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AUTHOR(S)	Nemili Zohra, Baazi Houria, Necer AbdeLdjabar, Saoudi Messaoud
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STATISTICAL CHARACTERIZATION OF GROUNDWATER QUALITY IN THE BISKRA REGION, NORTHEASTERN ALGERIA

Nemili Zohra
Natural Hazards and Territory Planning Laboratory (LRNAT), Faculty of Technology, University of Batna 2, Fesdis 05078, Batna, Algeria

Baazi Houria
Natural Hazards and Territory Planning Laboratory (LRNAT), Earth Sciences and Universe Institute, University of Batna 2, Fesdis 05078, Batna, Algeria

Necer AbdeLdjabar
Laboratory of Thermodynamics and Energetic Systems, USTHB university, BP 32 Bab Ezzouar, 16111 - Algeirs, Faculty of Natural and Life Sciences, University of Batna 2, Fesdis 05078, Batna, Algeria

Saoudi Messaoud
Laboratory of Biodiversity, Biotechnology, and Sustainable Development, Faculty of Natural and Life Sciences, University of Batna 2, Fesdis 05078, Batna, Algeria

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ABSTRACT

The main objective of this work is to characterize the groundwater quality in the Biskra region using Principal Component Analysis (PCA) on 59 samples from the most heavily exploited boreholes in the study area, more specifically those used for human consumption. The PCA results showed two axes that explain 70.8% of the information, with axis F1 summarizing 60.86% of the information and describing the parameters related to mineralization (EC, HCO3, TH, Ca+2, Mg+2, Cl-, SO4, K, Na), while axis F2 presents 9.9% of the initial information and describes a weak correlation of nitrates with respect to all other parameters, which confirms its origin given the proximity of agricultural land and industrial zones for certain boreholes. To this end, continuous monitoring of water quality is mandatory, as is the implementation of treatment to reduce water quality degradation and eliminate health problems.

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1. Introduction.

Groundwater is the main source of drinking water for the majority of the Algerian population, especially in rural areas. However, these resources are often highly vulnerable to climate changes, and their physico-chemical quality is mainly due to anthropic actions, such as the excessive use of fertilizers to meet the demands of agriculture, and industrial and even domestic discharges. While our investigation focuses on the Biskra region's groundwater resources, it has revealed elevated levels of certain chemical elements, including sulfates, nitrates, potassium, and chlorine. This is the case of studies made in the Biskra region (Guergazi and Achour 2005, BOUCHEMAL and ACHOUR 2015, Chabour, Dib et al. 2021) (Brinis, Boudoukha et al. 2009, Bouchemal, Bouchahm et al. 2011, Belhadj, Boudoukha et al.

2017, Rabilou, Mousbahou et al. 2018). These abnormally high levels are of natural origin, linked in particular to the lithology of the aquifer reservoirs in some areas, and even characterized by magnesian sulfate waters showing the influence of gypsum (calcium and magnesium sulfates) (Brinis et al., 2009). On the other hand, an increase in nitrates is linked to both point-source inputs (industrial discharges, urban discharges or livestock effluents) and diffuse inputs, the dominant source of which is agricultural activity.

2. Study Area.

The study area covers a total area of 21 671, 24 km² (Figure 1). It stretches from northwest to southeast, between latitudes 34° 51′ 50″ North and longitudes 5° 44′ 50″ East, encompassing the Chott Melghir region in the southeast.

With an average altitude of 750 m, the Biskra region is drained by a network of wadis including the Oued Djedi, Oued Biskra, Oued El-Arab, Oued el-Abiod, and Oued Chabro. These wadis all contribute to the vast Saharan watershed of the Chott Melghir.

The climate in the area is semi-arid, characterized by low average annual rainfall not exceeding 132.7 millimeters per year (BOUCHEMAL 2017). Temperatures vary considerably, with extreme lows reaching 2°C and highs exceeding 44.2°C. The rainy season generally extends from winter to spring, while the low-water period extends from May to October. This latter period is marked by high evaporation, in contrast to the low infiltration rate, which represents only about 1% of precipitation.

Due to these arid climatic conditions and very limited groundwater recharge from rainfall, vegetation is sparse and poor. The population is concentrated mainly around the city of Biskra, where agriculture and trade are the main economic activities. Industry is relatively underdeveloped and consists mainly of public companies.

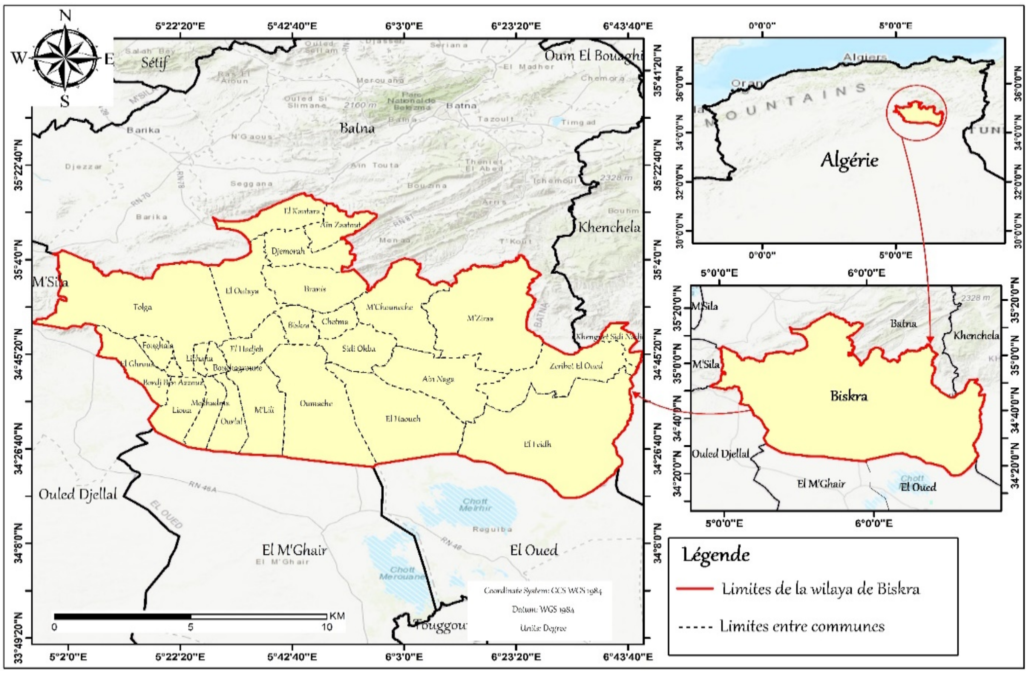

Figure 1. Study Area.

3. Materials and Methods.

3.1. Sampling and Analysis.

To evaluate the quality of drinking water in the Biskra region, water samples (Table 1) were collected from wells supplying the drinking water network. Immediately after collection, physicochemical parameters such as temperature, electrical conductivity, and pH were measured on site. Subsequently, the analysis of major ions present in the water was carried out in the laboratory of the National Agency for Water Resources (ANRH) in Biskra. For cations, the flame atomic absorption technique was used, while colorimetry was used for anions (Rodier et al, 1975).

Table 1. Descriptive Statistics of chemical elements.

Variables	CE	HCO_3.	TH	Ca2.	Mg2.	Cl.	$SO4^{2-}$	NO_3	K.	Na.
Min	1215	172.0	501	80.0	56.0	120.0	98.0	0.00	2.0	23
1st qu	2328	238.5	675	151.5	82.5	264.5	144.5	8.30	8.0	105
Median	3310	268.4	920	210.0	100.0	620.0	266.0	18.00	12.0	190
Mean	3387	317.0	994	226.4	108.1	613.5	251.3	37.66	15.2	223
3rd qu	4495	423.0	1215	286.5	124.0	839.5	333.5	29.60	20.0	315
Max	6400	590.0	2040	510.0	184.0	1616.0	428.0	1071.00	50.0	680

3.2. Principal Component Analysis.

The PCA principal component analysis method is based on multidimensional descriptive statistics allowing any number of quantitative variables to be processed at the same time (Gladitz 1988, Shen, Sayeed et al. 2006). The analysis of several individuals (n individuals) based on a large number of numerical variables. These variables generally present a correlation between them. It consists of searching for a limited number of factors by reducing the data considered as best as possible. This approach allows data to be visualized in the form of graphs, where each individual is represented by a point and each variable by an axis. These graphs, called scatterplots, allow you to observe the distribution of data and identify trends or potential relationships between individuals and variables.

Principal component analysis (PCA) is a statistical technique that aims to simplify a set of correlated variables by transforming them into a smaller number of uncorrelated variables, called principal components or axes. These principal components are ordered according to their importance, that is to say the part of the total variance of the data that they explain. In other words, PCA makes it possible to reduce the dimensionality of the data while retaining most of the information (Atkinson 1988).

4. Results and Discussion.

PCA analysis was performed using R© software with the Factoshiny package, which is a powerful tool for conducting multivariate analyses without the need for complex R programming. Its intuitive graphical interface and visualization options make data interpretation and utilization effortless, rendering data analysis more accessible to a wider audience.

The link between all the variables taken in pairs and the correlation coefficients between these different variables is given by the correlation matrix (Figure 3). While perfect correlations were recorded between the different physicochemical elements,such as EC, HCO3, TH, Ca+2, Mg+2, Cl-, SO4, K, and Na, a weak correlation was observed between NO3 and all the elements (figure 2). A high correlation between Chlorine and Magnesium ($r = 0.64$) was also recorded. In addition, sulfates are well correlated with sodium ($r = 0.58$) and exhibit a strong correlation with electrical conductivity, which can be explained by the dissolution of evaporative formations. However, a weak correlation was observed between nitrate and potassium levels ($r = 0.06$), confirming their different origins. A relatively high correlation between chlorine and calcium (0.68) was also observed, which can be attributed to calcium and chloride ions participating in precipitation and dissolution reactions that make them simultaneously available in solution. For instance, the dissolution of calcium chloride (CaCl2) can increase the concentrations of both ions simultaneously. Moreover, a strong relationship between Cl and K (0.69) suggests that some of the chlorides originate from the dissolution of KCl, but that the majority of these cations could come from the dissolution of other minerals. The weak relationship between bicarbonates and all parameters is likely due to differences in sources and formation mechanisms, leading to non-overlapping distribution dynamics and interactions, thus limiting possible correlations.

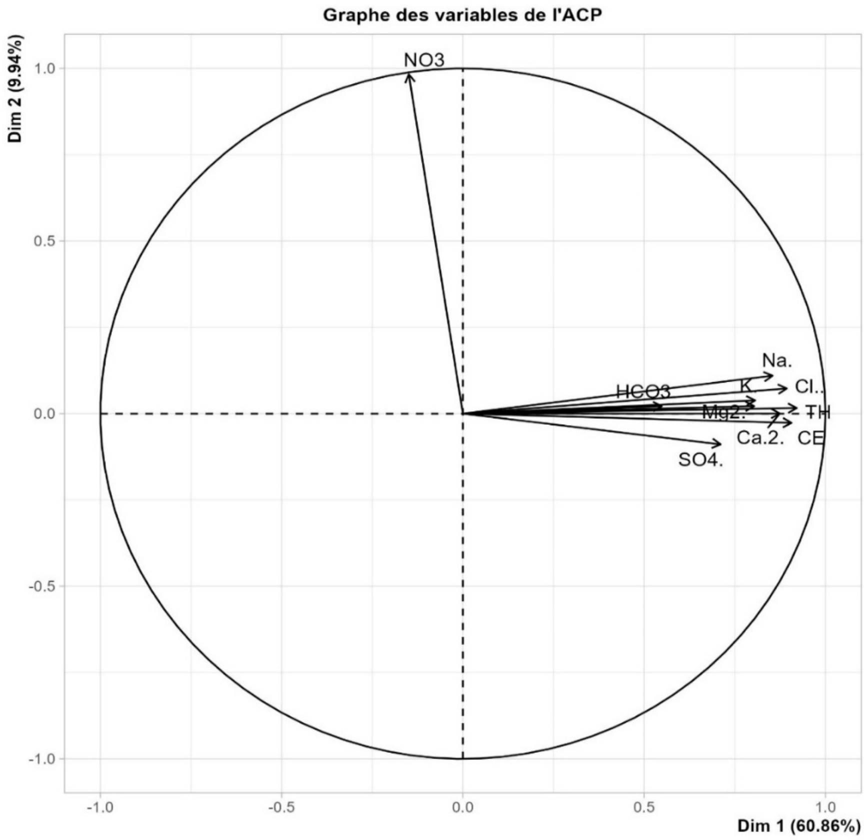

Figure2. ACP variable graph.

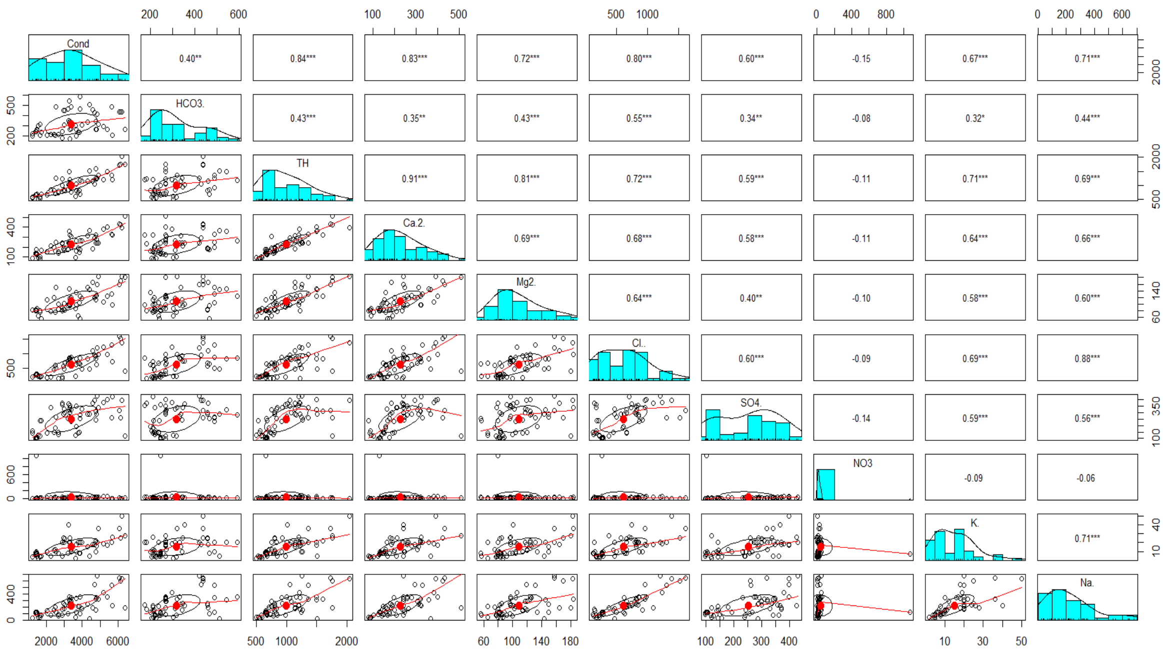

Figure 3. Correlation matrix.

To corroborate the preceding interpretations and facilitate the visualization of the influence of physicochemical parameters on each other and on the water quality in the Biskra region, a principal component analysis (PCA) biplot was generated. This biplot identifies two axes that account for 70.8%

of the information contained in these variables (Figure 4). Projections onto these two axes reveal that Axis 1 summarizes 60.9% of the information and represents variables related to mineralization (CE, HCO3, TH, Ca+2, Mg+2, Cl-, SO4, K, Na). This axis can be interpreted as a mineralization gradient linked to the nature of the rocks constituting the different aquifers supplying the study area with drinking water, urban wastewater, and industrial wastewater (Bouzid-Lagha and Djelita 2012).

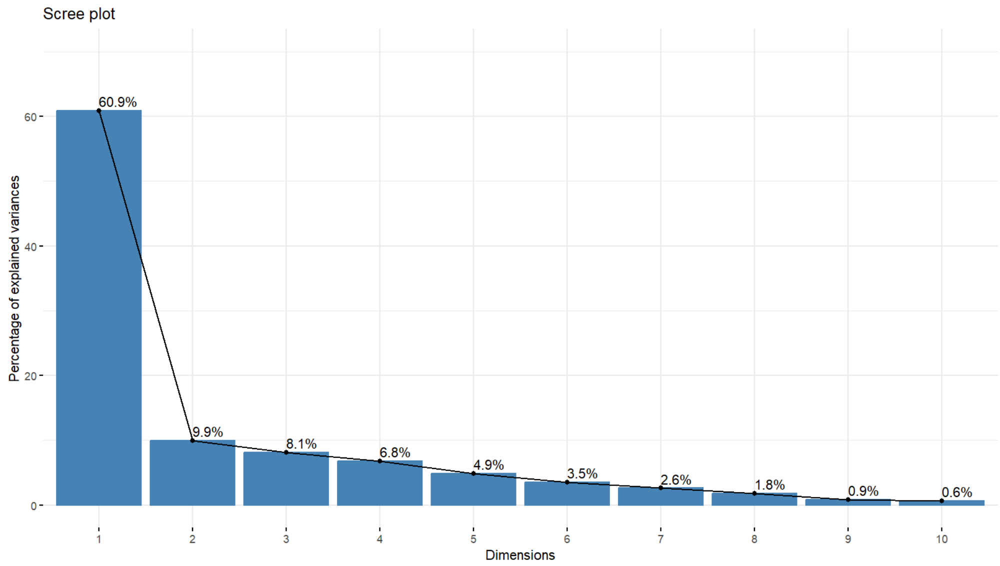

Figure 4. Scree plot.

5. Conclusion.

Analysis of groundwater in the Biskra region, which constitutes the main source of drinking water for the population, has revealed its key characteristics. The application of Principal Component Analysis (PCA) has identified two distinct origins for the different physicochemical elements present in these waters.

The first group, comprising electrical conductivity (EC), bicarbonates (HCO3), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), chlorides (Cl^-), sulfates (SO_4^{2-}), potassium (K^+), and sodium (Na^+), originates from the geological nature of the region. This conclusion is supported by the dissolution of carbonate and gypsum formations (evaporites), which release these elements into the groundwater.

The second group consists exclusively of nitrates (NO_3^-) and comes from two main sources: chemical fertilizers used in agricultural practices and discharges of domestic and industrial wastewater.

6. Conflicts of Interest. The authors declare no conflict of interest.

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