Temporal Analysis of Groundwater Quality in Al Hoceima, Morocco: A Comparative Study of a Well Over Two Periods

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Abstract. This study assesses the groundwater quality of the Ghiis Nekkour aquifer in northern Morocco, focusing on a specific well in the Al Hoceima region. This water source is vital for the local population. The research compares the groundwater quality during two distinct periods and characterizes its physicochemical and bacteriological properties. The study reveals that physicochemical analysis shows moderate water quality, with electrical conductivity values ranging from 2441 µS/cm to 2456 µS/cm, and turbidity levels below 0.61 NTU. Chemical analysis indicates calcium concentrations ranging from 181 mg/l to 195 mg/l, magnesium concentrations from 136 mg/l to 143 mg/l, ammonium concentrations of 0.05 mg/l, chloride concentrations from 453 mg/l to 478 mg/l, and nitrate concentrations of 40 mg/l. Bicarbonate concentrations vary from 789 mg/l to 856 mg/l. However, bacteriological analysis shows water contamination by coliform bacteria, intestinal enterococci, and Escherichia coli. The study emphasizes the urgent need to take measures to remedy this contamination and ensure the safety of the water source for the region's inhabitants.

1 INTRODUCTION

Groundwater is a crucial resource for numerous applications, especially in arid and semi-arid regions. Sourced from deep underground aquifers, this water can naturally emerge as springs or be collected in the water table, requiring extraction through wells and drilling[1]. However, its quality is a concerning issue, with significant implications for human and animal health[2, 3].
Today, strategic water management has become a crucial global challenge, demanding a policy approach integrated with sustainable development. Long-term preservation of groundwater quality is essential to ensure its sustainability and availability[4].
In this situation, this study goals to compare the water quality from a commonly used water source by the local population during two different periods[5]. This site was chosen as a potential source of drinking water in the region[6-8].

2 MATERIALS AND METHODS

2.1 Study Area

Al Hoceima, located in northeastern Morocco, is nestled in the Rif Mountains, near the Mediterranean Sea. The region is known for its complex topography, rugged terrain, and diverse geological formations, which are typical of the Rif areas. Figure 1 shows the location of this point within the Ghiis Nekkour aquifer[9].

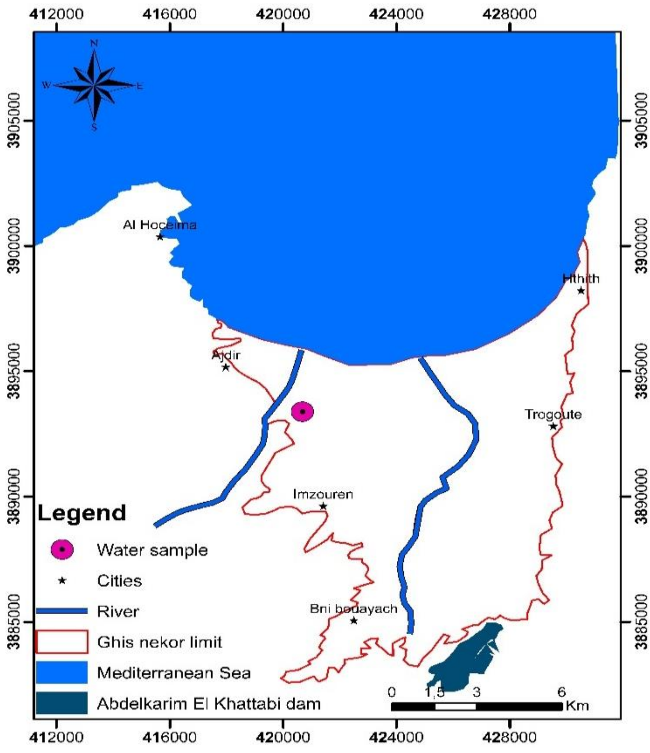

Fig. 1. Map depicting the geographical location of the study area.

2.2 Sampling and Analysis

To evaluate groundwater quality, a choosing system was established to collect information that accurately represents the structural diversity of the components under investigation. Samples were obtained during two distinct durations, hot season, and cold season (February 2023 and July 2023), to identify differences in parameters between the seasons and to observe potential fluctuations in water quality.

On-site measurements of physical parameters such as pH, conductivity, and turbidity were conducted using specialized instruments, while chemical and bacteriological analyses of the samples were carried out in the laboratory.

The bacteriological analysis focused on quantifying parameters indicating fecal contamination, including coliforms, Escherichia coli, and fecal streptococci[10].

3 RESULTS AND DISCUSSION

3.1 pH

The pH level indicates the concentration of hydrogen ions in water, with a pH of 7 representing neutrality. Field pH measurement is typically performed using a pH meter. In this study, pH readings of 7.9 and 7.5 were obtained, suggesting water of neutral nature. These values fall within the range specified by Moroccan standards, which typically spans from 6.5 to 8.5 [11], indicating compliance with regulatory guidelines [10, 12, 13]. An increase in pH levels can be caused by the presence of alkaline substances such as limestone or bicarbonate ions. While water with a pH within the recommended range is generally considered safe for consumption.

Fig. 2. Spatial variation of pH values.

3.2 Electrical Conductivity (C. E)

Conductivity serves as an indicator of mineralization levels in environments. The recorded values, ranging from 2441 µS/cm to 2456 µS/cm, suggest moderate mineralization within the studied aquifer. These measurements fall below the maximum electrical conductivity threshold set by Moroccan standards, which is 2700 µS/cm [14], indicating compliance with regulatory limits [7, 15].

Fig. 3. Variation in the electrical conductivity of the studied well water.

3.3 Turbidity

Turbidity serves as a significant metric for assessing water quality, indicating a decrease in the clarity of a liquid due to the existence of non-dissolved materials. Addressing turbidity is crucial as it encompasses suspended matter and colloidal particles, providing surfaces where various potentially pathogenic microorganisms can attach. Recorded turbidity values of 0.5 NTU and 0.61 NTU remain within acceptable limits, not exceeding the standard threshold of 5 NTU[14]. An increase in turbidity can be caused by soil erosion, urban runoff, and the presence of organic matter in water sources. High turbidity levels may indicate the presence of harmful pathogens such as bacteria, viruses, and parasites, which can lead to gastrointestinal illnesses and other health issues if ingested.

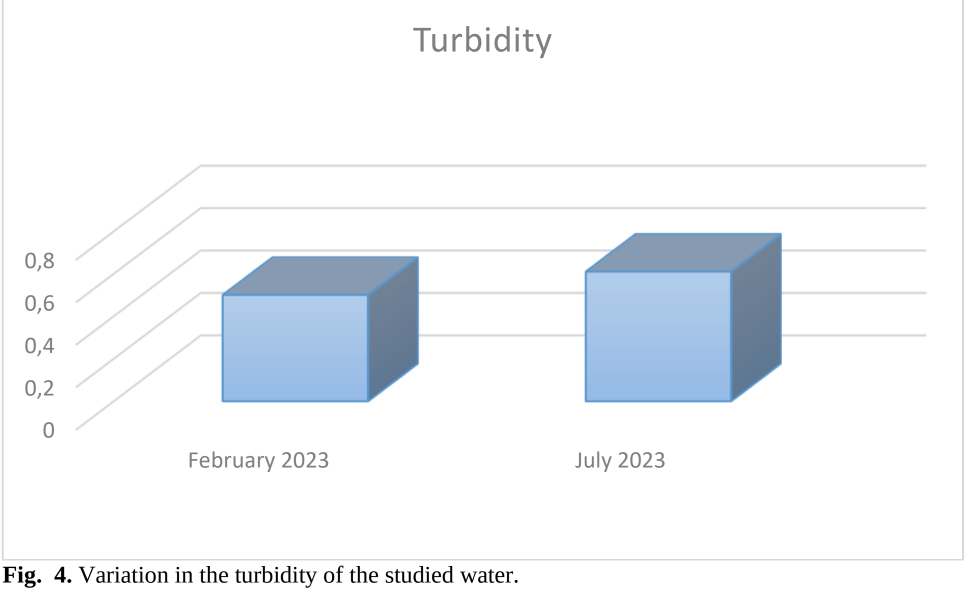

Fig. 4. Variation in the turbidity of the studied water.

3.4 Calcium (ca^{2+})

Calcium is vital for human health, often being the predominant element in drinking water, with its concentration varying based on the geological composition of the terrain it passes through, such as limestone or gypsum[2]. The calcium concentrations measured in the water samples are 181 mg/l and 195 mg/l, in order. These values remain below the Moroccan standard limit of 200 mg/l[9, 14]. Sufficient calcium intake is essential for bone health, nerve transmission, and muscle function. Although the calcium concentrations in the water samples are within safe limits, excessively high levels of calcium in drinking water can lead to scale buildup in pipes and appliances, as well as contribute to kidney stones in individuals predisposed to this condition.

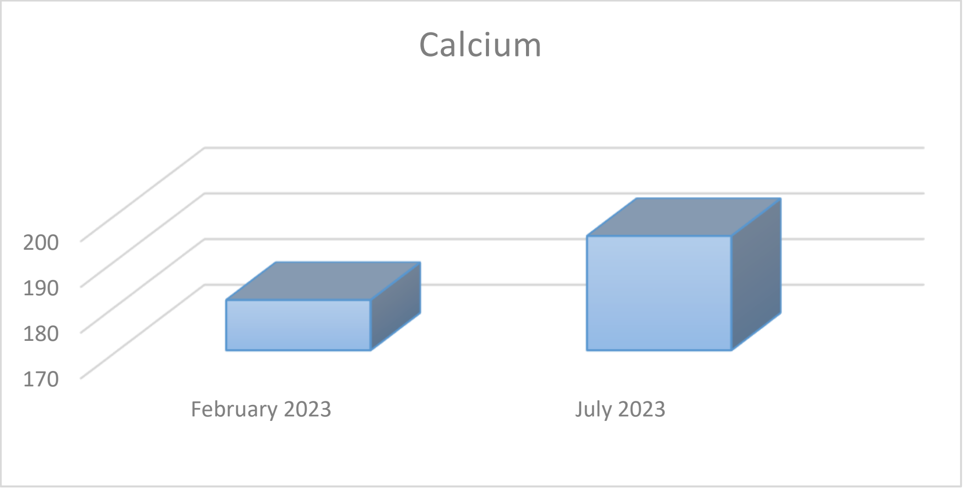

Fig. 5. Variation of calcium in the studied water.

3.5 Magnesium (Mg^{2+})

Magnesium plays a crucial role in many bodily functions, and a deficiency can have negative health effects, with diarrhea being a risk associated with increased magnesium consumption. The magnesium values of the water indicate that the concentration of this element is 136 and 143 mg/l, respectively, which does not exceed the Moroccan standard of 150 mg/l [13]. While the magnesium concentrations in the water samples are within safe limits, excessively high levels of magnesium in drinking water can have a laxative effect and may cause gastrointestinal discomfort in sensitive individuals.

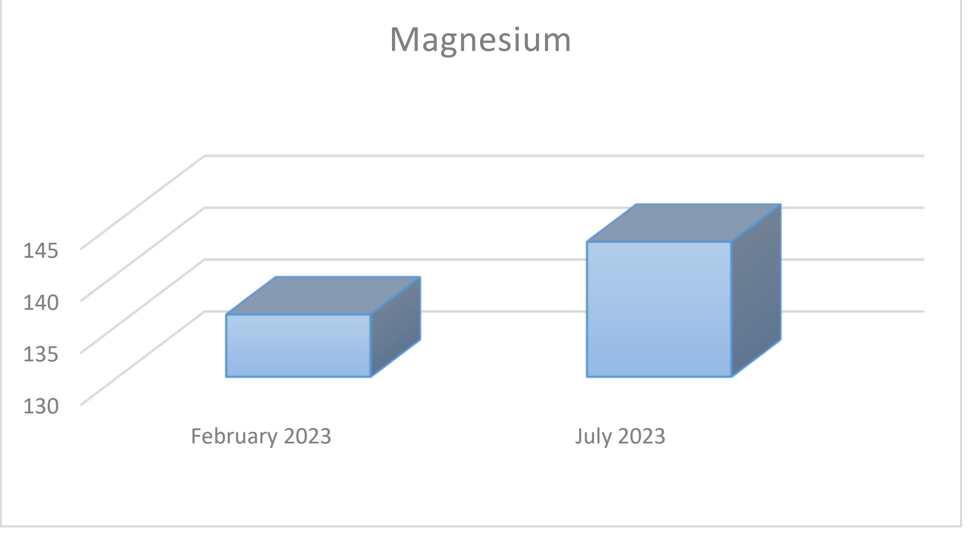

Fig. 6. Variation of magnesium in the studied well water.

3.6 ammonium (NH_4^+)

Ammonium in groundwater may be linked to nitrate reduction, often in conjunction with iron. Originating from natural processes, it can also stem from various anthropogenic sources such as agriculture, urban activities, or industrial operations. Extravagant levels of ammonium can impact water flavor (due to chloramines) or promote the growth of nitrifying bacteria within distribution networks.
The analysis indicates consistent ammonium concentrations of 0.05 mg/l across both periods, remaining well below the Moroccan standard limit of 0.5 mg/l[6, 16]. While low levels of ammonium in drinking water are generally considered safe, excessive levels can lead to taste and odor issues, as well as promote the growth of harmful bacteria, potentially causing gastrointestinal illnesses if ingested over extended periods.

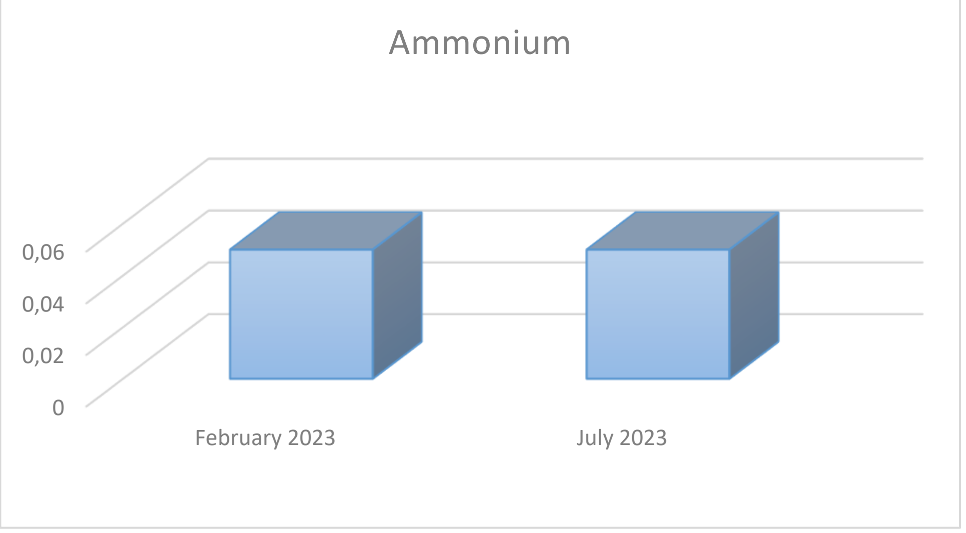

Fig. 7. Variation of ammonium in the well water.

3.7 Chlorides (CL^-)

The existence of chlorides in water is primarily attributed to the geological composition of the area it flows using, although they are ubiquitous in nearly all natural water sources. Chlorides represent significant inorganic anions present in varying concentrations across natural water bodies.
At the sampling point, chloride concentrations are measured at 453 mg/l and 478 mg/l, separately. These values remain well below the Moroccan standard limit of 750 mg/l[4].

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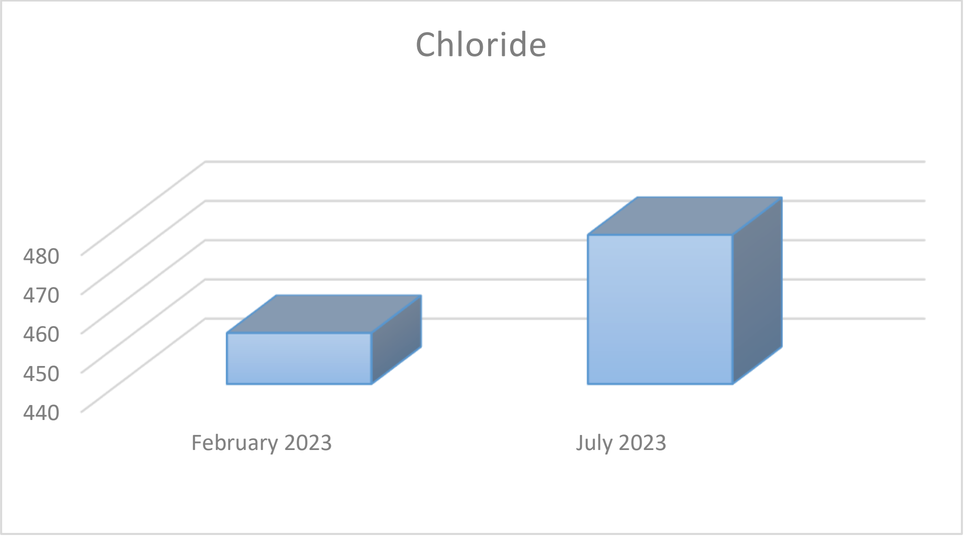

Fig. 8. Spatial variation in chloride concentration.

3.8 Nitrates (NO_3^-)

Increased nitrate levels can result from human activities and erosion, including the infiltration of wastewater from mineral industries and the use of nitrogenous fertilizers.
According to Moroccan standards, water of optimal quality should not exceed a concentration of 50 mg/l. Beyond this threshold, water is considered non-potable and requires treatment for safe consumption. In this study, nitrate concentration remained consistent at 40 mg/l during both sampling periods[17].

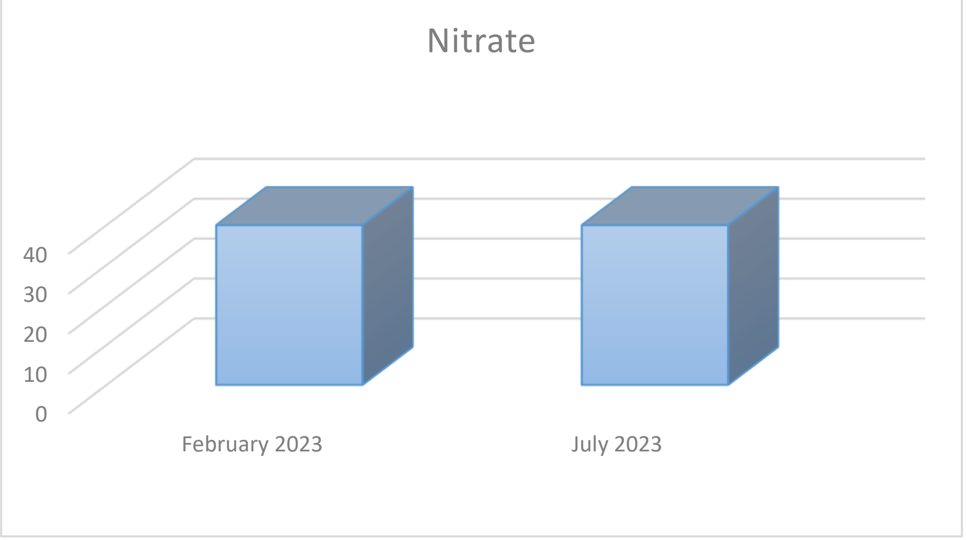

Fig. 9. Spatial variation in nitrate concentration.

3.9 Bicarbonate (HCO_3^-)

The concentration of bicarbonate in groundwater is primarily affected by the existence of carbonate minerals in the ground and aquifer, as well as by the levels of CO2 in the atmosphere and soil. In this study, bicarbonate measures in the water were measured at 856 mg/l and 789 mg/l, respectively [18].

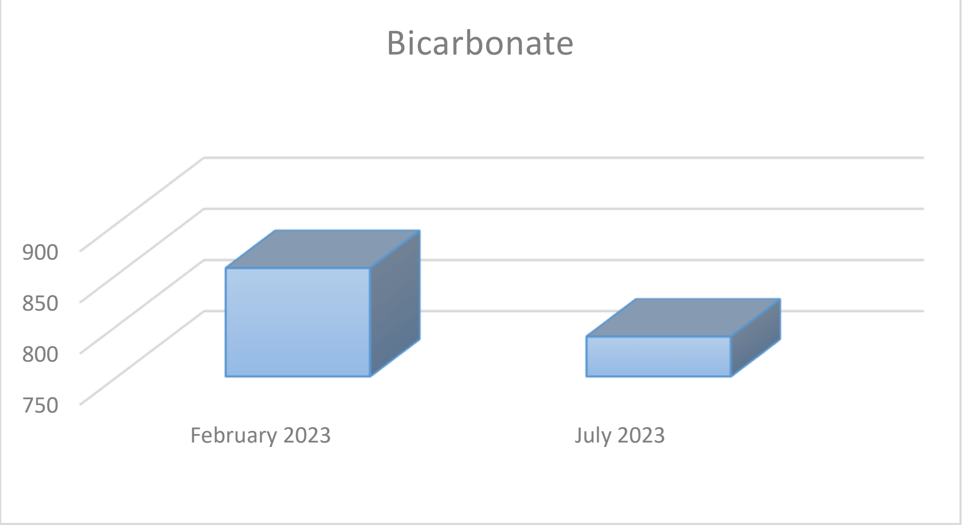

Fig. 10. Spatial variation in bicarbonate concentration.

3.10 Bacteriological Characterization

Traditionally, groundwater is reputed to be of better quality than surface water. However, it remains vulnerable to contamination, thus necessitating measures to preserve its purity. Despite its clear and often tasteless appearance, groundwater can harbor components detrimental to health, such as pathogens, undesirable substances, or toxins[15].
Subsequently, the results of these analyses are compared against regulatory standards, notably the maximum allowable values (MAV) established in national guidelines on drinking water quality[19].

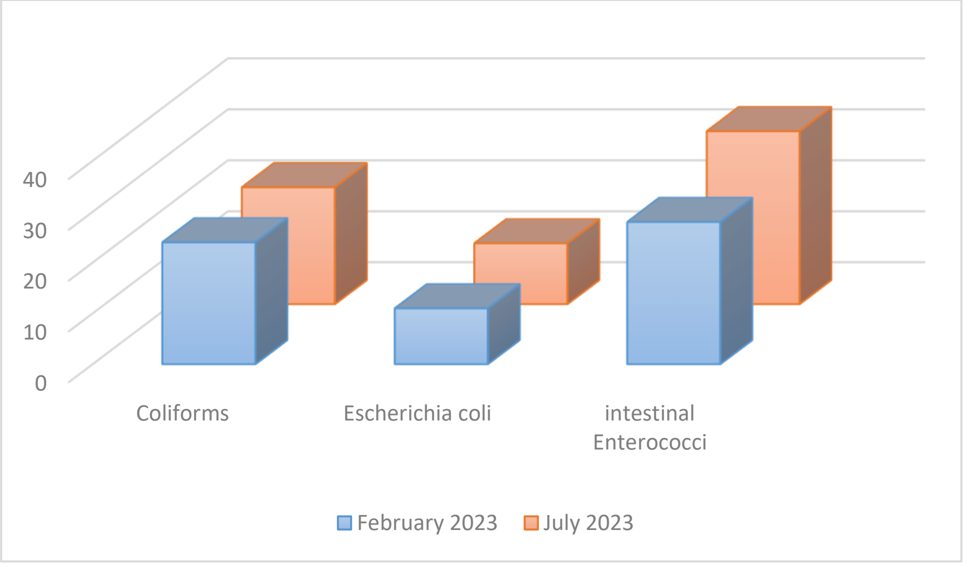

Fig. 11. Bacterial analysis of the studied well water.

The water sample analyzed for coliform bacteria was contaminated during both periods, with concentrations of 24 and 23 CFU/100ml. Similarly, for intestinal enterococci, the selected water source showed contamination, with concentrations of 11 and 12 CFU/100ml during the respective periods, thus not meeting Moroccan health standards. Regarding Escherichia coli, the selected water source was also contaminated during both periods, with concentrations of 28 and CFU/100ml, which does not meet the current health standards in Morocco[20].
The well has been subjected to bacterial contamination, indicating its exposure to harmful bacteria detrimental to health. Upon examination of the analysis results, it is evident that the water sample analyzed was contaminated with coliform bacteria during both periods, with concentrations of 24 and 23 CFU/100ml. Similarly, for intestinal enterococci, the selected water source exhibited contamination, with concentrations of 11 and 12 CFU/100ml during both respective periods, failing to meet Moroccan health standards. As for Escherichia coli, the selected water source was also contaminated during both periods, with concentrations of 28 and CFU/100ml, failing to meet the current health standards in Morocco[7, 12, 13].

3.11 Groundwater Hydrochemistry

The Piper diagram[21] (Figure 18) represents the chemical composition of the water sample plot, focusing on the predominant ions. It visually showcases the local measures of major cations and anions, delineated into two triangles with a central chart.

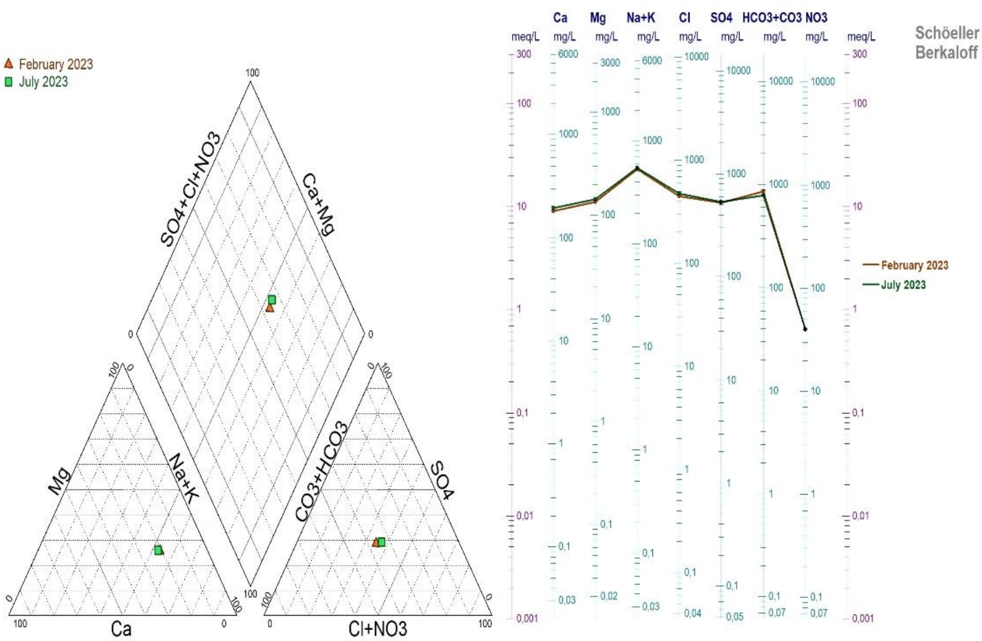

Fig. 12. Piper and Scholler's berkalof diagram of the studied water samples.

The main findings have been illustrated using the Schoeller diagram (Figure 19) to examine the lateral repartition of specific ions[22].
The diagram indicates a consistent chemistry of groundwater within the area. Hydrochemical classification based on the Piper and Schoeller-Berkaloff diagrams suggests that the samples are categorized as calcium and magnesium chloride and sulfate facies[23].
Both Schoeller-Berkaloff diagrams (Figures 18 and 19) corroborate the identification of calcium and magnesium chloride and sulfate facies by the samples[24].

4 Conclusion

In conclusion, this study evaluated the physicochemical and bacteriological quality of drinking water from a well in the Ghiis Nekkour aquifer, focusing on the Al Hoceima region of northern Morocco, and compared two distinct sampling periods. The majority of the analyzed physicochemical parameters met the standards outlined by the World Health Organization (WHO).
Chemical analyses revealed consistent concentrations of major elements across both periods, indicating stable water quality. However, bacteriological analyses showed non-compliance with Moroccan standards for water quality intended for human consumption, particularly concerning coliforms, intestinal enterococci, and Escherichia coli. This discrepancy suggests potential accidental contamination during sampling.
Urgent measures are required to address this pollution and ensure the safety of the water source for the region's inhabitants. Rationalizing irrigation practices and implementing proper water treatment procedures are crucial steps towards maintaining the quality of this vital water source.

In summary, while the water from this well within the Ghiis Nekkour aquifer shows moderate suitability for human consumption and irrigation purposes based on physicochemical parameters, addressing the bacterial contamination is imperative to safeguard public health and ensure the sustainability of the water supply.

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