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Evaluation of physicochemical properties and potability of natural water sources in souk-ahras region, northeast Algeria

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Abstract

Algeria is one of the largest countries in Africa, is made up of a multitude of reliefs; climate and soil. The availability of water is a major national constraint today. On that point, The impetus for this work which consisted of carrying out a study to the point of view of the physico and chemicals quality of three natural water sources in the region of Souk-Ahras (Ben Daoud, Harireche and Beskoui) during the rainy season from [March-May 2021]. The results of the physico-chemical analyzes showed that the parameters sought meet the WHO standards except for a few variables whose averages exceeded the standards such as: nitrite 0.2 mg/l in Ben Daoud, 0.1 mg/l in Harireche and Beskoui. The study of the physicochemical parameters made it possible to reveal values close to each other in natural sources, the latter are considered to be potable in comparison to Algerian standards. The present work makes it possible to classify the depths of the water tables of these sources according to their conductivity; Beskoui with a rises content 1378 µS/cm and Harireche 1046 µS/cm, this denotes a strong mineralization of ions such as and $Ca2+$ 200.79 mg/l at Beskoui and $Mg2+$ 58.99 mg/l at Harireche, this makes them classified as slicks deep underground, unlike Ben Daoud which has between shallow water tables from their low conductivity 557 µS/cm and their low mineralization $Ca2+$ 175.14 mg/l and $Mg2+$ 30.24 mg/l. The quality assessment ranks the sources from good to bad in the following order: Harireche admires good quality then, Beskoui medium and finally Ben Daoud poor quality.

Key Words: **:** Souk-Ahras / (Ben Daoud, Harireche and Beskoui) / Natural waters/ physic-chemical quality / Algerian standards of drinking waters.

Évaluation des propriétés physico-chimiques et de la potabilité des sources d'eau naturelles dans la région de Souk-Ahras, nord-est de l'Algérie

Résumé

L'Algérie est l'un des plus grands pays d'Afrique, est constitué d'une multitude de reliefs ; climat et sol. La disponibilité de l'eau constitue une contrainte nationale majeure aujourd'hui. A cet effet, le présent travail consiste à effectuer une étude du point de vu de qualité physico-chimique de trois sources naturelles situées dans la région de Souk-Ahras (Ben Daoud, Harireche et Beskoui) durant la période pluvieuse [Mars-Mai 2021]. Les résultats des analyses physico-chimiques montrent que les paramètres recherchés répondent aux normes Algériennes sauf quelques variables dont les moyennes ont dépassé les normes tels que : nitrite 0.2 mg/l à Ben Daoud, 0.1 mg/l à Harireche et Beskoui. L'étude des paramètres physico-chimiques a permis de révéler des valeurs proches les unes des autres dans les trois sources naturelles, ces dernières sont considérées comme potable en comparaison aux normes de l'Organisation Mondiale de la Santé. Les résultats obtenus ont permis de prédire la profondeur des nappes souterraines de ces sources en fonction de leur conductivité C'était le plus profond, respectivement; Beskoui d'une teneur élève 1378 µS/cm et Harireche 1046 µS/cm, cela désigner une forte minéralisation des ions tels que et $Ca2+$ 200.79 mg/l à Beskoui et $Mg2+$ 58.99 mg/l à Harireche, contrairement au Ben Daoud qui dispose entre des nappes peu profondes a partir de leur basse conductivité 557 µS/cm et leur faible minéralisation $Ca2+$ 175.14 mg/l et $Mg2+$ 30.24 mg/l. L'étude a conclu en évaluant la qualité de ces sources et en les classant de bon à mauvais dans l'ordre suivant : Harireche admire de bon qualité puis, Beskoui à moyenne et enfin Ben Daoud de médiocre qualité.

Keywords: Souk-Ahras /(Ben Daoud, Harireche et Beskoui)/ eaux naturelles/qualité physico- chimique/ normes algériennes de potabilité.

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1. INTRODUCTION

Water is a vital resource for life and a cornerstone of sustainable socio-economic development (Belghiti et al., 2013). Despite covering 70% of the Earth's surface, only about 0.3% of the world's water is usable by humans: freshwater and lakes account for 0.009%, inland seas 0.008%, soil moisture 0.005%, the atmosphere 0.001%, rivers 0.0001%, groundwater 0.279%, while the vast majority is in oceans (97.2%) and glaciers and ice caps (2.15%) (Taiwo et al., 2020). Drinking water quality is crucial for predicting and preventing water-related diseases (Gasmi & Refice, 2020). Water is considered potable when it is free from chemical and biological contaminants that could pose short-term or long-term health risks (Lebbihi & Derki, 2018). Assessing surface water quality involves measuring physicochemical parameters and examining the presence or absence of aquatic organisms and microorganisms, which serve as indicators of water quality (Persaud, 2022; Zinsou et al., 2016).The quality of water on a global scale has witnessed a significant decline in recent years, primarily due to unregulated industrial emissions and the widespread application of chemical fertilizers in agriculture. These pollutants trigger chemical alterations in water, making it unsuitable for numerous purposes (Reggam et al., 2015).

2. MATÉRIELS ET MÉTHODES

Study area

The Souk Ahras region is located in the extreme north-east of Algeria [36°17'N.; 7°57'E.; altitude 1000 m , close to the Tunisian border, bordered to the North and west by the wilayas of El Tarf and Guelma, to the south-west by the Wilaya of Oum el Bouaghi, to the south-east by the wilaya ofTébessa and the east by Tunisia (Figure 1). Administratively, the Wilaya of Souk Ahras comprises twenty-six communes covering an area of 4,360 km2. Its relief is rugged, with an average altitude of 1,000 in the North and 650 m in the south (Tlidjane et al., 2019). It is a mountainous region representing an extension of the Tellian Atlas. It is characterized by a semi-humid climate with hot summers and cold, wet winters, and rainfall averaging 800 mm per year (Hamaidia & Berchi, 2018) Figure 01. The wilaya of Souk-Ahras is characterized by two main features: the mountainous North, part of the TellianAtlas. The South spart of the high plains (Djouamaa et al., 2022)

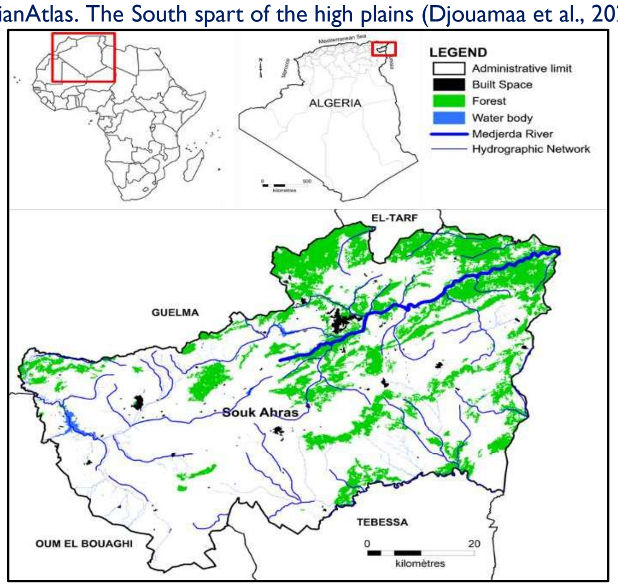

Figure1: The Geographicallocation ofthe SoukAhrasregion

Site selection

The Souk Ahras region is rich in natural water resources spread over a large number of its communes, which made it a challenge for us to choose the sites on which we would conduct our study, as the selection was not random, but rather we researched and discussed with the working group to choose well. In selecting the study sites represented in the natural water resources, we relied on numerous climatic, geological, and human factors of all kinds and all the activities surrounding the site, whether agricultural or industrial, commercial... etc. Three study sites were approved for sampling in three communes of the Souk Ahras wilaya, as follows:

- Study site 01: Ouled Driss commune (Ben Daoud spring water source);
- Study site 02: Hanancha commune (Harireche spring water source);
- Study site 03: Zarouria commune (Beskoui spring water source).

Sampling and samplepreparation

We have followed specific recommendations:

- Field measurements (temperature, pH, electrical conductivity, etc.) should never be taken from a sample that will be sent to the laboratory. These measurements should be taken directly in the watercourse or from a sample that will be discarded once the operation is complete.
- Samples are taken in sterilized 250 ml glass bottles if they are to be analyzed bacteriologically, and well-cleaned 1.5 liter PET (polyethylene) bottles are used for physicochemical analysis.
- The date and time of sampling, water and air temperature, pH, and electrical conductivity are recorded on site.
- The spring flows through a large pipe that fills the flasks and bottles directly.
- The bottles are labeled to indicate the origin of the sample.
- It's of utmost importance to conduct the analysis promptly after sampling. This is why we transport the samples in coolers at a temperature of between 4 and 6°C. Any delay or variation in temperature can potentially alter the composition of the sample (Sari, 2014) (Figure 2).

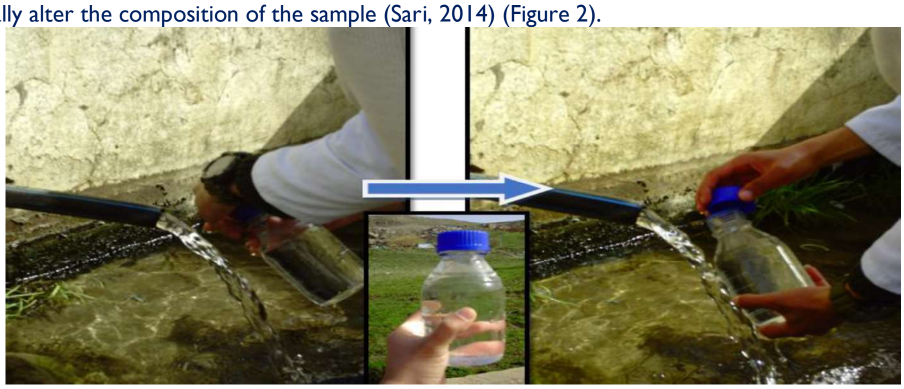

Figure2: Sampling Method**.**

The present study was conducted from March 2021 to May 2021, involving regular visits to the study locations to collect samples from the three sites. Physical analyses were performed on-site, and the samples were transported to the laboratory for chemical analyses. This approach allowed us to conduct comprehensive physico-chemical analyses of the water sources, with seven samples collected at each site to measure various parameters.

Samples were taken during both the rainy period (March, April, and May) and the dry period (June and July) of 2021, ensuring a representative assessment of the water quality across different seasons. The results are presented in the form of graphs and tables in this chapter. In situ measurements of organoleptic parameters, electrical conductivity, pH, dissolved oxygen (O2), and temperature were performed using a multi-parameter device (Consort - c 5010). All other analyses, including nitrate, nitrite, phosphorus, ammoniacal nitrogen, ammonium, calcium, magnesium, turbidity, and total hardness, were conducted in the Algerian Water Distribution Society of Souk Ahras region laboratory.

Data analysis

We used Principal Component Analysis to determine which factors (group of parameters) account for the numerical variation of the clusters (Güller et al., 2002) Also, the definition of PCs helps to extract related variables, giving more information than single parameters and to infer the processes that control spring water quality.

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3. RÉSULTATS ET DISCUSSION

The results of the physico-chemical parameters obtained are shown in
Table 1: The results of the physico-chemical parameters obtained

Physico-chemical parameter	The spring water sources			Algerian standards	WHO standards
	Ben Daoud	Harireche	Beskoui		
TC°	13.72	18.64	17.76	25	-
	11.06	16.93	14.66		
	14	16	14.9		
	15	17.76	16		
pH	7.61	7.04	7.49	6.5-9.5	6.5-9
	7.40	6.76	7.21		
	7.31	6.75	7.23		
	6.87	6.76	7.26		
Dissolved oxygen O_2	12.40	11.33	11.2	>10	5
	5	6.93	7.51		
	7.28	6	7.90		
	8.16	7.63	10.6		
Conductivity CE	448	1002	1223	2800 µS/cm	2500µS/cm
	572	941	1133		
	592	986	1624		
	619	1255	1532		
Turbidity (NTU)	0.45	0.48	0.45	5	5
	0.45	0.29	0.45		
	0.49	0.35	0.90		
	0.42	0.42	0.63		
Hardness	23.5	34.5	35.5	100	100
	25	32.8	35.2		
	29	33.4	40		
	32	33	37		
Nitrates (NO^3)	16	3.06	15.1	50	50-100
	13.8	2.98	13.3		
	11.5	2.53	7.67		
	12.1	1.93	11.3		
Phosphore (PO_4^{3-})	0.06	0.04	0.06	0.50	-
	0.12	0.08	0.05		
	0.41	0.17	0.17		
	0.16	0.18	0.16		
Ammoniacal (NH^{4+})	0.005	0.04	0.04	0.5	0
	0.013	0.06	0.06		
	0.016	0.05	0.001		
	0.011	0.06	0.08		
Nitrites (NO^{2-})	0.26	0.13	0.16	0.2	-
	0.38	0.15	0.18		
	0.18	0.09	0.13		
	0.02	0.05	0.09		

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Calcium (Ca^{2+})	148.29	180.36	200.4	200	100
	155.04	169.13	193.98		
	168.33	176.35	208.41		
	192.38	174.74	200.4		
Magnésium Mg^{2+}	22.4	53.76	47.04	150	50
	26.88	52.41	49.28		
	35.84	65.16	62.72		
	35.84	64.66	75		
Colour	Transparent	Transparent	Transparent	-	-
	Transparent	Transparent	Transparent		
	Transparent	Transparent	Transparent		
	Transparent	Transparent	Transparent		
Odour	Odorless	Odorless	Odorless	-	-
	Odorless	Odorless	Odorless		
	Odorless	Odorless	Odorless		
	Odorless	Odorless	Odorless		

Principal Component Analysis (PCA) was performed on a data matrix comprising 12 rows representing the surveyed study sites and 12 columns representing the physico-chemical variables measured or analysed. Projecting the variables onto the factorial planes (F1XF2) (1x3) (2x3) explained 80.14% of the total variance (Figure 4).
Axis 1 explained 45.02% of the total variance and grouped together temperature, conductivity, hardness, NH4+, Mg2+, and Ca2+ on the positive loading and NO3-and NO2- on the opposing, given the existing correlations between these different elements.
The second axis, with 21% of the variability captured, mainly contrasted pH and turbidity, which contribute negatively to its expression. On the third axis, which accounted for 14.12% of the variability captured, dissolved oxygen (O2) makes a negative contribution. In contrast, PO43—made a solid positive contribution to this axis (Figure 4)

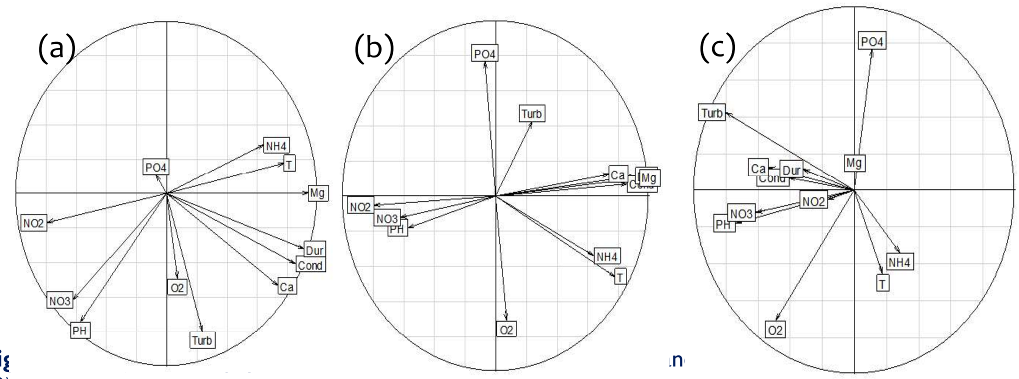

Fig .n X
F3).

Factorial Analysis of the Projection of Samples

The factorial analysis of the projection of the samples from the three sites onto the F1, F2, and F3 factorial axes reveals a subdivision of the measurement points into five distinct groups (Figure 5):
1. **Group 1**: This group includes variables related to temperature, electrical conductivity, hardness, and ammonium (NH4+). These points, characterized by high mineralization, are due to elevated calcium (Ca2+) and magnesium (Mg2+) levels. They are positioned on the positive side of the F1 axis.

2. **Group 2**: This group encompasses variables associated with nitrites (NO_2^-) and nitrates (NO_3^-), which exhibit a strong negative correlation on the F1 axis. Groups 1 and 2 account for 45.02% of the total variance.
3. **Group 3**: This group is linked to the pH variable and turbidity, presenting a negative contribution on the F2 axis and 21% participation in the total variance.
4. **Group 4**: This group includes the dissolved oxygen variable, which strongly contributes negatively to the F3 axis.
5. **Group 5**: This group is associated with phosphate (PO_4^{3-}), which exhibits a strong positive correlation on the F3 axis. Combined, Groups 4 and 5 represent 14.12% of the total variance.

These groupings provide a comprehensive understanding of the relationships among the physico-chemical parameters of the water samples (Figure 5).

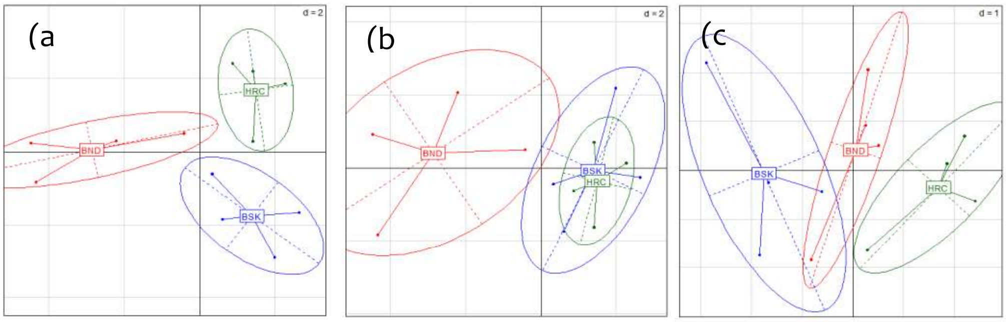

Figure 5: Projection of individuals in the factorial plane *(a): (F1 X F2), (b): (F1 X F3), (c): (F2 X F3).* of spring water in the Souk Ahras region.

Analysis of Temperature and pH Variations in Groundwater

It is recognized that temperature variations diminish beyond a depth of 3 meters and that the temperature of groundwater remains constant throughout the year (Belhadj & Yahia-Dahmania, 2017). The average natural water temperature in the springs at the three studied sites is 15.54°C, which is moderate compared to national and international standards, which are generally below 25°C (ADE, 2020). During the study period in March and April, we observed temperature variations across the three sites. The highest average temperature was recorded at Harireche at 17.33°C, followed by Beskoui at 15.83°C, and the lowest at Ben Daoud at 13.44°C due to its location in a mountainous area. The average temperature at Ben Daoud is slightly lower than in previous surveys conducted in February, March, and April 2018, which recorded an average of 15.9°C (Kouadria, 2018). At Beskoui, the average temperature is close to the values observed in February, March, and April 2017, estimated at 16.3°C (Hasnaoui & Sid, 2017).The pH of water provides critical information about its acidity and alkalinity (Nouayti et al., 2015). The average pH of groundwater analyzed at the three sites is 7.14, within the WHO recommended range of 6.5 to 9.5 (ADE, 2020). However, the pH values are near the lower limit of this range. The pH levels are slightly basic but tend to become slightly acidic during the rainy season.At Harireche, the slight acidity recorded, with an average pH of 6.82, is attributed to the surrounding forest and dense vegetation, possibly due to biogeochemical or anthropogenic processes. This process is driven by soil CO_2 generated through plant root respiration and the decomposition of organic matter (Kortatsi et al., 2008; Matini et al., 2009; Soro et al., 2019). A low pH may also indicate the presence of contaminants or vigorous mineralizing activity by bacteria near the water table (Matini et al., 2009 in Yaka, 2020). Conversely, the Beskoui and Ain Ben Daoud springs exhibit a pH of 7.29, close to neutrality. The results of the previous study in 2018 for the Ben Daoud site 7.31 are very close to the values of our study

(Kouadria, 2018). The PH of the Beskoui site for the 2017 study was estimated at 7.22 which is also close to our results 7.29 (Hasnaoui and Sid, 2017).

Analysis of Dissolved Oxygen, Electrical Conductivity, Turbidity, and Total Hardness

The average dissolved oxygen levels in the Harireche site were 7.89 mg/L, while at Ben Daoud, they were 8.21 mg/L. This increased dissolved oxygen at Ben Daoud is attributed to its higher elevation, which results in lower temperatures that enhance oxygen dissolution in water. In contrast, Harireche, located in a warmer area, exhibits lower dissolved oxygen levels. Historical data from 2018 also show higher dissolved oxygen levels at Ben Daoud, with an average of 9.6 mg/L (Kouadria, 2018).

The variation in dissolved oxygen is primarily due to temperature differences, as colder water contains more dissolved oxygen than warmer water (Hébert & Légaré, 2000).

Electrical conductivity measurements are valuable for assessing the quantity of dissolved salts in water (Rodier et al. 2014; El-Fadeli, 2015). The average electrical conductivity for the three sites is 995 µS/cm, well within the limits set by the WHO (2800 µS/cm) and national standards (2500 µS/cm) (ADE, 2020). The measured values vary among the sites: Beskoui has the highest at 1378 µS/cm, Harireche at 1046 µS/cm, and Ben Daoud at 555.75 µS/cm. The higher conductivity at Beskoui is due to increased temperatures in the area, which elevate conductivity levels (Nechad, 2014). Previous studies also indicate a noticeable increase in conductivity at Ben Daoud from 899 µS/cm in 2018 (Kouadria, 2018) to current levels, possibly due to changes in measurement temperatures.

High water conductivity may result from the geological composition of the aquifer (presence of sandstone and limestone) or exogenous pollution (El Kacemi, 2012). The studied spring waters exhibit mineralization levels ranging from moderate to significant (Rodier et al., 2009).

Turbidity provides visual information about water quality (Perroux & Kartologia, 2006; Mouissi & Alayat, 2016). In our study, Beskoui showed a slight increase in turbidity with an average of 0.60 NTU, Ben Daoud 0.45 NTU, and Harireche 0.38 NTU. Turbidity is influenced by mineral and organic particles suspended in the water, often due to runoff, bank erosion, and effluent discharges (Robert, 2014). The high turbidity at Ben Daoud is caused by waste and pollutants from nearby cattle farms, which seep into the water during rainfall. The 2018 study reported an average turbidity of 3.18 NTU for Ben Daoud (Kouadria, 2018). Beskoui, being in an urban area, also exhibits higher turbidity due to human activity, whereas Harireche, with dense vegetation and minimal human interference, has the lowest turbidity.

The total hardness of the water varies across the sites, with an increase observed during the rainy period. The Harireche site has an average hardness of 33.42 mg/L, Beskoui 36.92 mg/L, and Ain Ben Daoud 27.37 mg/L. This variation is linked to the lithological nature of the aquifer, particularly its magnesium and calcium content (Derwich et al., 2010). Comparing current results with previous studies at Beskoui, there is a slight increase in total hardness from 51 NTU (Hasnaoui & Sid, 2017).

Analysis of Nitrogen Compounds, Phosphates, Calcium, and Magnesium in Groundwater

Nitrates (NO_3^-) and nitrites (NO_2^-) are naturally occurring ions in the environment, resulting from the nitrification of ammonium ions (NH_4^+). Due to their toxicity and potential harm to living organisms, these compounds serve as indicators of water pollution. An increase in nitrogen compounds reflects pollution linked to human activities, particularly those occurring on the surface (Ratel, 2003).

The recorded nitrate, nitrite, and ammonium levels at the three sites show a significant increase at Ben Daoud and Beskoui compared to Harireche. However, they remain within national and international standards. The average nitrate values at Ben Daoud are 15.6 mg/L and at Beskoui 11.84 mg/L, significantly higher than the 2.62 mg/L recorded at Harireche. This disparity is due to human activities, such as livestock contamination near Ben Daoud and a population near Beskoui.

Similarly, the lowest ammonium values were recorded at Harireche, attributed to the absence of human activities that could generate pollutants affecting water quality. However, there was a notable increase in nitrite values, particularly at Ben Daoud (0.2 mg/L) and Beskoui (0.14 mg/L), compared to Harireche (0.1 mg/L). These levels exceed global standards (0 mg/L) for the three sites and Algerian standards (0.2 mg/L) at Ben Daoud. Compared to the study by Kouadria (2018) at Ben Daoud, which recorded an average nitrite value of 0.004 mg/L, the current values show a significant increase.

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The presence of agricultural activities near Ben Daoud and Beskoui and the use of chemical fertilizers contribute significantly to the infiltration of these pollutants into the soil, especially during rainfall, thus polluting the groundwater. Waste and pollutants from nearby Ben Daoud further exacerbate groundwater contamination, leading to high values of pollution indicators such as nitrites and nitrates.

Phosphate levels (PO43-) in the natural waters studied show an increase at the Ben Daoud site (0.18 mg/L) and Beskoui (0.14 mg/L) compared to the Harireche site (0.05 mg/L). This increase is due to agricultural activities and the use of fertilizers, as well as cleaning products like detergents near urban areas such as Beskoui. These phosphate levels are acceptable and comply with national and international standards of 0.50 mg/L (ADE, 2020). The results from Kouadria (2018) at Ben Daoud, which showed an average of 0.14 mg/L, are consistent with our study.

The calcium (Ca2+) levels at the three sites show an increase, with the highest values at Beskoui (208.41 mg/L), followed by Ben Daoud (193.98 mg/L) and Harireche (180.36 mg/L). Compared to Hasnaoui and Sid's (2017) results at Beskoui, which showed an average of 159.5 mg/L, our study indicates higher levels, likely due to the infiltration of rainwater through calcium-containing minerals such as plagioclases (Moussa, 2018).

The average magnesium (Mg2+) levels indicate an elevation at Harireche (58.99 mg/L) and Beskoui (58.52 mg/L), compared to Ben Daoud (30.24 mg/L). Previous studies by Hasnaoui and Sid (2017) at Beskoui showed a lower rate of 27.07 mg/L. The high magnesium levels may be due to carbonic acid attacking magnesian rocks, bringing magnesium into solution as carbonates and bicarbonates (Nouayti, 2015).

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