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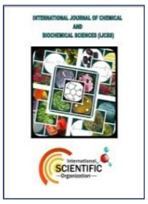

Evaluation of the Physicochemical Quality of the Groundwater Serving the Rural Population of the Kariat Ben Aouada Rural Commune, Morocco

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Abstract

Access to safe and healthy water for the residents of the Kariat Ben Aouda rural commune is not widespread, forcing many residents to meet their domestic water needs from sources whose composition, and therefore their safety, are unknown. Indeed, water from these sources can contain mineral and organic micropollutants that can present a threat to the health of those drinking it. Given the absence of data for the physicochemical composition of such water, we conducted a study to characterize the chemical quality of groundwater in the study area based on samples taken from the 11 wells during the 2022 dry season. The parameters measured included temperature, pH, conductivity, and sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride ($Cl^−$), sulfate ($SO_4^{2−}$), nitrate ($NO_3^−$), and nitrite ($NO_2^−$) content. The concentrations of the measured pollutants followed the following order: $Cl^− > SO_4^{2−} > NO_3^− > NO_2^−$ and $Na^+ > Ca^{2+} > Mg^{2+}$. An analysis of the measured parameters revealed that water from P4 and P9 had a slightly higher nitrate level than the value set by Moroccan Standard No. 03.7.001.2020, which relates to water for food use, with a non-compliance rate of 18.20%. The poor water quality in the area could have geological and/or anthropogenic origins. The chemical facies of the groundwater were analyzed according to a Piper diagram and a Schoeller–Berkaloff diagram, and two distinct facies types were observed, namely sodium–potassium chloride and calcium chloride facies.

Keywords: Underground water; anthropogenic; Moroccan Standards; specimens; consumers

Full-length article **Corresponding Author*, e-mail: akder.chibani@gmail.com

1. Introduction

Water is at the root of life on Earth and an essential requirement for all people and animals. The availability of good quality water is therefore crucial to maintaining the natural environment, human survival, and sustainable economic development [1]. Groundwater is the primary source of water in most of Africa, and its use has increased as the demand for water increased [2] due to strong population growth, improved standards of living, and industrial development. Indeed, the supply of water has increased considerably to meet the needs of industry and agriculture, which are activities that often negatively affect the quality of water resources. Water is therefore often exposed to chemical and/or bacteriological contamination [3]. In addition to being affected by pollutants caused by anthropogenic activities, groundwater is also affected by the geochemical nature of the ground it passes through [4].

Due to this vulnerability to pollution and overexploitation, threats to water resources must be identified, so mitigation measures can be considered [5] to ensure the sustainability of water resources, reduce the risks for their users, and safeguard ecosystems. Access to drinking water from the supply network is not widespread for the residents of the Kariat Ben Aouda commune, forcing them to obtain groundwater from wells. This study therefore set out to evaluate the physicochemical and microbiological quality of samples taken during June 2022 from such wells.

2. Materials and Methods

2 .1. Study zone

The study area is within the Sebou hydrological basin, being located on the northwest side. The rural commune of Kariat Ben Aouda is part of Kenitra province and located 92 km from the city of Kenitra. The climate is Mediterranean in nature with dry summers. The average annual temperature is 18.4 °C and precipitation averages 600.2 mm/year. In terms of basic infrastructure, 93.7% of households are connected to the electricity grid, but there is a very low rate of connection to the water supply network [6], meaning that many people traditionally use wells to satisfy their domestic water needs.

The selection of wells for the samples was based on their predominant use by the rural population of the study area. The samples taken for determining their physicochemical parameters were stored in sterile one-liter bottles that had been rinsed thoroughly with distilled water before being filled in the field with water from the relevant well. All samples were transported from the collection site to the laboratory in portable coolers at a temperature of 4°C. The temperature, pH, and electrical conductivity were measured in situ, while the chemical concentrations—namely calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}), chlorides (Cl^{-}), nitrite (NO_2^{-}), nitrate (NO_3^{-}) and sulfate ion (SO_4^{2-})—were determined in the laboratory using standardized techniques.

3. Results and discussion

The objective of our chemical analyses of the water samples was to evaluate their quality, characterize the chemical facies, and determine their suitability for domestic use. The results of these analyses are presented in Table 1 and discussed below.

3.1. Temperature

Temperature is crucial to a study of well water, because it provides an indication of the depth of the well. It also plays a role in determining chemical and microbiological transformations in the water [7]. The temperature is particularly influenced by climatic conditions and the season in which the sample was taken [8]. The temperature varied from 19.8 to 23.9°C for the samples, so all these values complied with Moroccan quality standards for drinking water.

3.2. pH

The pH plays a substantial role in determining the physicochemical balance of the water, with it being affected by the origin of the water and the composition of the terrain it passes through [9]. The pH values of the analyzed water samples ranged between 6.84 and 7.3, so they were close to pH neutral. The Moroccan standards for drinking water mandate a pH between 6.5 and 8.5, so all the analyzed water samples met the potability criteria for human consumption.

3.3. Conductivity

Conductivity was measured in order to estimate the concentration of salt dissolved in the water samples. Note that conductivity also depends on the water temperature, with it increasing as the temperature increases [10]. For all the samples, the conductivity values varied between 117 and 297.4 µs/cm, so none of the samples exceeded the maximum value of 2700 µs/cm set by the Moroccan standards.

3.4. Calcium

Calcium is the predominant element in drinking water, and its concentration in groundwater varies depending on the type of ground it passes through (i.e., limestone or gypsum) [11]. The presence of calcium in water is mainly attributable to two natural sources, namely carbonate and gypsum formations [12]. Calcium contributes to water hardness and can affect the organoleptic quality of water [13]. For the samples, the Ca^{2+} ion content varied from 22.91 to 87.32 mg/l, which is low. Calcium is the main component of water hardness, and its concentration varies mainly according to the nature of the terrain that the water passes through.

3.5. Magnesium

Water with an abundance of magnesium is beneficial to its consumers and offers significant benefits, particularly in terms of heart and blood vessel health. It influences aspects such as cardiac excitability, vascular tone, contractility, responsiveness, and growth [14]. Magnesium is abundantly present in most natural waters, and it contributes to water hardness and plays a crucial role in the production of certain hormones [15].

3.6. Sodium

Precipitation is the main source of sodium in groundwater through the leaching or infiltration of salt from saline soils or penetration by brackish water [11, 16]. The sodium content of the water samples (Fig. 6) was found to range between 21.4 mg/L and 127.5 mg/L.

3.7. Chlorides

Chlorides are most often found in the form of salts, such as sodium chloride (NaCl) and potassium chloride (KCl), and they widely present in nature, although a high concentration serves as an indicator of pollution [4]. Indeed, such presence in groundwater may indicate anthropogenic contamination due to it being present in urine and cleaning products [13]. Nevertheless, these concentrations in the water samples were well below the maximum value of 750 mg/l decreed by the Moroccan standards.

Table 1. Results of the physicochemical analyses of the groundwater samples (June 2022)

PUITS	T °C	pH	CE µS/cm	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^{+} mg/l	Cl^{-} mg/l	NO_2^{-} mg/l	NO_3^{-} mg/l	SO_4^{2-} mg/l
P1	22,7	6,84	189,7	33,51	3,85	21,436	185,2	0,08	7,4	12
P2	23,8	7,2	267,6	47,34	5,36	63,47	160	0,01	5,85	23
P3	21,7	7,3	131	85,46	4,96	34,74	290,2	0,01	23,13	17,8
P4	23,9	7	297,4	68,39	3,46	112,24	48,5	0,1	51,4	123
P5	22,6	6,98	208	37,62	6,85	25,37	57,4	0,04	12	72,5
P6	22,4	7,06	195	28,74	9,99	35,72	44,3	0,35	15,8	32
P7	22,1	7,2	182	57,83	13,7	127,46	63,7	0,05	19,5	27,5
P8	20,3	7,2	134	87,32	4,96	98,15	71	0,02	32,5	11,6
P9	22,5	7,15	227,3	22,91	13,5	74,63	140,8	0,02	52,2	87,5
P10	20,7	7,3	152	61,34	18,4	46,62	159	0,2	39,5	21
P11	19,8	7	117	74,95	3,01	57,53	34,7	0,05	26,4	36
NM 03.7.001		6,6 - 8,5	2700			200 (OMS)	750	0,5	50	400
Max	23,9	7,3	297,4	87,32	18,4	127,46	290,2	0,35	52,2	123
Min	19,8	6,84	117	22,91	3,01	21,44	34,7	0,01	5,85	11,6
Moy	22,05	7,11	191	55,04	8	63,39	114,07	0,08	25,97	42,17
Ecartype	1,33	0,147	57,22	22,67	5,14	35,96	79,99	0,1	16,3	36,22

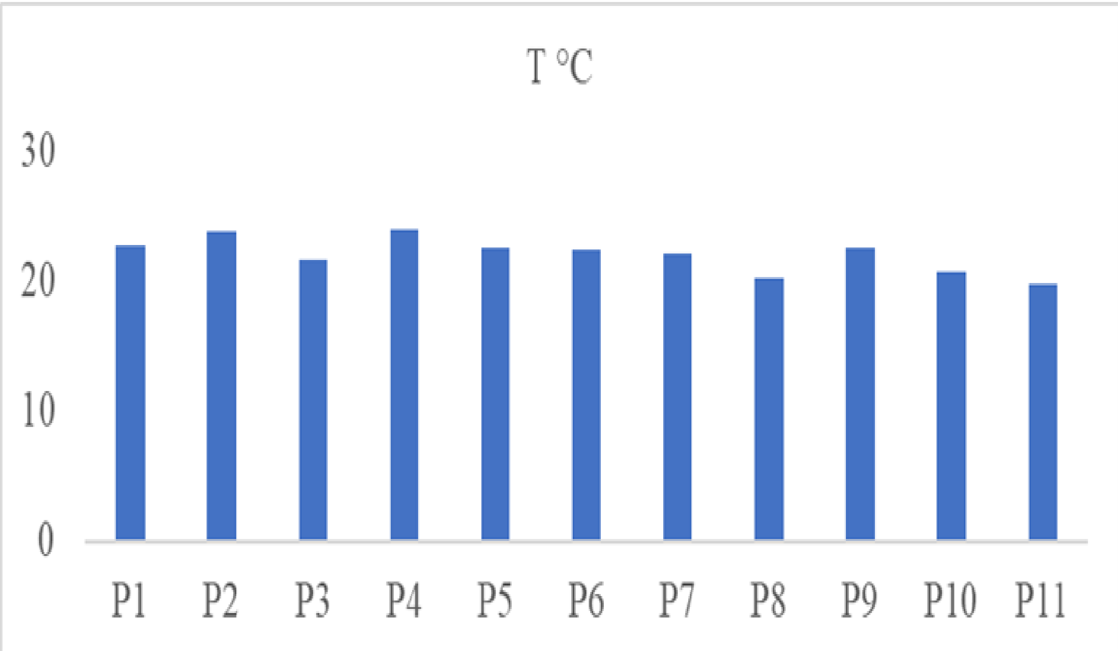

Figure 1. Variation in temperature

Figure 2: Variation in pH values

Figure 3: Variation in conductivity

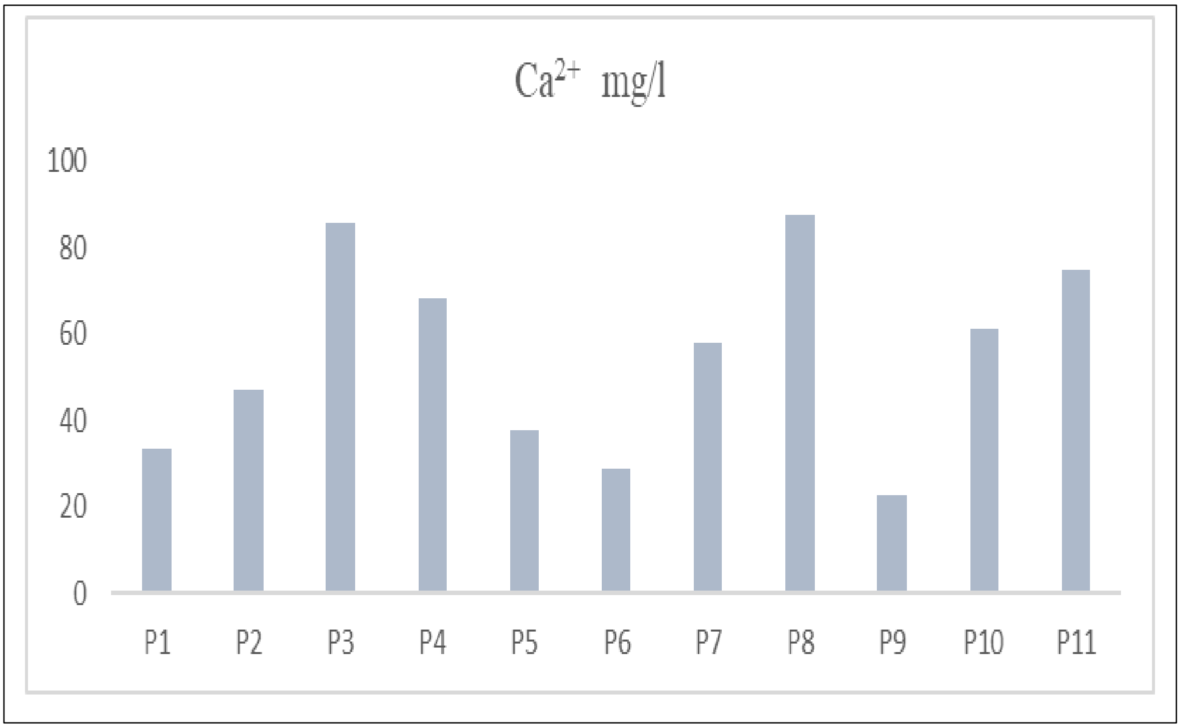

Figure 4: Variation in calcium content

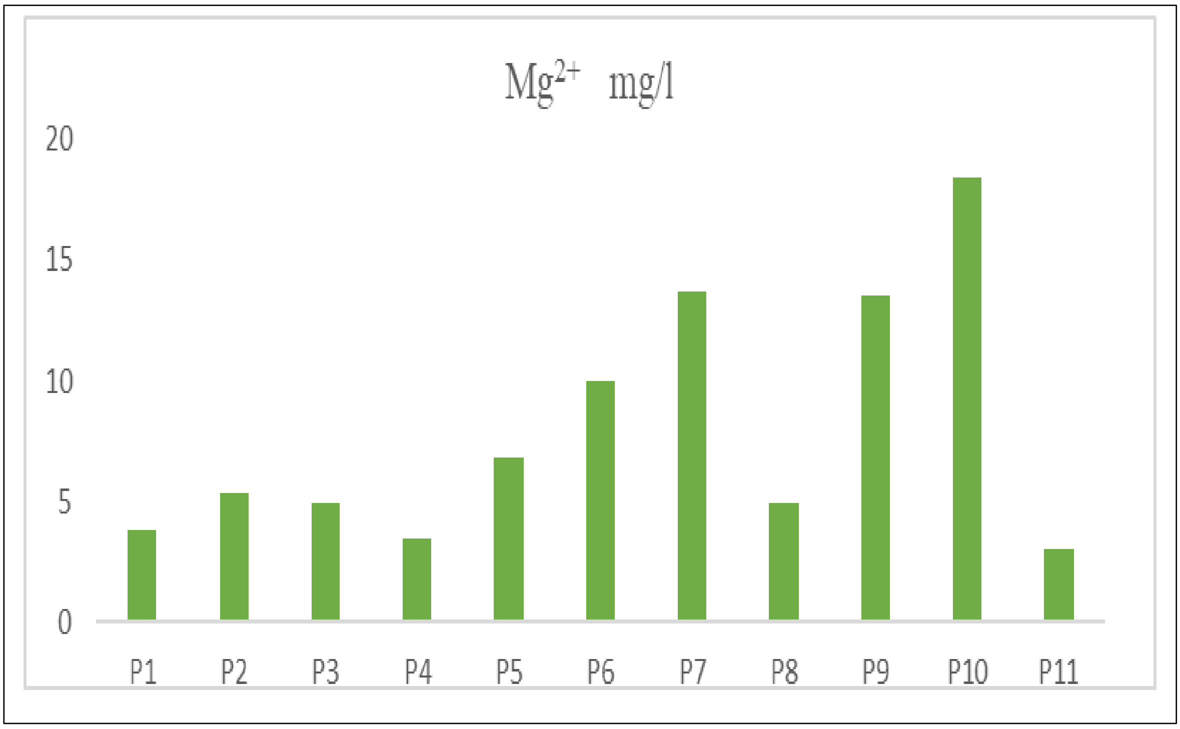

Figure 5: Variation in magnesium content

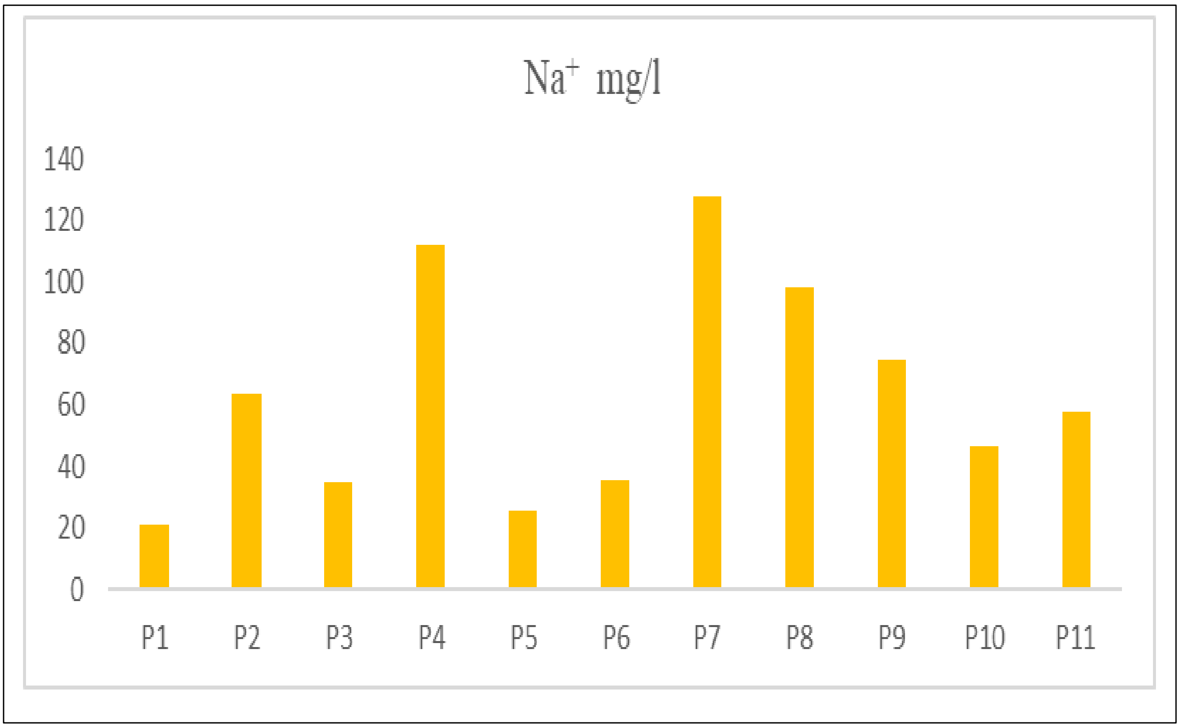

Figure 6: Variation in sodium content

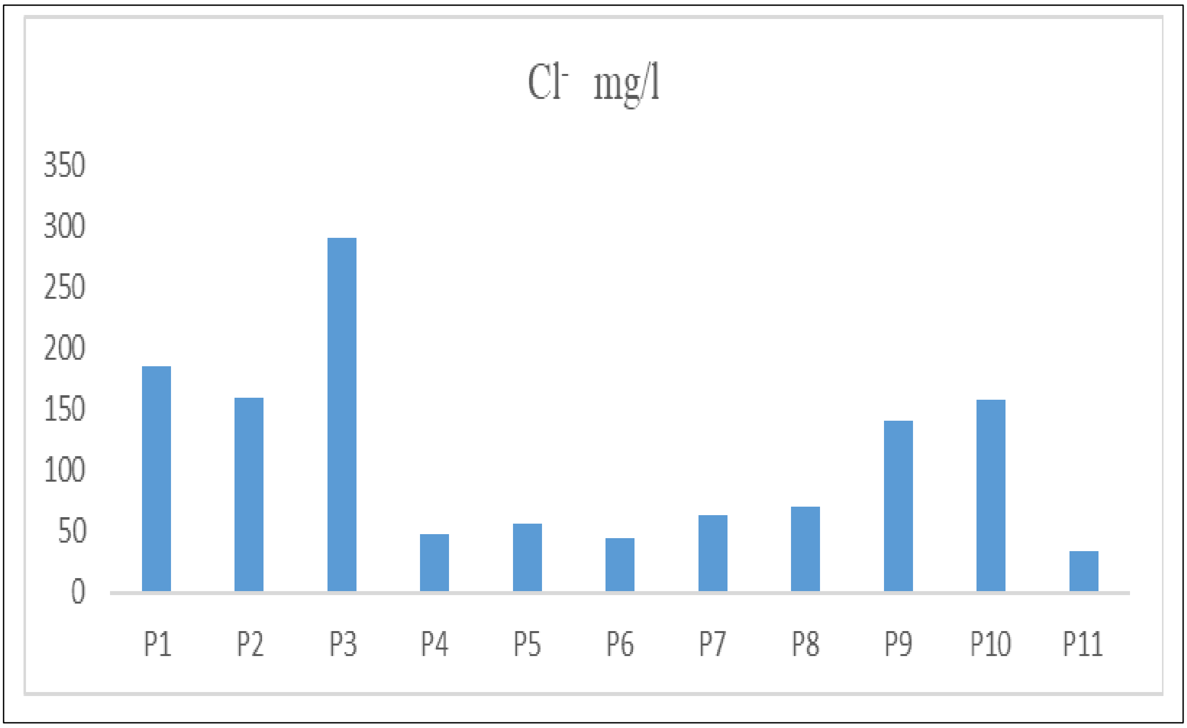

Figure 7: Variation in chloride content

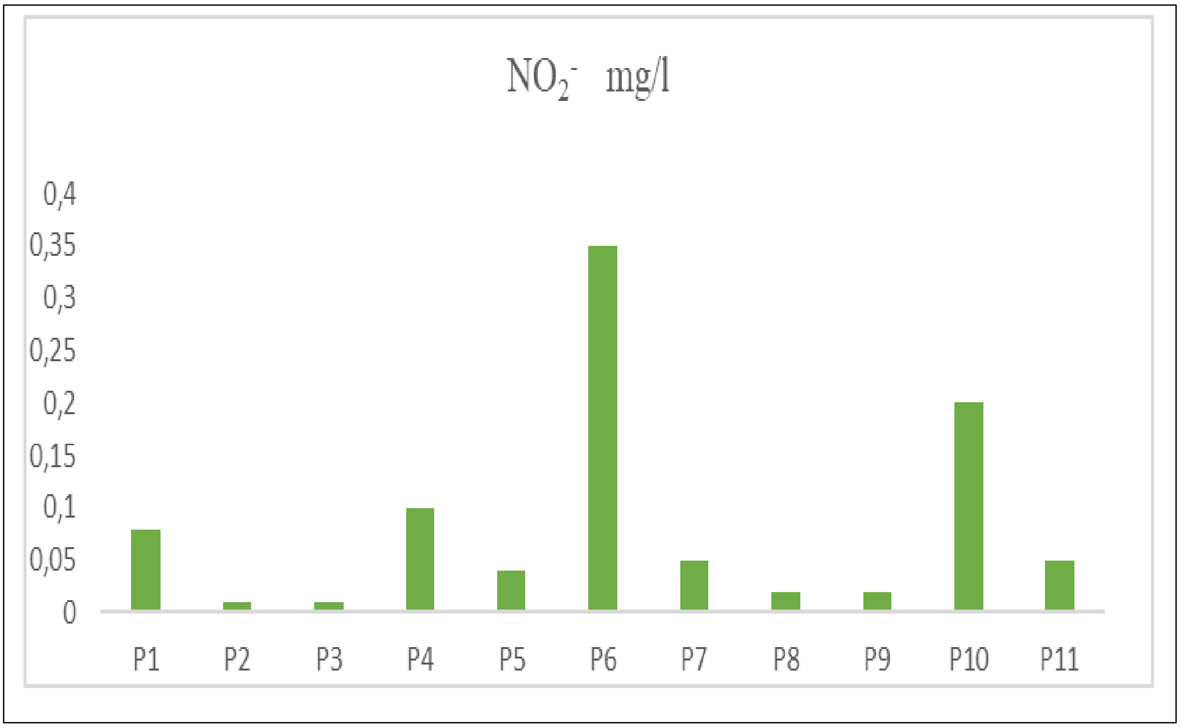

Figure 8: Variation in the nitrite content

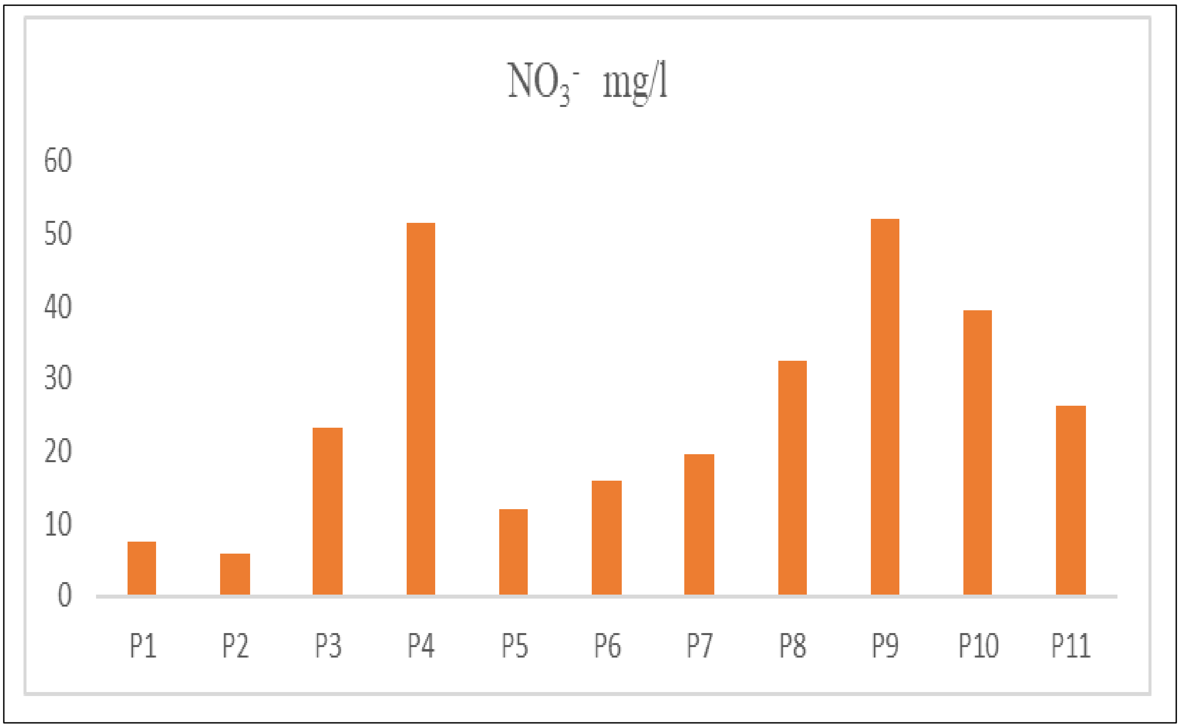

Figure 9: Variation in the nitrate content

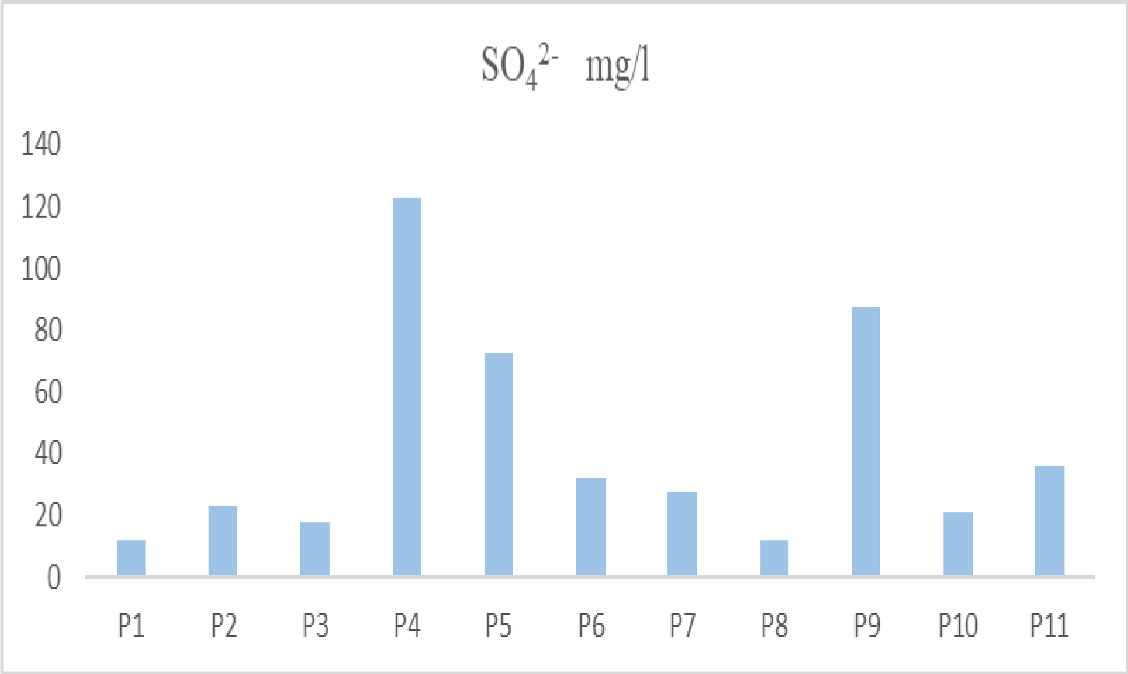

Figure 10: Variation in the sulfate content

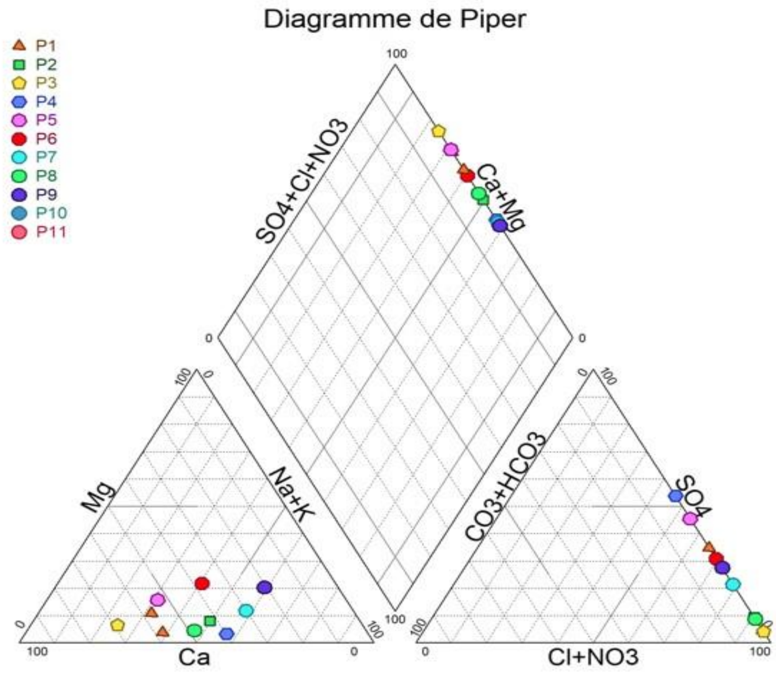

Figure 11: The analysis results represented in a Piper diagram

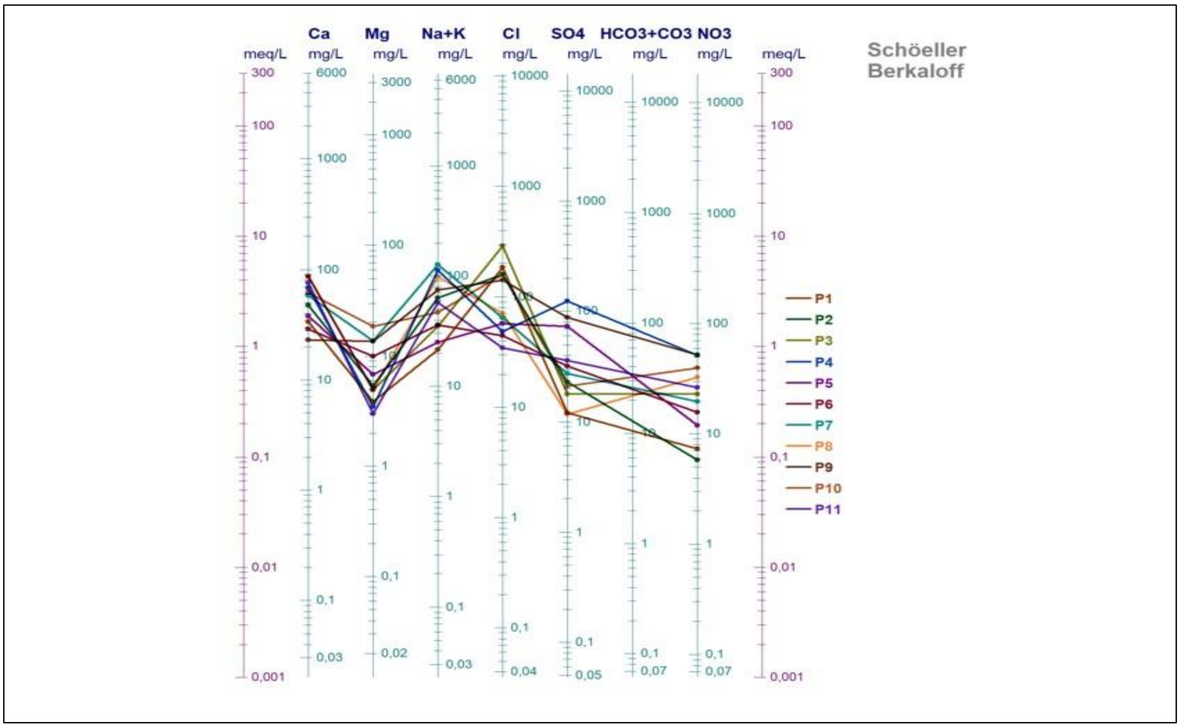

Figure 12. The analysis results represented in a Schoeller–Berkaloff diagram

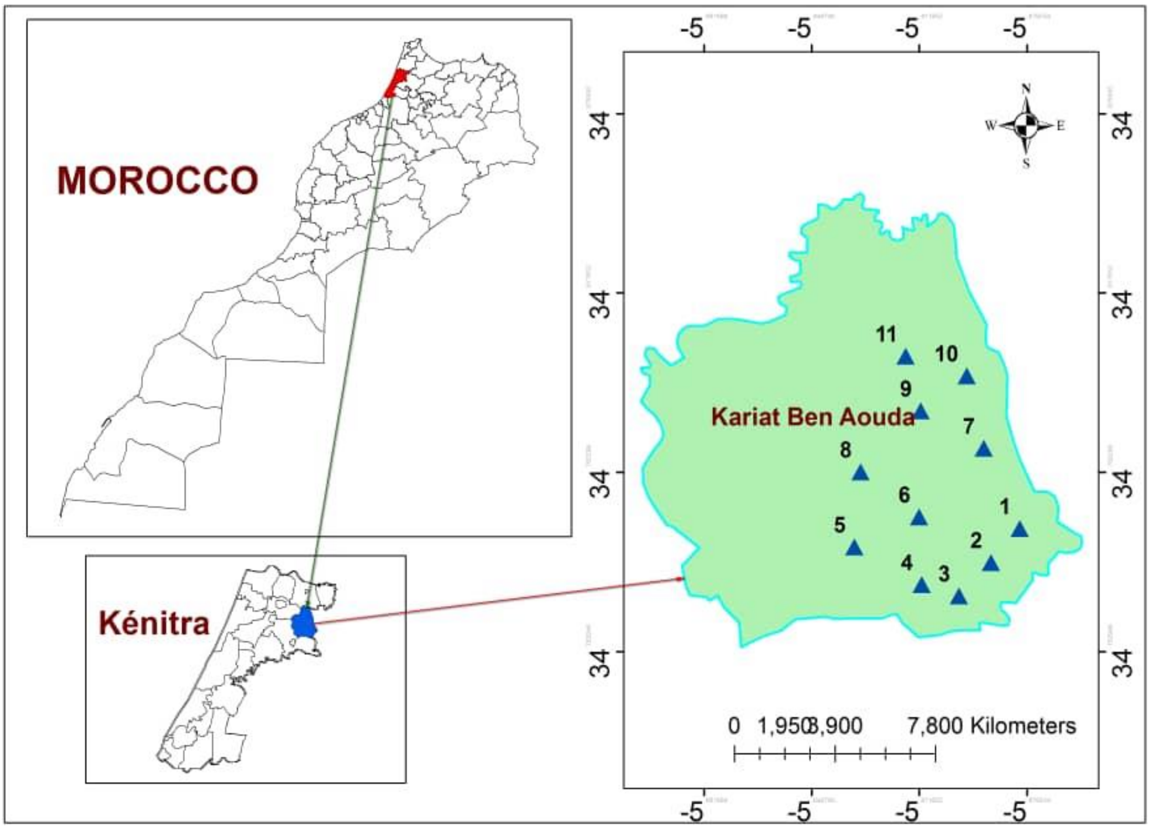

Figure 13. The location of the study area

3.8. Nitrites

Nitrites are anions that are naturally present in the environment, but due to their oxidizing power, they are toxic above a certain threshold [17] and can cause methemoglobinemia. High concentrations of nitrites can result from anaerobic sulphite-reducing bacteria and the bacterial oxidation of ammonia. Nevertheless, all the samples had concentrations lower than the Moroccan standard maximum value of 0.5 mg/l. The greatest value was 0.35 mg/l for well no. 6, while the lowest value was 0.02 mg/l for wells no. 2 and 3.

3.9. Nitrate

Nitrates in the environment mostly result from the use of fertilizers to support intensive agricultural activities [18, 20]. High concentrations of nitrates present a risk to potability of water, because its presence is frequently linked to reduced microbiological quality [15]. The nitrate content was found to be slightly too high at wells no. 4 and 9 with a non-compliance rate of 18.18%.

3.10. Sulfate

Sulfates are found in almost all natural waters in the environment. These sulfates manifest in the form of sulfur that is dissolved in water, with this mainly having geochemical and/or atmospheric origins. A high concentration of sulfate gives a bitter taste to water and makes its consumption unpleasant [20]. In addition, it can cause diarrhea of osmotic origin in adults, while in children it has been associated with disorders such as colitis and gastroenteritis [21]. The spatial distribution of the physicochemical analyses of groundwater through the Piper diagram reveals the dominance of certain chemical facies, namely calcium chloride and the sodium–potassium chloride facies. In the cations triangle, the water samples are grouped around the calcium pole, while in the anions triangle, we can see how most samples can be classified as lacking dominant anions combined with a dominance of chlorides.

According to the Schoeller–Berkaloff diagram, the sampled waters are characterized by the sodium–potassium chloride and calcium chloride facies. The Na^+ and Cl^- ions that exist in groundwater generally result from the dissolution of halite. On the other hand, the high concentration of Ca^{2+}, combined with the low concentration of Na^+, points to cationic exchanges between the waters of the Plio-Quaternary aquifer and the clay matrix that constitutes the wall of the aquifer [22].

3. Conclusion

It is essential to understand the mineralization of groundwater in order to manage and preserve this resource in a way that will meet the current and future water needs of the people who rely on it. The results of our analyses of water samples from the 11 studied wells allowed us to detect an overly high concentration of nitrate in the waters of two of the wells in relation to the maximum values that are mandated by Moroccan standards. This suggests the presence of nitrogen pollution, most likely because of organic waste, domestic discharges, and the excessive use of agricultural fertilizers. Nevertheless, these results should be built upon by further investigations, such as by studying the presence of heavy metals and pesticides. Overall, this study revealed the presence of two hydrochemical facies, namely sodium–potassium chloride and calcium chloride facies.

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