International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 8, 2025
https://theaspd.com/index.php

Comparative Evaluation Of The Physicochemical Properties Of Spring And Mineral Waters Marketed In Algeria

Mohamed Gorine[1,], Younes Bourmita[2]
[1] Department of Agronomy (Second cycle), Higher School of Agronomy Martyr Mohamed El Amdjed Ben Abdelmalek 027100 Mostaganem. Algeria,
[1]Dr. GORINE Mohamed, Higher School of Agronomy Mostaganem, Mostaganem, 0271000, Algeria. m.gorine@esa-mosta.dz, ORCID : 0009-0003-4192-0364 –
[2] Higher School of Agronomy Mostaganem, Mostaganem, 0271000, Algeria. y.bourmita@esa-mosta.dz

Abstract:
Water, the cornerstone of human life, deserves sustained attention. As an essential element for hydration, hygiene, cooking, and food production, its quality directly influences public health. Therefore, it is crucial to regularly monitor indicators such as turbidity, pH, and the presence of pathogenic bacteria or chemical pollutants. These controls allow for the rapid detection of any contamination and the implementation of necessary corrective measures to guarantee clean and safe drinking water. The constant vigilance of health authorities and the involvement of citizens in preserving this vital resource are thus essential to ensuring sustainable access to quality water. This study aimed to evaluate the physicochemical quality of water resources, primarily from coastal and central Algeria, intended for consumption. To this end, twenty water samples were collected from retail markets. The results of the physico-chemical analyses showed that all the samples had values in accordance with the Algerian national standards relating to the quality of drinking water with the exception of bicarbonates from the resources of ***Mesaad****,* ***Ovital****,* ***Ayris****,* ***Ifri****,* ***Togi****,* ***Taya****,* ***Menbaa****,* ***Medjana****,* ***Qniaa****,* ***Arwa****,* ***Guerrioun****,* ***Besbassa****,* ***El kantara****,* ***Toudja****,* ***Ain bouglez****,* ***Tazliza****,* ***Guedila****,* ***Mansourah*** *and* ***Messerghin****. In this study, the Water Quality Index (****WQI****) for eleven physicochemical parameters (****pH, Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, HCO_3^{-}, Cl, NO_2^{-}, NO_3^{-}, SO_4^{2-}, and SR****) was used to assess the drinking water quality of groundwater resources in northern, central, and eastern Algeria during the period from* ***January to April 2025****. The majority of these water resources are of excellent quality, with the exception of the Ain Bouglez resource, which was of Moderate quality due to its low calcium, magnesium, and bicarbonate content, which reduced the water's mineral content.*
Keywords*: Water resources, properties, physicochemical,* ***WQI****, drinking water quality, Algeria*

I. INTRODUCTION

Water is a natural resource essential to the life of any ecosystem **[1]**. Maintaining its quality is a crucial concern for a society that must meet increasingly significant water needs **[2]**. However, increasing and uncontrolled urbanization, particularly in poor and developing countries, has a negative impact on the quantity and quality of this resource. Thus, water resources are a major concern in countries with arid or semi-arid climates, as they are absolutely essential for the development of human, economic, and social activities **[3]**.

In Algeria, groundwater represents approximately **20%** of global water reserves (around 1000 billion m^3), is the main source of supply due to its relatively easy extraction, formed by the percolation of rainwater, surface water and runoff, this water is microbiologically safe and protected against the risk of pollution **[4]**.

It is noted that there is significant diversity in groundwater intended for consumption, specifically the ethological differences in soil stratigraphy, which generally influence the mineralogy of the water. Population growth and the development of the industrial and agricultural sectors have led to a dramatic increase in water needs. This greater increase compared to the quantities mobilized has generated a deficit between water supply and demand, which will create an insurmountable obstacle to development in the long term and a negative socio-economic impact. Climate change has a significant and growing impact on water resources in Algeria **[5]**.

This country, already characterized by a semi-arid to arid climate, is facing a progressive decrease in rainfall and a rise in average temperatures. These phenomena are leading to a reduction in the flow of wadis (seasonal rivers), a drop in groundwater levels, and increased evaporation from surface water reserves such as dams. Furthermore, the frequency and intensity of droughts have increased in recent decades, exacerbating water stress in many regions. This situation jeopardizes not only the supply of drinking water but also agricultural activities, which are heavily dependent on irrigation **[5]**. Faced with these challenges, Algeria is strengthening its sustainable water management policies, promoting the reuse of treated wastewater, and developing modern irrigation techniques to preserve its water resources in an increasingly uncertain climate context.

Water quality is an important criterion for meeting water demand and supply **[3].** Ensuring soft water that meets health and environmental standards is a major challenge within the framework of integrated natural resource management and sustainable development. To clearly represent water quality, various water quality indices are used to assess groundwater quality. The Water Quality Index **(WQI)** is a simple method used as part of overall water quality analysis. It uses a group of parameters to reduce large amounts of information to a single, usually dimensionless, number in a simple and reproducible manner **[6].** This method was initially proposed by **[7]** and **[8].** To calculate this index, **Horton (1965)** proposed the first formula that takes into account all the parameters necessary for determining groundwater quality and reflects the composite influence of various parameters important for water quality assessment and management **[9]; [10].** This index was first used to highlight the physicochemical changes that may occur throughout the year and their impact on the quality of drinking water **[11]; [12].**

Drinking water quality is assessed by calculating the Water Quality Index **(WQI)**, which represents the cumulative impact of various physicochemical parameters on its overall condition **[13].**

The objective of this study is to determine the groundwater quality of northern Algeria by calculating the overall Water Quality Index **(WQI)** based on physicochemical parameters in order to highlight the temporal, seasonal, and spatial evolution of these resources from west to east.

II. Presentation of the Study Area

The study area for groundwater drinking water resources covers almost the entire Algerian coastline, extending along the Tell Atlas Mountains for approximately 1600 km in length and 100 km in width. Geographically, it lies between 35° 03' and 37° 02' North latitude and 1° 16' and 9° 54' West longitude, and has an elongated shape oriented generally NW-NE **(Fig. 1)**. It is bordered to the Northwest by Moroccan territory and to the Northeast by Tunisian territory, to the North by the Mediterranean coastal basins, and to the South by the Saharan Atlas mountain range, which marks the natural and geographical boundary between the fertile North and the desert south.

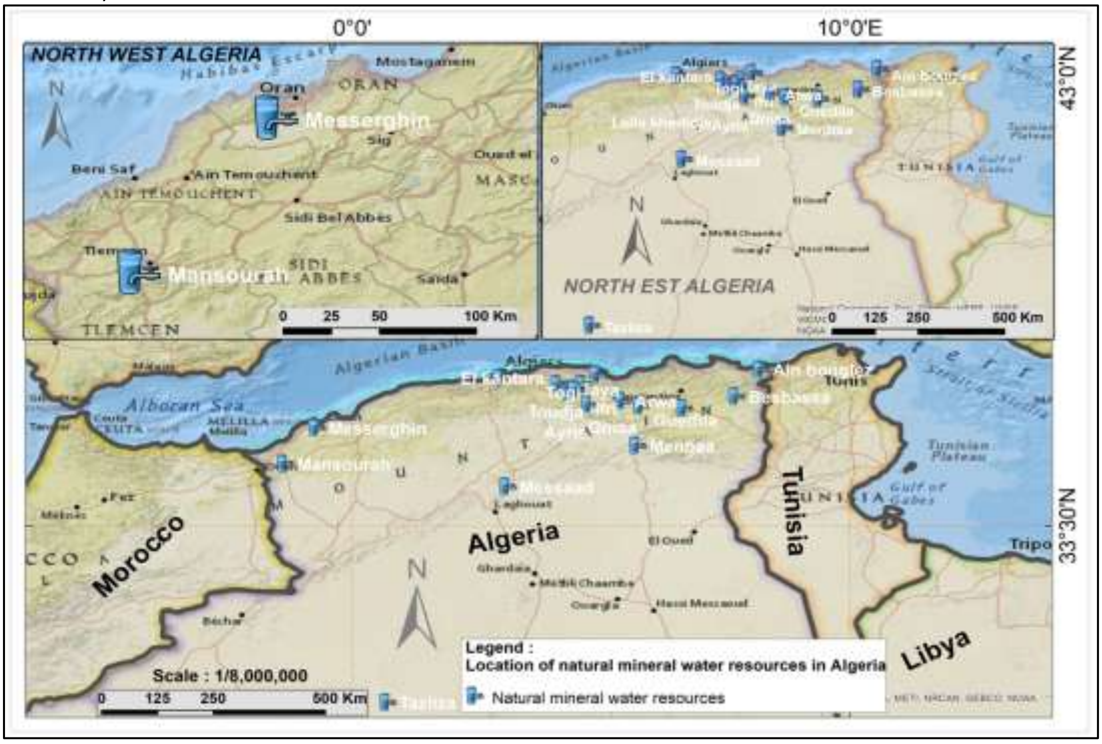


Figure 1. Geographical location of the study area

The coastal mountains of Algeria form part of the Tell Atlas mountain range, which runs parallel to the Mediterranean coast. They consist of a succession of mountain ranges and hills close to the sea, separated by fertile plains and valleys.

They extend from the northwest to the northeast of the country, along the Mediterranean Sea, often a short distance from the coastline. These mountains have average altitudes, ranging from **500** to **1200** meters, with higher peaks sometimes reaching **1600** meters. They directly overlook the coastal plains and the sea, creating contrasting and picturesque landscapes. Subject to a Mediterranean climate, with mild, rainy winters in the northeast and hot, dry summers in the northwest, this maritime influence moderates temperatures and fosters diverse vegetation.

From a geological perspective, the coastal mountains belong to the Tellian atlas chain, which formed during the Tertiary period (**Alpine orogeny**). Their structure is primarily the result of the collision between the African and Eurasian plates, responsible for the folding and thrusting of the terrain.

- They exhibit a great diversity of rock types: schists, sandstones, limestones, marls, as well as local volcanic formations in central and eastern Algeria, with folded and faulted relief, sometimes divided by longitudinal valleys.
- Erosion and weathering have given rise to clay-limestone and red calcareous-magnesian soils, with vast plains in western Algeria suitable for agriculture.

From a hydrological perspective, groundwater resources are concentrated in central and northeastern Algeria, reflecting the abundance of rainfall and the stratigraphic context, where less soluble rocks indirectly influence water quality. This contrasts with the northwest, which is characterized by an arid climate and more or less soluble geological formations.

III. METHODOLOGY AND DATA USED

III.1. Database

The data used in this study include data relating to the physicochemical analyses of groundwater intended for drinking water use. Water samples were collected at the point of sale in the Algerian market over a three-month period, from January to **April 2025**. The database comprises a total of **20** samples.

The physicochemical parameters include **pH,** calcium (**Ca^{2+}**), magnesium (**Mg^{2+}**), sodium (**Na^{+}**), potassium (**K^{+}**), sulfates (**SO_4^{2-}**), chloride (**Cl^{-}**), bicarbonate (**HCO_3^{-}**), nitrates (**NO_3^{-}**), nitrites (**NO_2^{-}**), and dry matter (**DM**). These parameters are listed on the packaging insert, each with its concentration.

The evaluation and visualization of the results were performed using **Excel 2010** and Geographic Information System (**GIS**) software.

III.2. Calculation of the Water Quality Index (**WQI**)

Eleven important parameters (**pH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+},** SO_4^{2-}**,** Cl^{-}**,** HCO_3^{-}**,** NO_3^{-}**,** NO_2^{-}**, and DM**) were selected to calculate the Water Quality Index (**WQI**). This index is based on the water quality classification technique, which involves comparing water quality parameters to international or Algerian national standards within the framework of this study. The **WQI** summarizes large amounts of water quality data in simple terms (Excellent, Good, Inferior, very inferior, etc.). In this study, the **WQI** is applied to estimate the influence of natural and anthropogenic factors based on several key parameters for the chemical characterization of coastal groundwater in Algeria.

This index is calculated using the weighted arithmetic index method **[14]; [15]; [16]** and **[17].** In this approach, a numerical value called the relative weight (Wi), specific to each physicochemical parameter, is calculated (**Table 1**) according to the following formula:

$$\mathbf{Wi = \frac{k}{Si}} \quad \text{..} \ (1)$$

Or :

$$\mathbf{k = \frac{1}{\sum_{i=1}^{n}\left(\frac{1}{Si}\right)}} \quad \text{..} \ (2)$$

K : proportionality constant and can also be calculated using the following equation:

n : number of parameters

Si: maximum value of the Algerian standard for drinking water (**Algerian Standard for Drinking Water Quality, 2014**) for each parameter in mg/l except for pH.

Next, a quality assessment scale (**Qi**) is calculated for each parameter by dividing the concentration by the standard for that parameter and multiplying the result by **100** as in the following formula:

$$\mathbf{Qi = \left(\frac{Ci}{Si}\right) X\ 100} \quad \text{..} \ (3)$$

Qi : scale for assessing the quality of each parameter,

Ci : the concentration of each parameter in mg/l

Finally, the overall water quality index is calculated using the following equation:

$$\mathrm{WQI} = \mathbf{\sum_{i=1}^{n} Qi\ X\ Wi \,/ \sum_{i=1}^{n} Wi} \text{...} (4)$$

Five water quality classes can be identified based on the water quality index (**WQI**) values (Table 1).

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 8, 2025
https://theaspd.com/index.php

Table 1. Classification and possible uses of water according to the WQI (Brown et al., 1972; Chatterji and Raziuddin, 2002; Aher et al., 2016)

(WQI) Class	Water Type	Possible Use
0–25	**Excellent quality**	Drinking water, irrigation, and industry
>25–50	**Very Good quality**	Drinking water, irrigation, and industry
>50–75	**Moderate quality**	Irrigation and industry
>75–100	**Very inferior quality**	Irrigation
>100	**Non-potable water**	Appropriate treatment required before use

IV. RESULTS AND DISCUSSION

The results obtained in this study are analyzed, interpreted and presented in the form of thematic maps using the tools of the geographic information system **GIS**, in order to give a general idea of the overall quality of groundwater and its spatial evolution.

IV.1. Descriptive Statistics

The descriptive statistical characteristics of the physicochemical variables used in this study are presented, including minimum and maximum values, mean, median, standard deviation, coefficient of variation, and standard error (**Table 2**). The results show that the pH is slightly alkaline, ranging from 6.87 to 7.7, and does not differ significantly from other sources, a finding confirmed by the coefficient of variation of 2.87%. This pH range, referring to drinking water quality standards, shows that the pH values of the studied waters conform to Algerian standards, which set the range at 6.5 to 9.

The levels of dry residues measured show values between 140 mg/l and 953 mg/l (**Table 2**), the results therefore do not exceed the Algerian standards of 1500 mg/l, with a high coefficient of variation of 43.67% which means dispersion between the samples with less homogeneity.

Nitrate and nitrite concentrations range from 0.29 to 46.5 and from 0.011 to 0.06 mg/l respectively, with extremely high coefficients of variation of 110.02 and 117.61% (Table 02), reflecting a significant dispersion between water resources, but these results comply with Algerian standards, the values of which are 50 and 0.2 mg/l respectively.

The concentrations of sulfates, bicarbonates, and chlorides ranged from **0** to **211** mg/l, **0** to **458** mg/l, **and 7** to **105** mg/l, respectively (**Table 2**). These analytical results show that the sulfate and chloride concentrations comply with Algerian drinking water standards, with the exception of bicarbonate concentrations in a few sources that significantly exceeded Algerian standards. The coefficients of variation for these mineral elements were **89.5%, 70.41%,** and **56.95%,** respectively, which are very high and exhibit remarkable diversity.

The levels of soluble cations such as sodium, potassium, calcium, and magnesium were found to be between **3.1** and **68** mg/l, 0.**4** and **11.5** mg/l, **4.6** and **136** mg/l, and **2.64** and 78 mg/l, respectively (**Table 2**). These values correspond to the Algerian drinking water standard, but the coefficients of variation of **47.28%, 103.72%, 45.46%,** and **72.79%** are very high and indicate significant heterogeneity and remarkable diversity among these water resources.

Table 2. Descriptive statistics of the relative physicochemical parameters of the twenty samples

	pH	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	HCO_3^-	SO_4^{2-}	Cl^-	NO_3^-	NO_2^-	DM
		mg/l	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
Min.	6,87	4,6	2,64	0,4	3,1	0	0	7	0,29	0	140
Mean	7,26	69,68	23,43	2,56	37,60	200,53	69,48	53,71	9,25	0,011	451,45
Max.	7,7	136	78	11,5	68	458	211	105	46,5	0,06	953
Median	73	72,70	21,50	02,00	36	240,62	67,33	47,5	5,94	0,01	407
Standard deviation	0,16	23,89	11,86	1,63	14,06	116,75	48,87	25,34	5,89	0,007	150,44
CV %	2,87	45,46	72,79	103,72	47,28	70,41	89,50	56,95	110,02	117,61	43,67
Standard error	37,25	7,08	3,81	0,59	3,98	31,57	13,91	6,84	2,28	0,003	44,1

IV.2. Results of the WQI index calculation and water quality assessment

The relative weight (**Wi**) of each physico-chemical parameter and the proportionality constant k are first calculated using the maximum values of the Algerian standard for drinking water quality (**Algerian Water Quality Standard, 2014**) for the physico-chemical parameters studied (**Table 03**).

Table 3. Weight of physico-chemical parameters and Algerian standard for the quality of drinking water.

Parameters	Algerian Standard	Maximum standard value, Algerian	1/Si	Wi= K/Si
pH	6,5 à 9	9	0,111	0,011
Ca^{2+} mg/l	200	200	0,005	0,000
Mg^{2+}mg/l	150	150	0,007	0,001
K^{+} mg/l	12	12	0,083	0,008
Na^{+}mg/l	200	200	0,005	0,000
HCO_3^{-}mg/l	250	250	0,004	0,000
SO_4^{2-}mg/l	400	400	0,003	0,000
Cl^{-}mg/l	500	500	0,002	0,000
NO_3^{-}mg/l	50	50	0,020	0,002
NO_2^{-}mg/l	0,1	0,1	10,000	0,977
Dry residue mg/l	1200	1200	0,001	0,000
			10,240	
		K= 1/∑(1/Si)	**0,098**	

After calculating the overall water quality index (**WQI**) using the results of physicochemical analyses and the standard values of the Algerian standard (**Algerian Standard for the Quality of Drinking Water, 2014**), the water quality class was determined for the **20 samples** collected from the Algerian coast (**Table 4**). Two quality classes (**Excellent, Inferior**) were identified in this study.

Table 4. IQE index values and classes of groundwater in the Algerian coast

Water resources	WQI	Water type
Messaad	10,871	Excellent quality
Ovital	0,997	Excellent quality
Ayris	10,904	Excellent quality
Ifri	20,660	Excellent quality
Togi	10,851	Excellent quality
Taya	10,795	Excellent quality
Menbaa	20,814	Excellent quality
medjana	10,926	Excellent quality
Qniaa	10,953	Excellent quality
Arwa	11,005	Excellent quality
Guerrioun	1,119	Excellent quality
Besbassa	10,871	Excellent quality
El kantara	10,991	Excellent quality
Toudja	10,738	Excellent quality
Ain bouglez	**59,538**	**Moderate quality**
Tazliza	11,329	Excellent quality
Guedila	10,87	Excellent quality
Mansourah	1,062	Excellent quality

Messerghin	1,791	Excellent quality
Lalla khedidja	0,988	Excellent quality

The figure below presents the **WQI** values of all the water resources studied. The only resource in **Ain Bouglez** has an **WQI** of **59.53,** representing **5**% of the total, with inferior quality. In contrast, the other resources are of excellent quality, with a percentage of **95**%, but with variable **WQI** indices as follows: **Ifri** and **Manbaa** have indices of **20.66** and 20.81 respectively, with a percentage of 10%. **Messaad**, **Ayris**, **Togi**, **Taya**, **Medjana**, **Qniaa**, **Arwa**, **Besbassa**, **El Kantara**, **Toudja**, **Tazliza** and **Guedila** have **WQI** values that vary between **10** and **11**, with a percentage of **60**%. **Ovital**, **Guerrioun**, **Mansourah**, **Messerghin** and **Lalla khedidja** are the most excellent water resources with an **WQI** that does not exceed 1 and represent **25**% of all the resources studied.

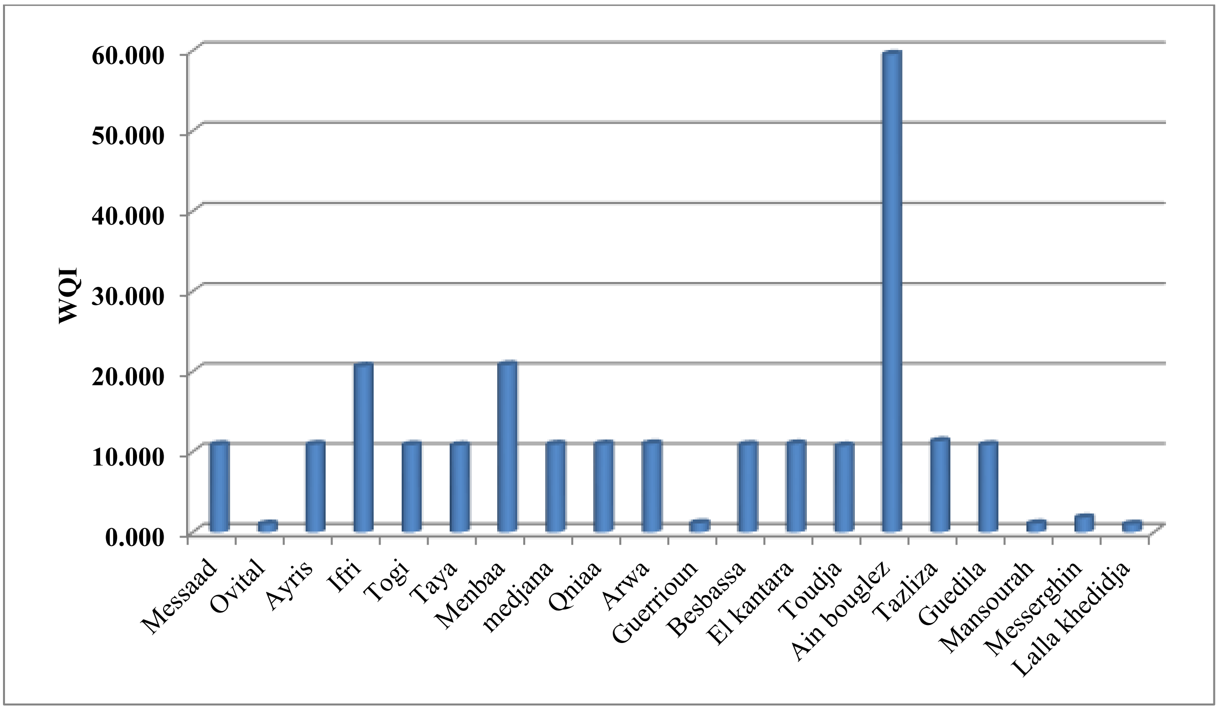


Figure 2. WQI values of drinking water resources intended for consumption
Water suitability map for human consumption using the WQI method

Figure 03: Illustrative map of drinking water quality indices

The suitability of water for human consumption depends on various physicochemical parameters and their concentrations. This study assessed water quality using the Water Quality Index (**WQI**), in accordance with Algerian Standards (**AS**). The Water Quality Index (WQI) provides a comprehensive numerical assessment reflecting the overall quality of water for specific uses **[18].** This index simplifies numerous physicochemical data into a single term, representing the overall water quality. It quantifies the impact of various parameters, providing clear and valuable information to decision-makers **[7].**

The water quality index **(WQI)** was calculated according to the Algerian drinking water standards (Algerian Standards, 2014) using a weighted arithmetic method **[19].** Eleven parameters were considered, each assigned a weight **(wi)** reflecting its impact on water quality, from 1 (lowest) to 5 (highest) **[20].**

The Wi values were calculated using the **formula Wi = K / Si**, where Wi represents the weight of each parameter.

The quality index **(Qi)** for each parameter was determined using the formula **Qi = (Ci / Si) x 100**, where Ci represents the concentration in the sample and Si the **WHO** standard. The sub-index **(SIi)** for each parameter was then calculated using the formula **SIi = Wi x Qi**. The overall water quality index **(WQI)** was obtained by summing all the **SIi** values.

Water was classified according to its Water Quality Index **(WQI)** into excellent quality **(0-25),** Very good quality **(25-50),** inferior quality **(50-75),** very inferior quality **(75-100)**, and unsafe to drink **(>100).** The **WQI** was assessed using **11** parameters across **20** water resources, and the results are presented in Table 4, which shows the water quality status.

The thematic map presents all **WQI** values across Algeria, categorized into two classes. A dominant class, with an index ranging from **0** to **25**, represents **95%** excellent water quality. The other class, with an index between **50** and **75**, represents Moderate quality, unsuitable for drinking water but suitable for irrigation and industrial use.

IV.3. Correlation Matrix

The results show that the correlations are strongly positive and significant between **Ca^{2+}/HCO_3^-, Ca^{2+}/SO_4^{2-}, DR/Mg^{2+}, DR/HCO_3^-, and DR/Na^+,** and very strongly positively correlated between **DR/SO_4^{2-}.** The other variables apparently show non-significant correlations **(Fig. 4)**. In the context of spring water mineralization, this results from the progressive dissolution of soluble rock minerals (limestone, gypsum, sodium, magnesium, halite, etc.) by circulating water under the influence of **CO_2** and chemical reactions, thus enriching the water with mineral ions.

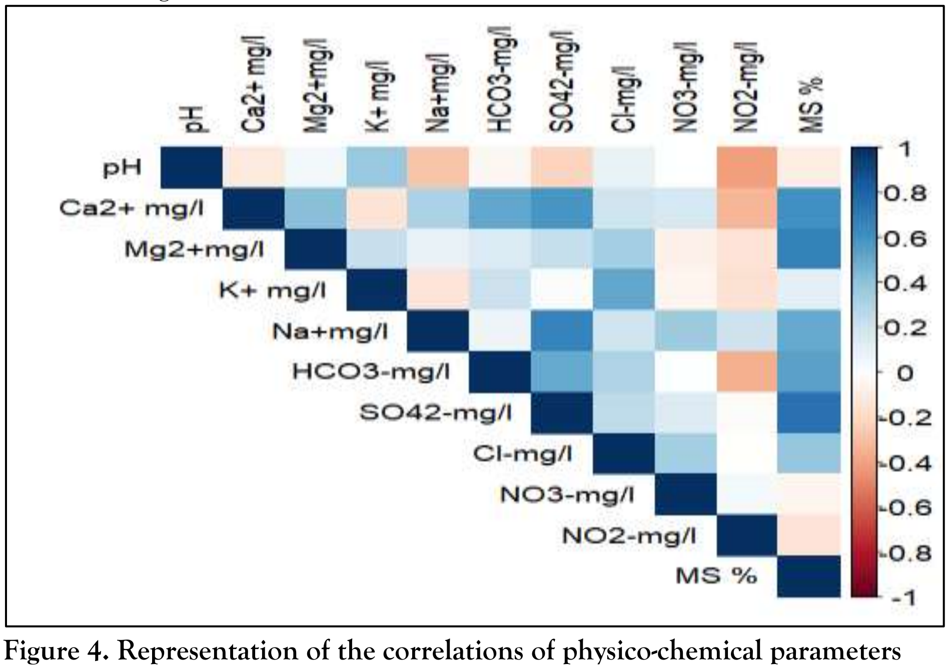


Figure 4. Representation of the correlations of physico-chemical parameters

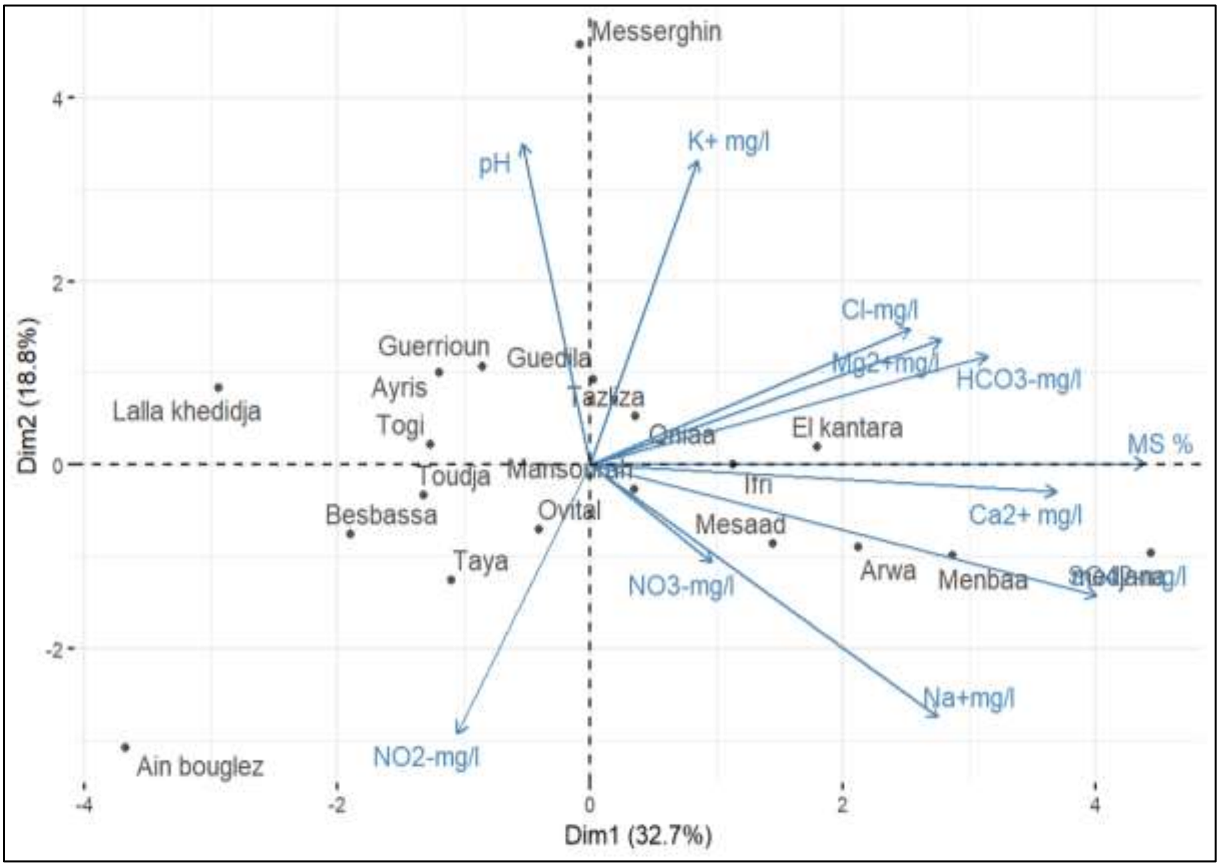
IV.4. Principal component analysis of the physico-chemical parameters of water resources

The following results were obtained by a **PCA** performed on the correlation matrix which allows us to distinguish two axes explaining 51.5% of the total variability of the data.

The first axis, representing **32.7%,** corresponds to a mineralization gradient dominated by dry matter **(DM)**, major cations **(Ca^{2+}, Na^+, Mg^{2+})**, and anions **(Cl^-, HCO_3^-).**

The second axis, representing **18.8%,** contrasts basic waters **(pH, K^+)** with those enriched in nitrites **(NO_2^-)**.

Graph 04 below represents water resources **(Messaad, Ovital, Arwa, Menbaa, etc.)** as points, while variables represented by arrows are physicochemical **parameters (pH, Ca^{2+}, Na^+, Mg^{2+}, etc.)**. The **PCA** shows two principal component axes (**dim. 1 and dim. 2**) with respective inertias of **32.7%** and **18.8%** of the variance.



Graph 5. PCA of the physico-chemical parameters of drinking water resources

Axis 1 (**Dim. 1 – 32.7%**): A strong correlation is observed on this axis between variables such as DM, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, and SO_4^{2-}, resulting in a mineralization gradient in the soluble matter of the water. As the water resources (**Menbaa, El Kantara, Mesaad, and Medjena**) are located on the right side of graph 4, they exhibit characteristics of hardness and mineralization exposure.

Axis 2 (**Dim. – 18.8%**): This axis indicates that **pH** and **K^+** are positively and negatively correlated with NO_2^-, reflecting a gradient of acidity and nitrogen pollution. The **Messerghin** spring water has a higher pH, is slightly alkaline, and has a low nitrogen content. The resources in the lower left of the graph (e.g., **Ain Bouglez**, **Taya**) are more influenced by nitrites (**NO_2^-**), suggesting the possibility of organic or agricultural chemical contamination.

This graph shows three groups of natural water resources: Group 1 on the right represents water resources (**Mesaad**, **Menbaa**, **El Kantara**, **Arwa**, **Qniaa**, **Ifri**, **and Medjena**) characterized by highly mineralized waters, rich in dry matter, calcium carbonate (**Ca^{2+}**), and sodium carbonate (**Na^+**), indicating high hardness. Group 2 in the center left represents resources (**Guedila**, **Ayris**, **Togi**, **Mansourah**, and **Ovital**) characterized by moderately mineralized, balanced waters, often of good quality.

Group 3 left bottoms, represented by the resources (**Ain bouglez, Lalla Khedidja, Besbassa and Taya**) are characterized by weakly mineralized waters, sometimes influenced by nitrites, therefore potentially sensitive to pollution.

V. CONCLUSION

The study presented a comparative assessment of water quality from twenty springs across Algeria to determine their suitability for human consumption. Twenty samples were analyzed for a total of eleven parameters. Most parameters met the standards, although some slightly exceeded the Algerian limits for **HCO_3^-**, **SO_4^{2-}**, and total dissolved solids (**TDS**). Water Quality Index (**WQI**) values ranged from **0.988** to **59.538**, indicating water quality from poor to excellent. A **PCA** analysis was also conducted in this study to understand the evolution of water consumption patterns, revealing three distinct groups of springs. The first group consisted of highly mineralized springs with high hardness, the second group of moderately mineralized springs often of good quality, and the third group of weakly mineralized springs susceptible to pollution.

According **to Harish et al., (2024)**, water sources must be properly monitored by government agencies and tracking systems to reduce the presence of pollutants **[21]**. It is necessary to reduce the city's river discharges to protect groundwater and spring waters in order to ensure proper water management and preserve water resources for aquatic life and future generations, and to meet the needs of a growing population.

DECLARATIONS

Funding: The author would like to confirm that this work has received no financial support from any authorities. The work is self-supported

Competing interests' statement, the authors approved that there is no conflict of interest from any parties upon publication of this manuscript

Ethics statement. All authors approved that this research followed the journal's ethical guidelines, as indicated on the journal's author guidelines page

Author contributions. All the authors contributed equally to designing research, data collection, data acquisition, data analysis, reporting, and manuscript preparation

Acknowledgments. The authors would like to acknowledge all supporters for helping complete this study

- This research study received support from a scholarship offered by the **Ministry of Higher Education and Scientific research in Algeria.**

Data availability. Datasets related to this article will be available upon request to the corresponding author.

REFERENCES :

[1]. Tampo, L., Gnazou, M., Akpataku, V., Bawa, L. et Djaneyé-Boundjou, G. (2015). Application des méthodes statistiques à l'étude hydro chimique des eaux d'un hydrosystème tropical : Cas du bassin versant de la rivière Zio (Togo). European Scientific Journal, 11(14), (pp. 204-225).

[2]. Foto, M. S., Zebaze, T. S. H., Nyamsi T. N. L., Ajeagah, G. A. et Njnié, T. (2001). Evolution Spaciale de la Diversité des Peuplements de Macro invertébrés benthiques dans un cours d'eau anthropisé en milieu Tropical (Cameroun). European Journal of scientific Research, 55(2), (pp. 291-300).

[3]. Talhaoui, A., El Hmaidi, A., Jaddi, H., Ousmana, H. and Manssouri, I. (2020) Calcul de L'indice de qualité de L'eau (IQE) pour L'évaluation de la qualité physico-chimique des eaux superficielles de L'oued moulouya (NE, Maroc). European Scientific Journal ESJ, 16, Article 64.

[4]. Fetter, C. W. (2001). Applied Hydrogeology (4° éd.), Pearson, Higher Education, New Jersey.

[5]. Guechi, S., et Beloulou, L. (2025). Depletion curve analysis and assessment of chemical indicator for pollution detection in seraidi springs (Annaba – Algeria). Acque Sotterranee, Italian Journal of Groundwater, 52(770), (pp. 101-118).

[6]. Abbasi, T., et Abbasi, S. A. (2012). Water quality indices. 1st ed., Elsevier, Amsterdam, The Netherlads, (384p), Paperback ISBN: 9780444638366.

[7] Horton, M. K. (1965). An index number system for rating water quality. Journal of Water Pollution Control Federation, 37(3), (pp. 300-306).

[8]. Brown, R. M., McClelland, N. I., Deininger, R. A., Tozer, R. G. (1970). A Water Quality Index- Do We Dare? Water and Sewage Works, 117, (pp. 339-343).

[9]. Liou, S. M., Lo, S. L., Wang, S. H. (2004). A generalized water quality index for Taiwan, Environmental Modeling et Assessment, 96(1-3), (pp, 35-52).

[10].Tyagi, S., Sharma, B., Singh, P., Dobhal, R., (2013). Water quality assessment in terms of water quality index. American Journal of Water Ressources, 1(3), (pp. 34-38).

[11]. House, M. A., Ellis, J. B. (1987). The development of water quality indices for operational management, Water science and Technology, 19(9), (pp. 145-154).

[12]. House, M. A. (1990). Water quality indices as indicators of ecosystem change. Environmental Modeling and Assessment, 15(3), (pp. 255-263).

[13]. Navneet Kumar, Gaurav Kumar Rastogi, Raj Kumar (2025). Water Quality Index for Drinking Water in Amroha, Uttar Pradesh, India. (2025). International Journal of Environmental Sciences, 2929-2935. https://theaspd.com/index.php

[14] Brown, R. M., McClelland, N. I., Deininger, R. A., O'Connor. M. F. (1972). A Water Quality Index-crashing the psychological barrier In Indicators of environmental quality (pp. 173 – 182). Springer, Boston, MA.

[15]. Chatterji, C., Rasiuddin, M. (2002). Determination of water quality index of a degraded river in Asanol Industrial area, Ranigani, Burdwan, West Bengal. Nature, Environment and Pollution Technology, 1 (2) (pp. 181 – 189).

[16].Yidana, S. M et Yidana, A. (2010). Assessing water quality using water quality index and multivariate analysis. Environmental Earth Sciences, 59(7) (pp. 1461 – 1473).

[17]. Aher, D. N., Kele, V. D., Malwade, K. D., et Shelke, M. D. (2016). Lake Water Quality Indexing To Identify Suitable Sites For Household Utility. A Case Study Jambhulwadi Lake, Pune (MS). Int. Journal of Engeneering Research and Applications. 6(5). (pp. 16 – 21).

[18]. Allia, Z., Lalaoui, M. and Chabbah, M. (2022). Hydrochemical assessment for the suitability of drinking and irrigation use of surface water in Grouz Dam Bassin. Northeast Algeria. Sustain. Water Resour. Manag; 8(88): 3-16. https://doi.org/10.1007/s40899-022-00663-8
[19]. Allia, Z. and Lalaoui, M. (2024). Formation mechanism of hydrochemical and quality evaluation of shallow grandwater in the Upper Kebir sub-bassin. Northeast Algeria. Journal of Groundwater Science and Engineering, 12(1): 78-91. https://gwse.iheg.org.cn/en/article/doi/10.26599/JGSE.2024.9280007
[20] Dheeraj, V.P., Singh, C.S. and Sonkar, A.K. (2023). Assessment of surface and groundwater quality around Korba Coalfield, India: An integrated approach of water quality index, Sustain, Water Resour, Manag., 9: 191. https://doi.org/1.1007/s40899-023-00973-5
[21]. Harish chand, Praveen Bhardwaj, Rakesh Kumar, Daljeet, Sandeep Kumar, Nikita Gupta (2024).Water Quality Investigation by Physicochemical and Biological Parameters of various sources In District Shimla (Himachal Pradesh). (2024). International Journal of Environmental Sciences, 229-246. https://doi.org/10.64252/v44v9307