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Contribution of physicochemical analysis and hydrochemical characterization of groundwater of Beni Amer (Tadla basin, Morocco)

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Abstract In this investigation, the physicochemical characteristics of six well water quality of the Beni Amer region from Morocco were evaluated in January 2017 and August 2017 period. These studies were treated by means of a hydro-chemical method that uses the Piper diagram, Schoeller Berkaloff chart and multivariate statistical methods including Principal Component Analysis normalized (PCA) and Hierarchical Classification ascending (CHA). It is found that the water wells are chlorinated sodium and potassium or sodium sulphate. Generally, it is found by measuring the values of certain parameters such as conductivity, sulfates and chlorides that that the water quality of poor well is very bad except for P5 and P6 well according to Moroccan standards [1]. The Principal Component Analysis and Ascending Hierarchical Classification also showed that water resources studied are strongly influenced by water rock interaction (very important mineralization) and human activities.

Keywords Groundwater; Piper; Principal normalized Component Analysis; Ascending Hierarchical Clustering; Beni Amer.

Introduction

Water is a vital natural resource in people life, animals and plants. Having it available in enough quantity and quality helps maintain health. But it can also be a source of disease because of its pollution by industrial waste, sewage, household or agricultural waste. The groundwater contamination by various types of pollution "agricultural, industrial and domestic" has attracted the interest of researchers and policy makers in several regions of the world. In their environmental protection program, some countries have established national networks and / or regional monitoring of groundwater quality. These monitoring systems are aimed to diagnose and monitor the long-term evolution of the quality of groundwater resources. This work focuses on the study of physical and chemical quality of groundwater in the region of Beni Amer.

Materials and Methods

Geographic location

The aquifer of Beni Amir spreads along the irrigated perimeter of Beni Amir and "bour" areas constituting its hydraulic continuity in the west over an area of 600 km^2. It's stretching spreads:

- Oued Oum Er-Rbia South,

- The main channel of the Beni Amir to the North,
- At the limits of Mio-Pliocene outcrops-Quaternary formations in the East and West.

Hydrogeology

Groundwater perimeter Beni Amir flowing NE to SW, has an elliptical shape, and circulates in a plioquaternaire shape, corresponding to a very heterogeneous river-lake continental series extending over approximately 600 km^2 and composed essentially by marls alternations, limestone roughly marl and clay polygenic conglomerates cement. Silts locally calcareous concretions, and conglomerates assigned Quaternary overcome these alternations [2]. Thus, groundwater Beni Amir is contained in low permeable surface formations. Its wall is located on top of a phosphate Eocene formation at a depth of 90 m corresponding to dolomitic clays. Its thickness increases from north to south, it is between 50 and 100 m over most of its extent. This thickness rises to about l0 m in the North (south of El Brouj and Boujaad) to 100 m to the south and is 200 m (north of Dar Ouled Zidouh). The transmissivity varies from 1.10^{-3} to 1.10^{-1} m^2/s. the lower transmissivities meet along the river Oum-Er-Rbia and outside perimeters.

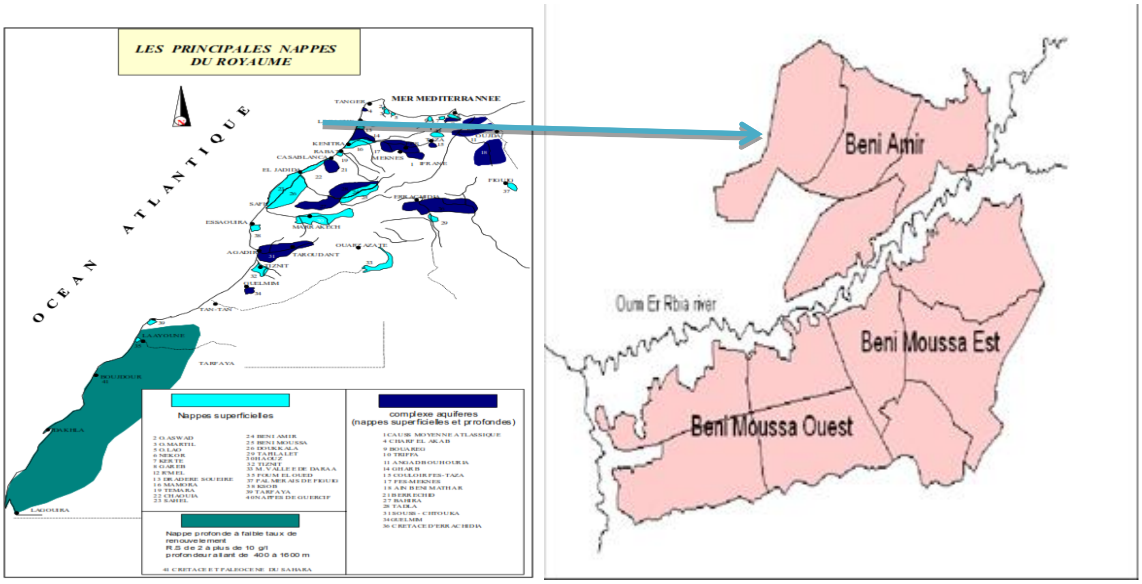


Figure 1: Map the study area (Water Basin Agency State Oum Errbia Quality Water)

Sites levies

Water points were chosen so as to have an overall picture of the groundwater. We took a total of 12 samples for physicochemical analysis of water as follows: six samples during the period of January 2017 and six withdrawals during the period of August 2017.

Analysis

- *In situ* measurements

Some physicochemical parameters change during transport and storage of samples on the way from the sampling site (land) to the laboratory. Therefore, it is always better to make on-site measurements. Temperature measurements, pH and electrical conductivity are carried out "in situ" using a field device (multi parameter Hanna HI 991300).

- Laboratory measurements

The measurements of all physicochemical parameters are made within 48 hours after sampling. Chlorides are measured by Mohr volumetric method in the presence of silver nitrate [3]. Calcium and magnesium ions were determined by complexometric using a disodium salt solution of ethylenediamine tetraacetic acid (EDTA) [3]. Carbonates and bicarbonates are dosed by a volumetric titration with HCl 0.1 N. For the sodium and potassium ions, we used a photometer atomic emission Corning type flame.

Data analysis
The physicochemical data were processed by Principal Components Analysis (PCA) using the XLSAT software Version 2014.

Results and discussion
Physicochemical parameters
Conductivity
The figures shows the spatio-temporal variation of conductivity (the left represent January and the right represent august throughout the manuscript) In January, the waters of the sheet of Beni Amir are noticed to be very salty with conductivities between 2713 µS/cm and 7070 µS/cm waters of all wells are noticed to be poor to very poor quality.
In august, waters of the web Beni Amir are noticed to be salted except for the well which is characterized by an average size (2776 µS/cm for the well P5). All other sites have very poor water with conductivities between 3000 µS/cm and 8000 µS/cm.

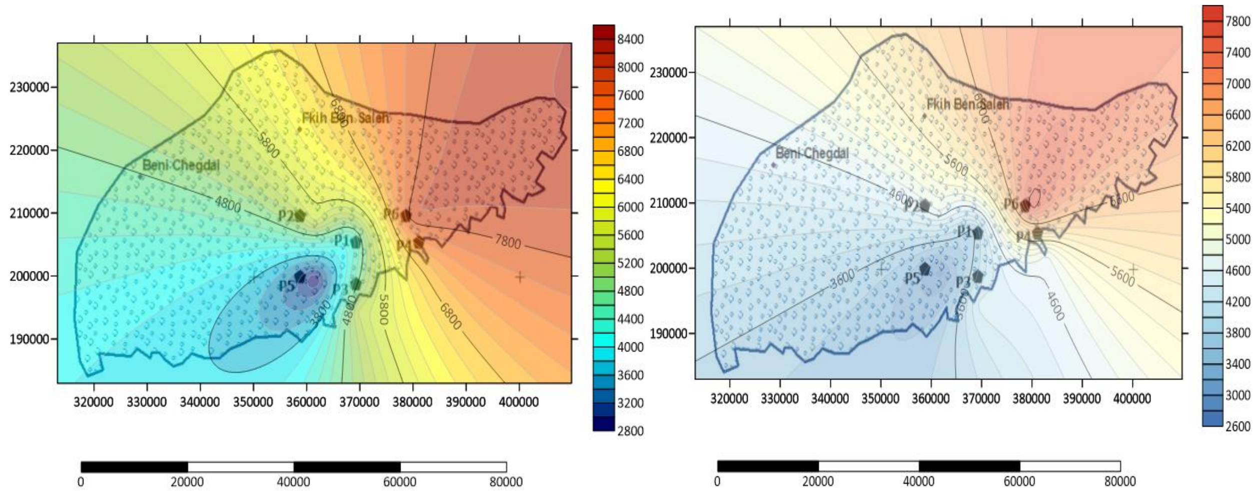


Figure 2: Spatio-temporal variation of the conductivity of wells

Hydrogen potential

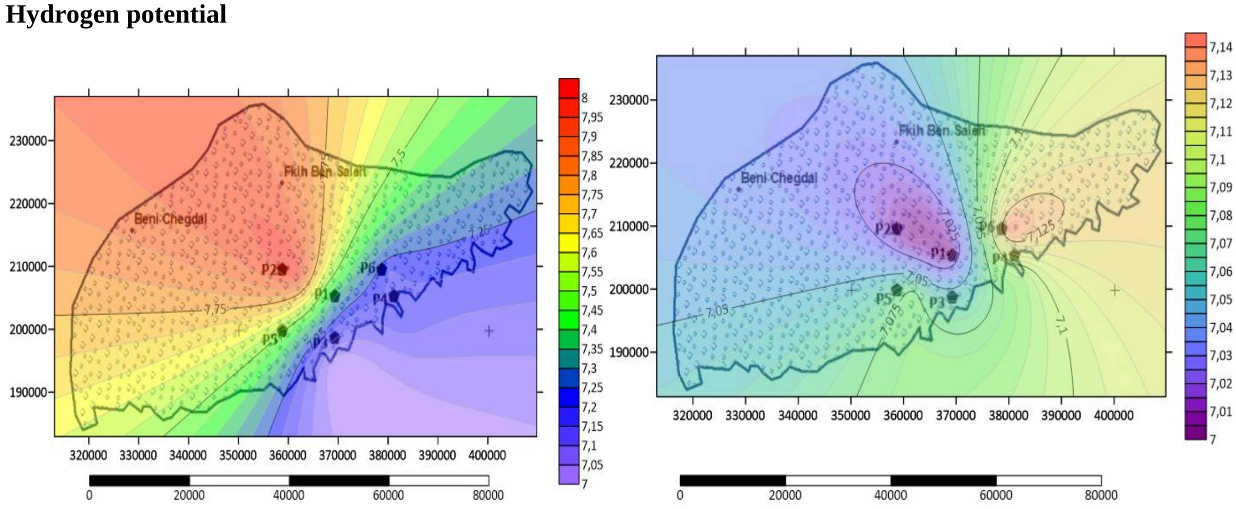


Figure 3: Spatio-temporal variation of the potential hydrogen of wells

The pH depends on the origin of water as well as, the geological nature of the type of land water has crossed. This parameter determines a number of physico-chemical equilibrium between water, the dissolved carbon dioxide, carbonates and bicarbonates [4]. In most natural waters, the pH is usually between 6 and 8.5 while in the warm water, the pH being between 5 and 9. For the study area, the values of pH of the water show no significant variations, with a minimum of 6.95 in the well P3 in august and a maximum of 7,96 in P6 well (January) reflecting a slight alkalinity of the medium

Carbonates

According to figure 4, it is noted that the higher levels of carbonates are stored in the winter season. It is also noted that variations in alkalinity almost remain constant in different stations and very high in almost all the wells with concentrations that vary between 400 mg/L and 490 mg/L. the water is very poor for this parameter except for the P6 site whose quality is average.

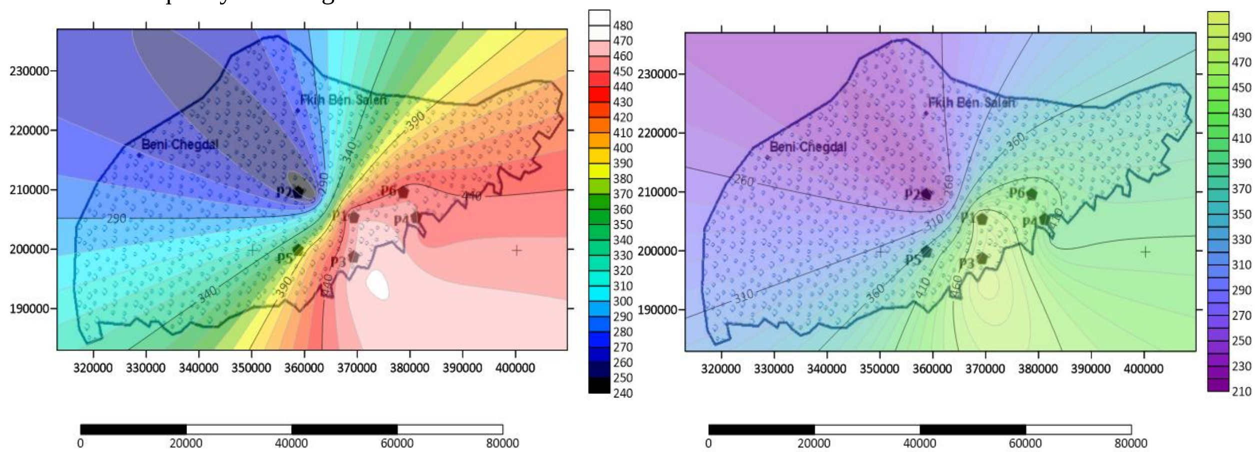


Figure 4: Spatio-temporal variation of carbonate in groundwater

The chlorides

The concentration of chlorides in the water, also depends on the land traversed [5]. Based on the results of the analysis for samples of the water, we note that the chloride ion concentration is very high in almost all the sites with grades between 1087 and 2520.5 mg/L: the waters are very bad for this parameter. Except for two sites (P5 and P6) which is average.

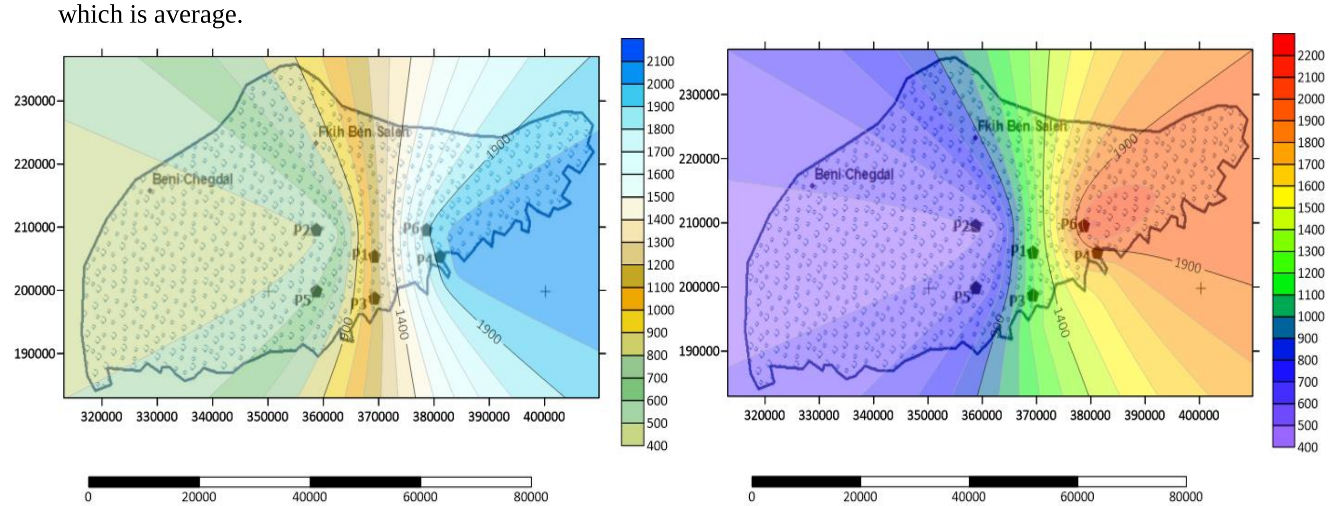


Figure 5: Spatio-temporal variation of chloride ions in groundwater

Nitrates and sulphates

In January or August, nitrate content is variable: some wells have medium nitrates rate (P2, P3, P4) and good rate for (P5 and P6), whereas the other site is polluted with high levels between 52.25 and 93 mg/L. as for sulfate, water wells quality classified from excellent too good.

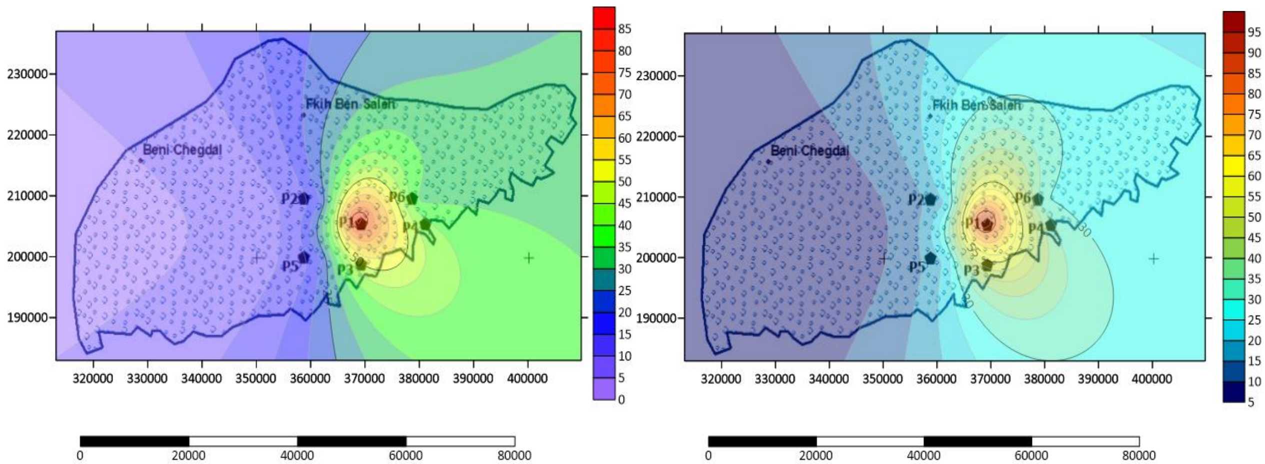


Figure 6: Spatio-temporal variation of nitrates in groundwater

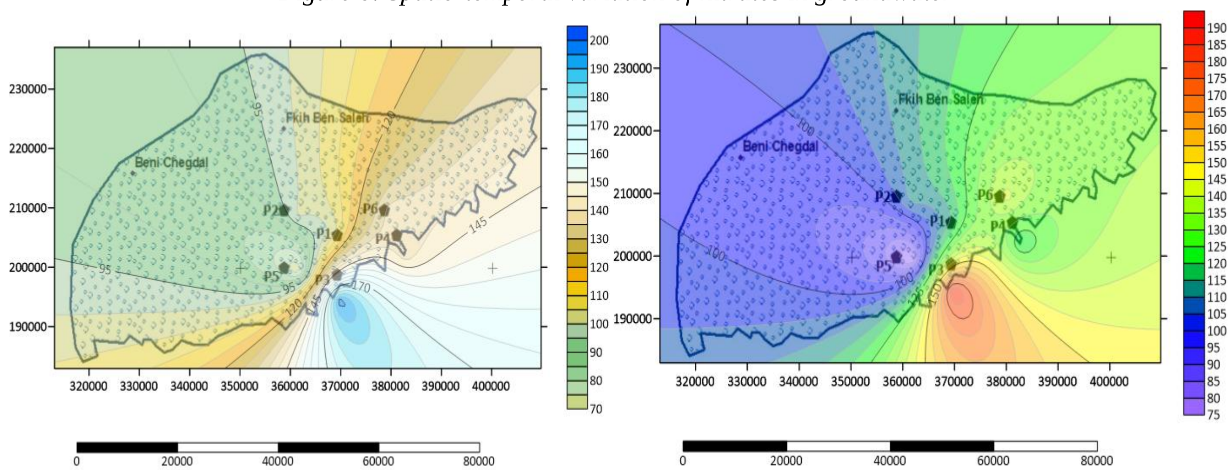


Figure 7: Spatio-temporal variation of sulfates in groundwater

Sodium and Magnesium

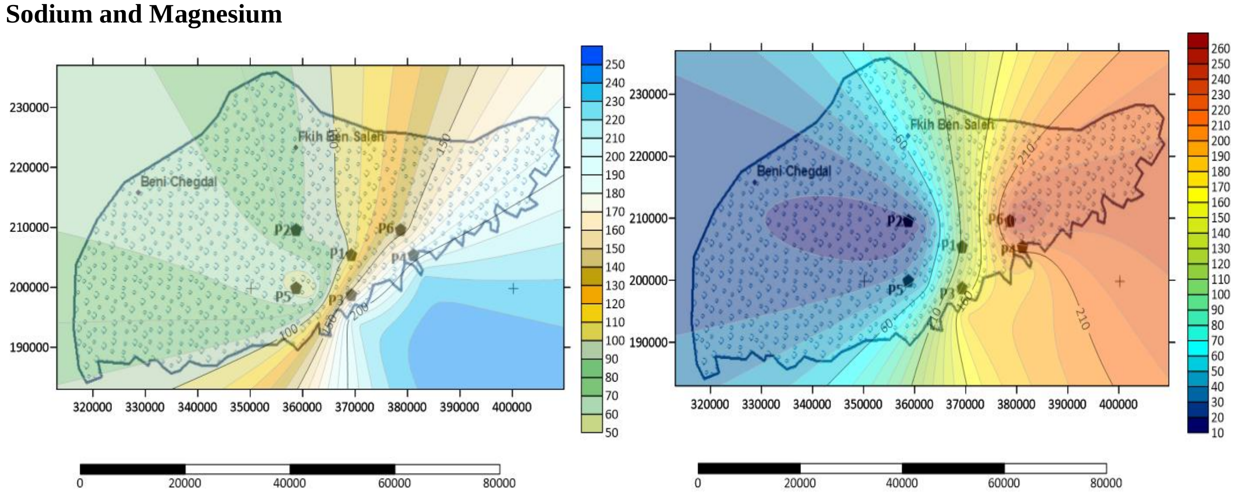


Figure 8: Spatio-temporal variation of magnesium in groundwater

This compound is an indispensable element, in small quantities, to all living organisms. A high concentration of sodium can give the water a salty taste. Sodium in drinking water can have adverse effects on the health of people on a salt-depleted diet. In nature, the sodium contents are relatively constant and vary only in the order of a few tens of milligrams per liter, independent of the leaching of the geological formations containing sodium chloride, for these water the content of sodium is high in most sites with rates high above the value of 200 mg/L This shows that the water is of poor quality.

Magnesium water content is high in the P2 site, P3 and P4 with rates between 147 mg/L and 257 mg/L, against the well P1, P5 and P6 having a rate which does not exceed 100 mg/L. This shows these waters are classified from good to average.

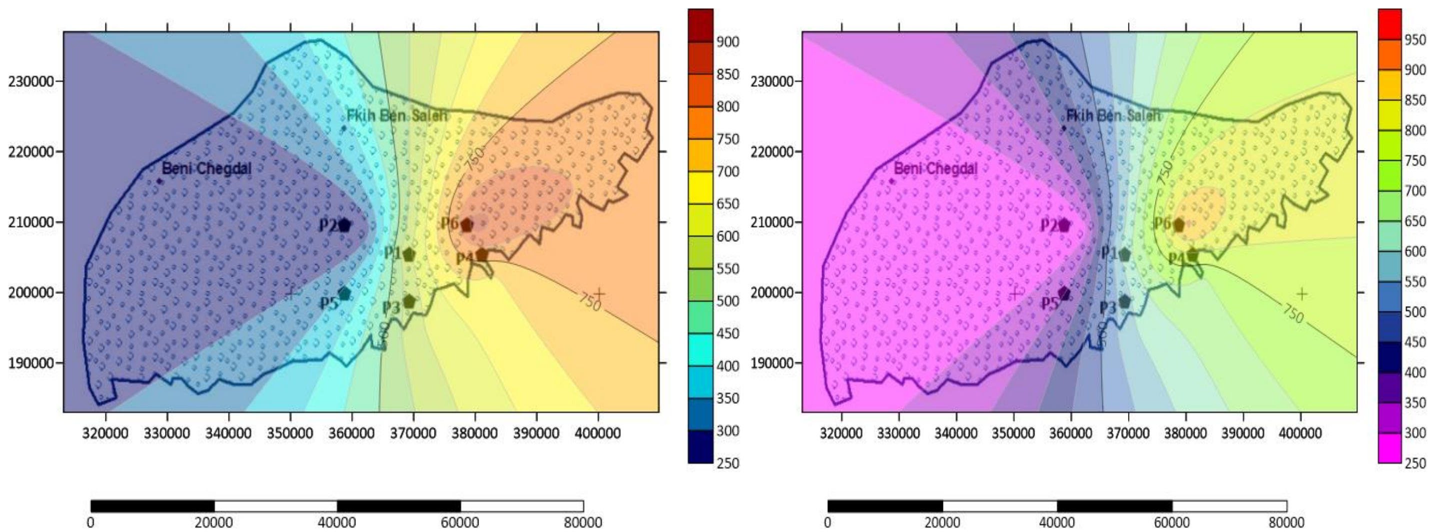


Figure 9: Spatio-temporal variation of sodium in groundwater

Potassium and Calcium

The calcium content is very high in the summer compared to the winter period. It varies between 100 mg/L and 267 mg/L, the calcium level in most wells exceeds the standards except for wells P5 and P6.

Concerning potassium, all the stations show very low levels with concentrations between 2.33 mg/L and 4.10 mg/L.

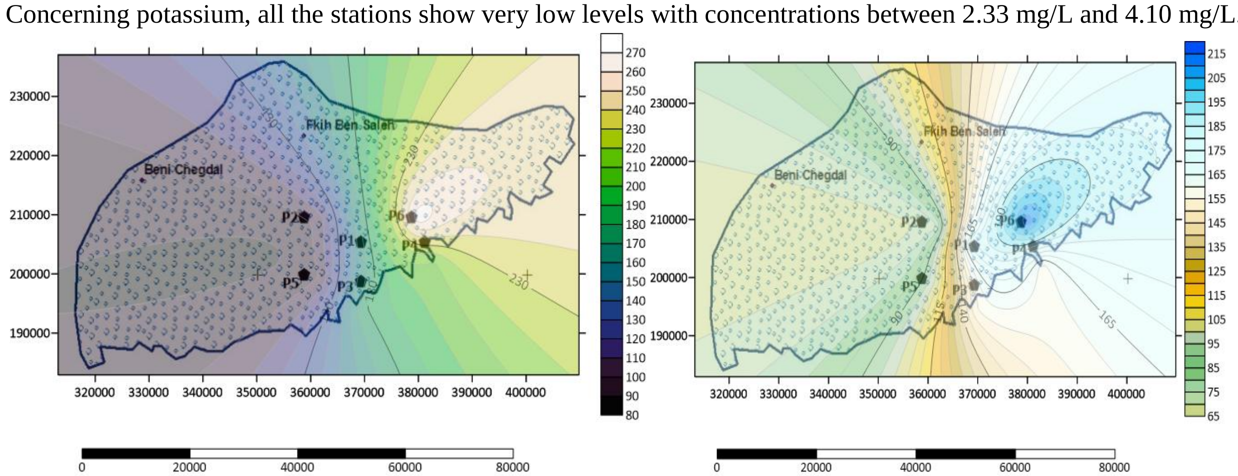


Figure 10: Spatio-temporal variation of the pot calcium in groundwater

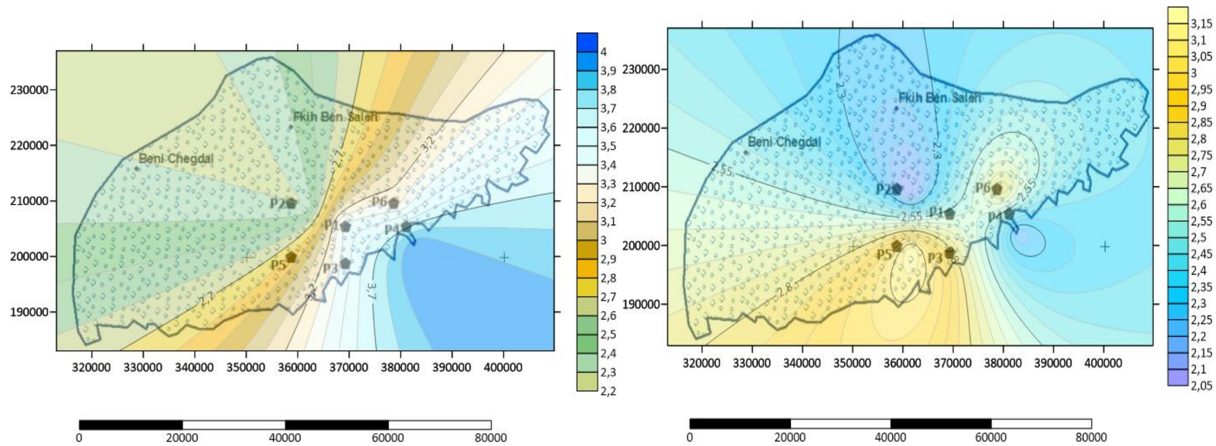
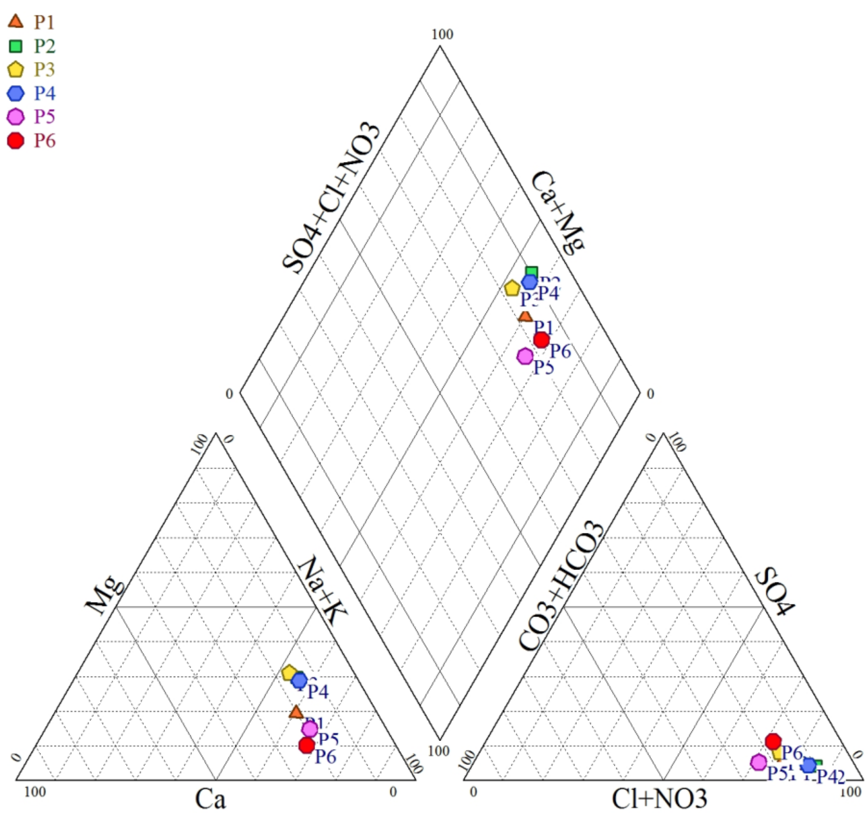


Figure 11: Spatio-temporal variation of the potassium in groundwater

Graphical representations

The representation of the results of chemical analysis in diagrams of Piper and Schoeller Berkaloff identified the type of facies crossed by groundwater (Figure 8). Most of the well are characterized by a facies chlorinated sodium and potassium or sodium sulphate. The waters of the region are therefore characterized by a predominance of chloride ions to bicarbonate ions and sulfate ions which are found in waters with lower content than the WHO (250 mg/L). This result is consistent with that of many authors who worked on the area studied "Tadla region" and have all led to the conclusion drawn by Aghzar *et al* [2].



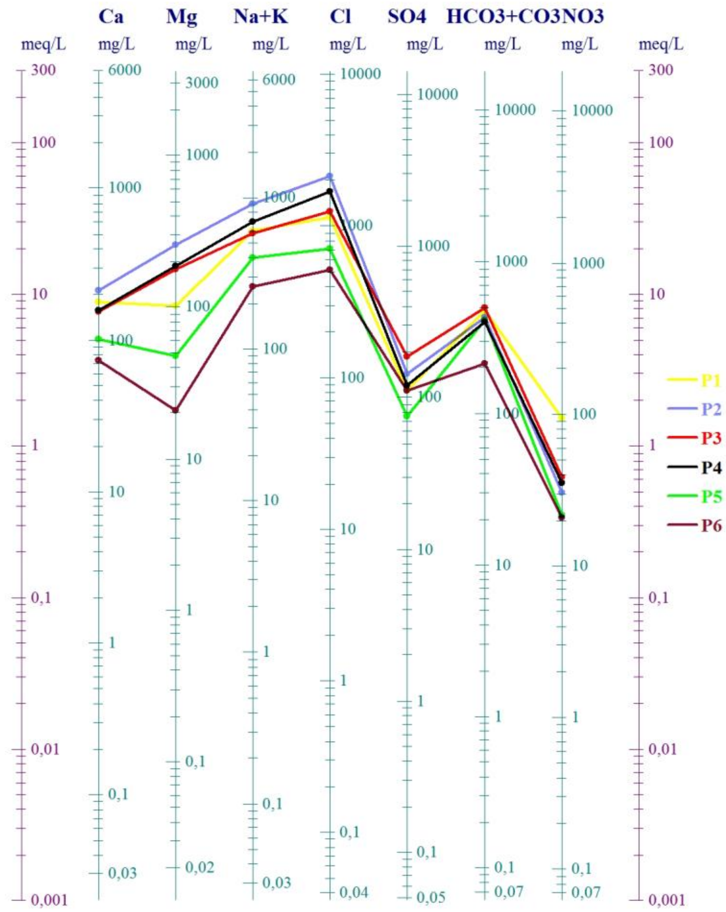


Figure 11: Piper diagram (a) and scholler (b) for different sations in August

The Principal Component Analysis and Hierarchical Ascending Classification

The Principal Component Analysis

This statistical method has been widely applied to investigate environmental phenomena and hydro -geochemical processes around the world [6]. The PCA allows the analysis of quantitative numeric data tables to reduce dimensionality. The principal components are obtained by diagonalization of the matrix of bi-varied correlations. This diagonalization defines a set of eigen-values whose observation for each component makes it possible to determine the number of graphs to be examined [7]. The PCA makes it possible to explain the structure of correlations or covariances using linear combinations of the original data. Thus, its use makes it possible to reduce and interpret the data in a small space. We start from Table 1 consisting of the concentration values of the physicochemical parameters of the six wells of the Beni Amer aquifer.

Table 1: Average concentrations in mg / l of some elements in the waters of the Beni Amer aquifer

Wells	X	Y	T °C	pH	°C 25	NH_4^+	Cl^-	SO_4^{2-}	NO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	HCO_3^-
P1	368.46	206	21	7.4	4256	0.031	1087	101.6	84	572	3.4	160	98	453
P2	380	209.5	19.7	7.2	7986	0.024	1957	137.5	34	874	3.3	267	149	448
P3	369.75	194.39	20.9	7	5434	0.011	1145	198	39.7	578	3.5	178	217	468
P4	382.95	202	20	7.2	6998	0.12	1978	137	42.6	690	4	209	230	445
P5	361.7	199.45	21.4	7.4	2776	0.075	698	71.5	18.56	410	3	100	48	408
P6	361.7	208.88	18.4	8	5680	0.038	524.7	101	18.57	249	2.3	104	96	241

Analysis of the results of the ACP of the design variables space factorial F1-F2 (Figure 10) shows that factorial F1-F2 expresses 74.59 % of the variance expressed. Table 2 presents the values, variances expressed for each factor and their combination. The F1 factor with a variance of 53.40 % expressed is the most important factor, and the factor F2 expresses 21.19 % of the variance.

The F1 axis is strongly correlated to the positive side with temperature, EC, NO_3^-, Cl^-, PO_4^{3-}, HCO_3^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, K^+, Na^+ and NH_4^+. This axis expresses both mineralization and the organic pollution of water. Conversely, the axis 2 is highly correlated with the negative side temperature, chlorides, sulfates, and the calcium hardness (linked principally to the amount of calcium and magnesium in water) and correlated positively with nitrates, ammonium and bicarbonates. This axis expresses less mineralization of water compared to the axis 1 [8].

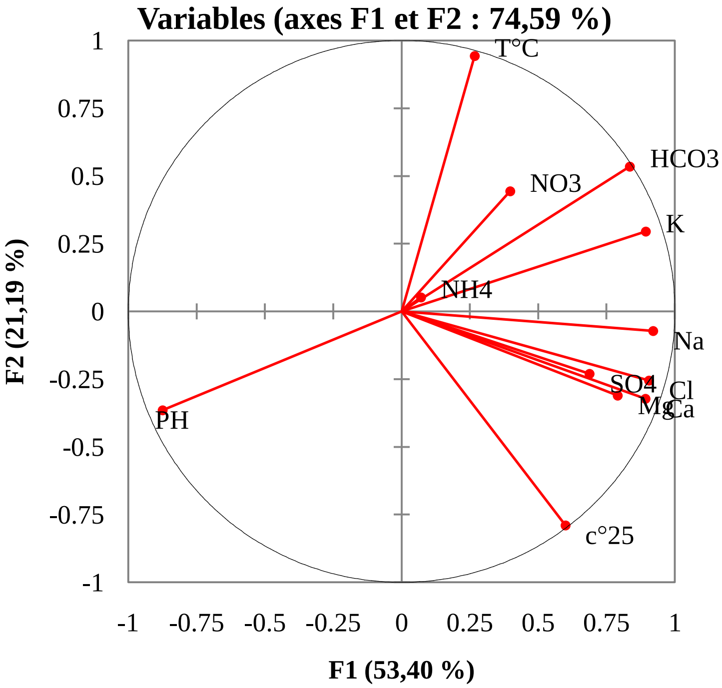


Figure 12: Distribution of variables in the factorial design consisting of CP 1 and 2

Table 2: Values and percentages expressed for the main axes

	F1	F2
Own value	6,408	2,543
Variability (%)	53.401	21.190
Cumulative%	53.401	74.591

The Hierarchical Ascendant Classification

The dendrogram showing the hierarchical cluster wells (Figure 13) obtained from physicochemical data shows three groups of stations:

-Group 1: it consists essentially of P6 well.

-Group 2: it includes the wells P1, P5

-Group 3: it combines well P2, P4 and P3

This distribution is based on the mineralization and nitrogen pollution which indicates a contribution of human activities

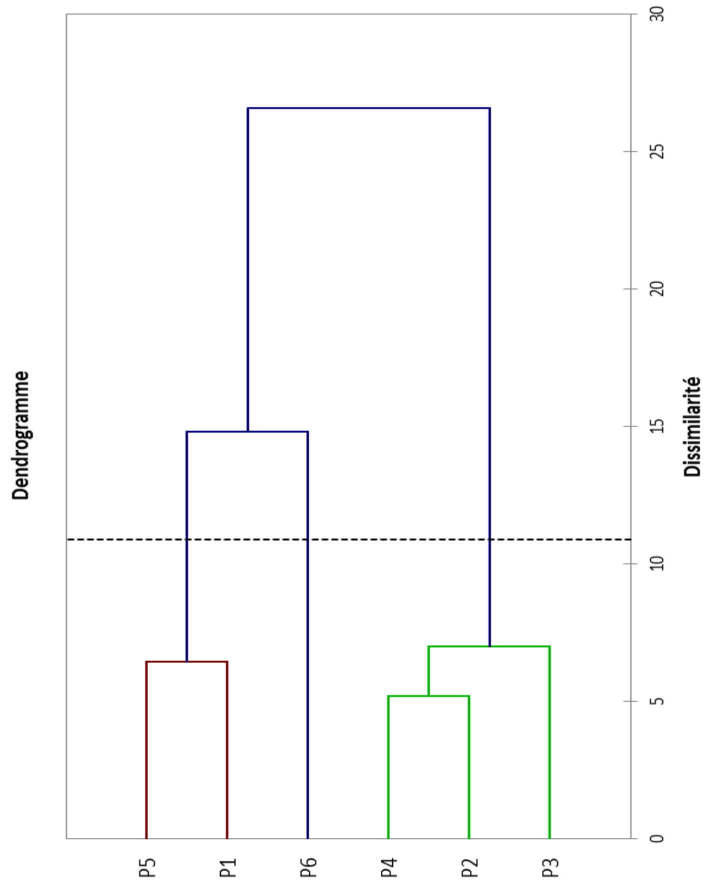


Figure 13: Dendrogram waters of the study area

Conclusion

The Hydrochemical study of groundwater Tadla basin showed that the waters are moderately to strongly mineralized. Piper diagram highlights a type of chemical facies sodium and potassium or sodium chloride sulfated. The conductivity of the water is generally high and ranges between 2713 µS/cm and 7070 µS/cm. this mineralization would come from the dissolution of the aquifer rock.

The results of the physico-chemical analysis of the water of Groundwater Beni Amer, showed that conductivity, sulfates, chlorides testify generally that the water quality of wells in from bad to very bad except for P5 and P6 well according Moroccan standards [1]. Besides, the studied water wells show average concentrations of nitrate to be lower or equal to the standards of drinking water 50 mg/L according to the World Health Organization (WHO) except for the P1 well which exceeds the standards. This confirms the intense impact of agriculture and the discharges of domestic and industrial sewage.

The Principal Component Analysis and Ascending Hierarchical Classification also shows that water resources studied, "water wells" are strongly influenced by water rock interaction (very important mineralization) and human activities.

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