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Groundwater Quality Assessment of the Northern Region of the Middle Sébaou in Algeria, Using Water Quality Index and Multivariate Analysis

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ABSTRACT

In Algeria, groundwater frequently serves as a main source of drinking water supply. Given the country's geographical characteristics and water resource availability, many municipalities rely on groundwater to meet their drinking water needs.In this study, the quality of groundwater for drinking purposes in the northern region of the Middle Sébaou was assessed by obtaining hydrochemical data from ten groundwater samples in 2019. The study aimed to analyze and evaluate the hydrochemical composition of the groundwater using multivariate analysis and the water quality index (WQI) to determine its suitability for human consumption. Statistics showed that most of the groundwater analysis parameters are within acceptable limits except calcium (Ca^{2+}) and bicarbonates (HCO_3^-) which exceed the potability standards set by the guidelines of the World Health Organization (WHO) for drinking water. Piper diagram demonstrates the existence of two hydrochemical facies: bicarbonate calcium and magnesium, and chloride as well as sulfate calcium and magnesium. According to the WQI values obtained in this study, ranging from 53.32 to 71.18, all of the groundwater samples exhibit good water quality based on the classification of the WQI method. On the basis of these results, the groundwater of the northern region of the Middle Sébaou is suitable for drinking purposes.

Keywords: groundwater quality, hydrochemistry, water quality index, Northern of the Middle Sébaou, multivariate analysis.

INTRODUCTION

The available water source in many arid and semiarid areas is groundwater (Kazakis et al., 2017), used not only for domestic purposes, but also in agriculture and industry (Ben Moussa et al., 2021; Kalaivanan et al., 2018). Thus, the protection of this resource is important for human health and the sustainable development of a country's economy (Ravindra et al., 2022). Hydrochemical processes in the saturated and the unsaturated zones, as well as human activities, mainly influence the quality of groundwater (Liu et al., 2003; Sunitha & Reddy, 2022). When groundwater quality is suitable for consumption by humans, it can also be effectively utilized for irrigation and industrial purposes (Ravindra et al., 2022). The hydrochemistry elements of groundwater are of utmost importance for the management of this vital resource, particularly for drinking water purposes and, it can also help in identifying the mineralization sources and contamination factors affecting the groundwater quality (Bahir et al., 2020).

In numerous studies conducted worldwide, the Water Quality Index (WQI) is employed to evaluate the quality of groundwater intended for drinking purposes (Adimalla & Qian, 2019; Alqarawy et al., 2022; Jha et al., 2020; Masoud et al., 2022; Ram et al., 2021). The data collected for groundwater characterization can be conveniently converted into mathematical values, simplifying

the process of classification and subsequent interpretation (Bahir et al., 2020).The qualitative values resulting from these studies are highly beneficial in the context of developing groundwater management technology by the authorities (Selmane et al., 2023).

In the northern region of the Middle Sébaou, where groundwater serves as the primary source of drinking water, studying the potability of these waters becomes crucial. However, this study aimed to evaluate groundwater in the specified zone using multivariate statistical technique and the Water Quality Index (WQI).

MATERIAL AND METHODS

Study area

Situated within the northern region of Algeria, the study area is located in the Oued Sebaou basin, spanning between 36°30′N and 37°00′N latitude and 03°30′E and 04°30′E longitude. This region finds its place within the coastal Algiers watershed (Zerouali et al., 2021). The Oued Sébaou Watershed is delimited by various geographic features. To the north, it is bounded by the Mediterranean coastal range, while to the south, it is bordered by the Djurdjura mountain range (located in the Bouira province). The eastern boundary is formed by the Akfadou and Béni-Ghobri massifs (in the Bejaia province), and to the west, it is defined by the Sidi Ali Bounab and Djebel Bouberak massifs (in the Boumerdes province). The watershed comprises three main sub-basins: the Upper Sébaou, the Middle Sébaou, and the Lower Sébaou (Zerouali et al., 2015).

Within the Oued Sébaou Watershed, the Middle Sébaou sub-basin forms an initial bend or curve when it meets the Upper Sébaou at the Belloua gorge. At this point, the river changes its course and flows in a northeast to southwest direction. This

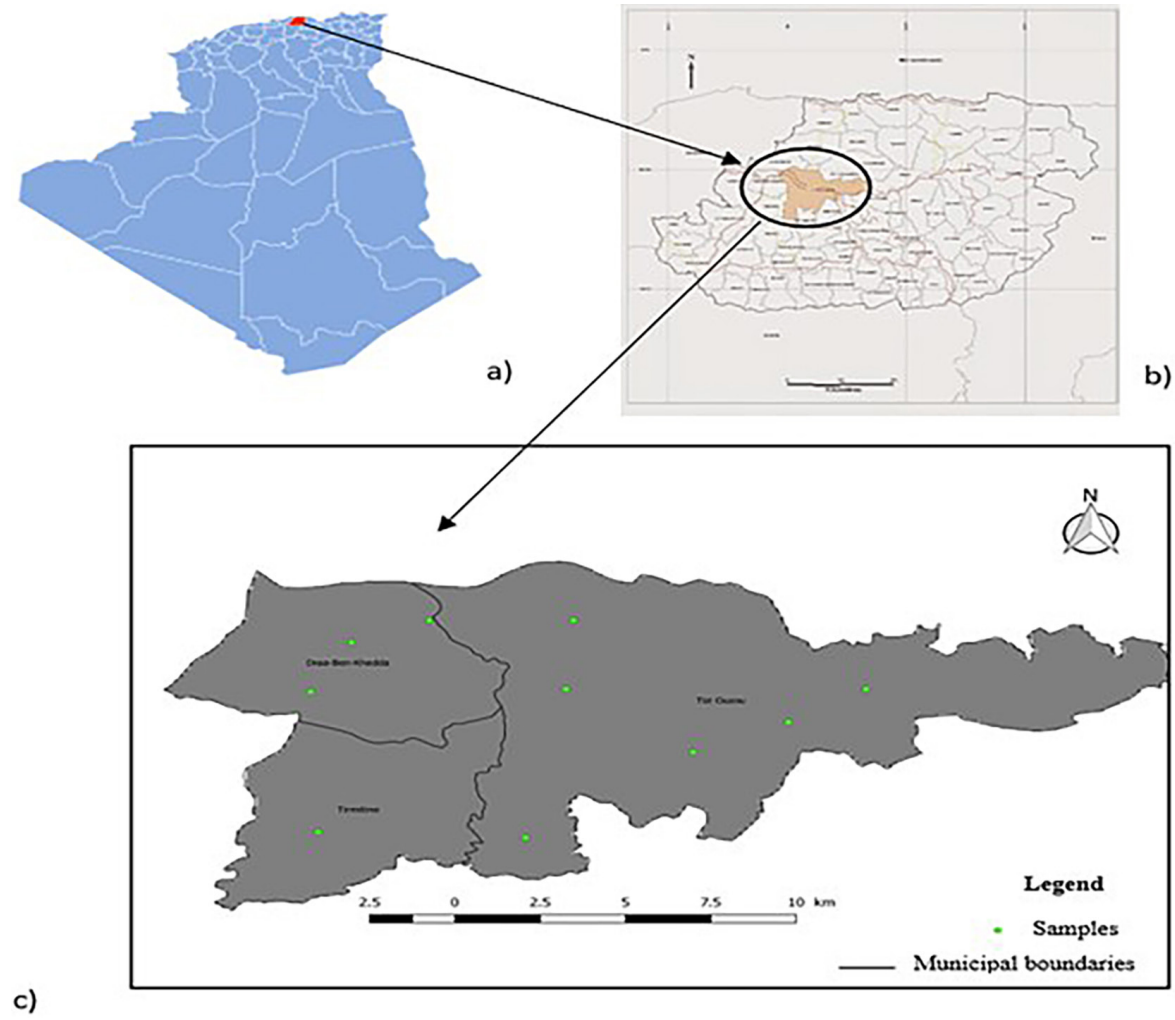

Fig. 1. (a) Algeria, (b) Department of Tizi-Ouzou, (c) sampling point location in the north of the Middle Sébaou

study focused on the municipalities of: Tizi-Ouzou, Draa Ben Khedda, and Tirmitine, collectively representing the northern region of the Middle Sébaou (Fig. 1), which is spread over 168.68 km^2.

Sampling point

For assessing the quality of groundwater for drinking, 10 sampled data have been collected in various location of the northern region of the Middel Sébaou during the period of March in 2019. All the analyses were conducted in the laboratory of the Algerian water company of Tizi-Ouzou (ADE Tizi-Ouzou). A total of 11 parameters have been analyzed, which include: pH, EC, TH, Mg^{2+}, Ca^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, NO_3^{-} and SO_4^{2-}.

Calculation of the water quality index

The calculation of the water quality index is based on the perspective of assessing the appropriateness of groundwater for human consumption. The water quality index (WQI) is widely recognized as one of the most effective tools for evaluating and assessing water quality (Sahu & Sikdar, 2008).

The primary objective of the WQI is to simplify and transform complex and extensive hydrochemical data into a more easily understandable format. The calculation of the WQI is based on predetermined standard values for each hydrochemical parameter, which are suggested by various organizations such as the World Health Organization (WHO), Bureau of Indian Standards (BIS), Indian Council of Medical Research (ICMR), Food and Agriculture Organization (FAO), among others (Sutradhar & Mondal, 2021). By utilizing these standard values, the WQI provides a comparative assessment of water quality and helps in identifying the potential issues or concerns related to water suitability for various purposes, including human consumption (Sutradhar & Mondal, 2021).

This methodology involves the process of assigning weights to the measured parameters in the initial step, considering their relative importance in determining the overall water quality for drinking purposes (Table 1) (Sahu & Sikdar, 2008). The assigned weights typically range between 1 and 5. The higher values indicate their greater importance in water quality assessments, such as: EC, $NO_3^{-}$and SO_4^{2-} (Bouderbala, 2017).

Then, a relative weight RWi of the water quality parameters is calculated from formula 1:

$$RWi = \frac{wi}{\sum_i^n wi} \quad (1)$$

where: *wi* – the weight of each parameter and n represents the number of parameters being considered.

Table 1 provides the calculated relative weight (RWi) values for each parameter. To determine the quality rating scale in the third step for each parameter, the concentration of the parameter in each water sample is divided by its respective standards, as defined by the World Health Organization (WHO) in 2011 (WHO.2011). The resulting value is then multiplied by 100.

$$qi = \left(\frac{Ci}{si}\right) \times 100 \quad (2)$$

where: *qi* – refers the quality rating scale, *Ci* – represents the concentration of each hydro chemical parameter in each sample, in mg/l, *si* – the WHO standard for the same parameter, in mg/l in accordance with the

Table 1. Drinking water weight (wi) and relative weight (RWi) of hydrochemical parameters

Parameter	WHO (2011)	Weight (wi)	Relative weight (RWi)
pH	8.5	4	0.1176
EC (µS/cm)	1500	5	0.1471
TH (mg/l)	500	2	0.0588
Ca^{2+} (mg/l)	75	2	0.0588
Mg^{2+} (mg/l)	100	2	0.0588
Na^{+} (mg/l)	200	2	0.0588
K^{+} (mg/l)	12	2	0.0588
HCO_3^{-} (mg/l)	300	2	0.0588
Cl^{-} (mg/l)	250	3	0.0882
NO_3^{-} (mg/l)	50	5	0.1471
SO_4^{2-} (mg/l)	250	5	0.1471

2011 guidelines established by the World Health Organization (WHO) (WHO.2011).

The calculation of the Water Quality Index (WQI) involves determining the Subindex (SI) using formula 3 for each parameter, which is subsequently utilized to calculate the WQI using the equation 4 for each sample.

$$SIi = RWi \times qi \quad (3)$$

$$\mathrm{WQI} = \sum_{i=1}^{n} SIi \quad (4)$$

The results of the Water Quality Index (WQI) are categorized into five deferent classes of drinking water for evaluation (Table 2) (Sahu & Sikdar, 2008; Yidana & Yidana, 2010).

RESULTS AND DISCUSSION

Hydrochemical characterization

Table 3 presents the results of the chemical analyses conducted on the groundwater, along with the corresponding percentage of compliance with the World Health Organization (WHO) guidelines established in 2011. With the exception of calcium and bicarbonates, most of the parameters in the groundwater analysis are within the acceptable limits set by the World Health Organization (WHO) guidelines for drinking water. In all of the samples, calcium is the most abundant cation, exhibits a range of values from 84.97 to 137.88 mg/l. On the other hand, bicarbonate is the most abundant anion in the samples, with its value ranging from 336.72 to 454 mg/l (Table 3).

The utilization of the Piper diagram is beneficial for comparing the origins and distribution of groundwater, as it effectively represents the hydrochemical characteristics and composition of groundwater. This diagram provides comprehensive information that aids in understanding the hydrochemical properties and enables comparisons between different sources and distribution patterns of groundwater (Gao et al., 2020; Sutradhar & Mondal, 2021).

Figure 2 illustrates the hydrochemical facies of the groundwater in the northern region of the Middle Sébaou, revealing the identification of two distinct hydrochemical facies: bicarbonate calcium and magnesium, as well as chloride and sulfate calcium and magnesium. These results explain the high values of calcium and bicarbonate.

Table 2. Water quality index classification of drinking water (Zhang et al., 2021)

WQI value for drinking purpose	Type of groundwater water
<50	Excellent water
50–100	Good water
100–200	Poor water
200–300	Very poor water
>300	Water unsuitable for drinking

Water quality purposes

Table 4 provides the results of applying water quality indices to evaluate the appropriateness of groundwater for drinking purposes in the northern region of The Middle Sébaou. The WQI values ranging from 53.32 to 71.18, indicate clearly that the groundwater in the study area is of acceptable quality for human consumption.

Table 3. Basic statistics of the physicochemical parameters from the samples of the study area

Parameter	Min	Max	Mean
pH	7.03	7.41	7.22
EC (µS/cm)	887	1392	1192.40
T (°C)	14.6	19.5	17.40
TH (mg/l)	356	480	415.20
Ca^{2+} (mg/l)	84.97	137.88	112.65
Mg^{2+} (mg/l)	26.25	45.22	34.38
Na^{+} (mg/l)	34	140	89.50
K^{+} (mg/l)	4	8	5.70
HCO_3^{-} (mg/l)	336.72	454	406.96
Cl^{-} (mg/l)	49.63	214.85	115.51
NO_3^{-} (mg/l)	1.32	8.85	6.13
SO_4^{2-} (mg/l)	104	200	125.80

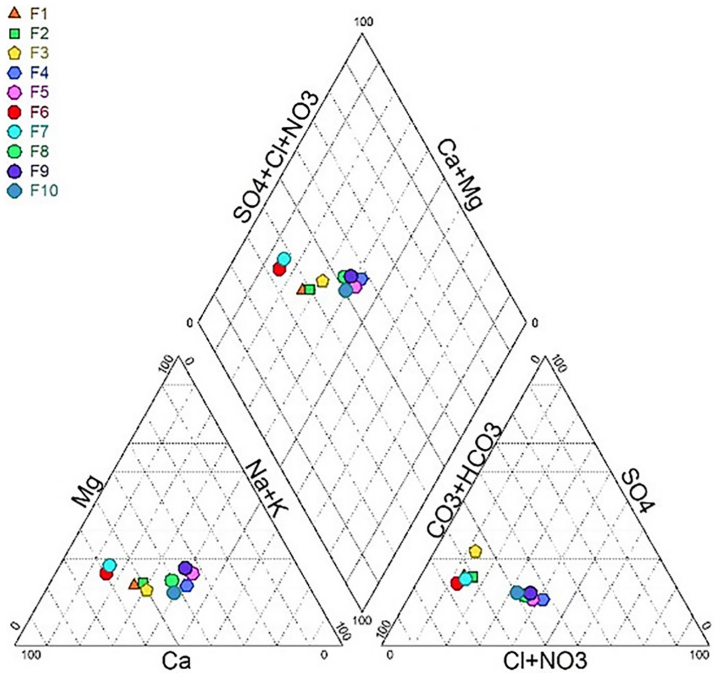

Fig. 2. Piper diagram of groundwater samples

Table 4. WQI for all samples and classification of groundwater of the northern region of the Middle Sébaou

Sample	WQI	Water type
F1	65.09	Good
F2	53.32	Good
F3	68.84	Good
F4	69.95	Good
F5	71.18	Good
F6	59.63	Good
F7	56.89	Good
F8	70.29	Good
F9	64.08	Good
F10	61.85	Good

CONCLUSIONS

Hydrochemical methods are employed to assess the suitability of groundwater for drinking purposes, considering that the groundwater from Tiziouzou, Draa Benkhadda, and Tirmitine (represented in this study by the northern region of the Middle Sébaou) is utilized for human consumption. These methods analyze the hydrochemical composition of the groundwater to evaluate its quality and ensure its suitability for drinking. The concentrations of Ca^{2+} and HCO_3^- in the groundwater exceeded the standard limits set by the World Health Organization (WHO) for drinking water, as stated in the WHO 2011 guidelines, contrary to the other chemical elements that meet the standards. The groundwater in the study area belongs to two hydrochemical facies: bicarbonate calcium and magnesium, as well as chloride and sulfate calcium and magnesium. According to the assessment using the Water Quality Index (WQI), all water samples of the study area were categorized as good, indicating that the groundwater is suitable for human consumption.

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