ml sample.

The elimination of coliform bacteria in potable water is essential for public health. Coliform bacteria act as indicators of possible faecal contamination, which may contain harmful pathogens such as *E. coli*, *Salmonella*, and *Giardia*. Ingesting water tainted with coliform bacteria may result in gastrointestinal disorders, such as diarrhoea and vomiting, and in extreme instances, more severe infections **[16].**

Conclusion:

The examination of five groundwater samples from Ain Temouchent indicates that the majority of physicochemical parameters, such as pH, temperature, turbidity, calcium, sodium, sulphate, and potassium, conform to the acceptable thresholds established by the World Health Organisation (WHO). Nevertheless, two samples surpassed the advised thresholds for Total Dissolved Solids (TDS), potentially impacting water quality and consumer perception. Furthermore, four samples exhibited electrical conductivity values exceeding the WHO guidelines, signifying a substantial

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concentration of dissolved ions. Nitrate concentrations in two samples exceeded the safe threshold of 50 mg/L, potentially posing health hazards, particularly for infants. Elevated magnesium concentrations were observed in two samples, potentially contributing to water hardness and minor health issues. All samples tested negative for bacterial contamination, including total coliforms, E. coli, Streptococcus, and sulfite-reducing anaerobes, thereby confirming excellent microbiological quality. Although the water is typically appropriate for consumption, the heightened levels of TDS, conductivity, nitrate, and magnesium in certain samples indicate that treatment or blending is recommended to guarantee safety and acceptability.

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