Geostatistical Approach for Evaluating Heavy Metal Contamination in Groundwater in the High Ziz Basin (Morocco)

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ABSTRACT

In the south of morocco, especially the Ziz basin, access to the drinking water becoming a concern for the populations. In addition, is a main factor in the economic development of the region and the key to improving the standard of living of people and improving their health and ensure their stability in the region. Hence, the objective of this study is to evaluation of the concentration of the heavy metal (Cd, Cu, Fe, Ni, Pb and Zn) and determine the sources of pollution in groundwater of the high Ziz basin. Heavy metals soluble in groundwater after filtration is evaluated by atomic emission spectroscopy with inductive coupled plasma (ICP-AES) using a JY-type spectrometer.

For a better evaluation the impact of deposits mineral deposits and geological formations on groundwater quality, we have analyzed the different variables through their correlations, orientation in the factorial plan F1 * F2 to identify the main factors which influence the quality of groundwater in the study region.

Based on this fact, we have adopted a multi-tool approach based mainly on hydrochemical studies and geostatistical techniques. Indeed, the Principal Component Analysis (PCA) shows four groups of groundwater according to the degree of contamination and the nature of the metal pollutants.

Keyword. Groundwater, Heavy metals, Geostatistical, ACP, High Ziz Basin, Morocco.

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1 INTRODUCTION

Water is a renewable resource constantly threatened by pollution, among others, demographic backgrounds, agricultural and industrial factors [1]. Access to safe drinking water is a prerequisite for health, a basic human right and a key component of effective health protection policy [2]. Currently, many groundwater sources in the "High Ziz Basin" suffer from the negative impact of human activities and natural environmental conditions on their water quality [3]. The objective of this study is to evaluate the groundwater mineral quality of the High Ziz Basin in the south of Morocco and to identify the sources of pollution with a view to establishing a groundwater quality map.

A standard sampling procedure was used to collect 20 groundwater samples [4] from the various wells and boreholes distributed over the study area. For the assessment of groundwater quality statistical techniques were used [1, 2].

2 Study area :

The study area is located in Ziz high basin (Central High Atlas, Morocco (Figure 1)

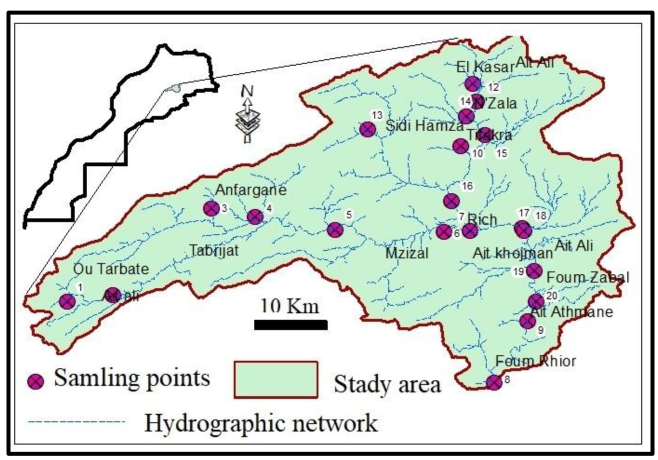

Fig. 1 Study Area located in the Ziz high basin (Central High Atlas, Morocco) of Morocco

***Geologically**, the Ziz watershed includes distinct structural domains that span from the Mesozoic until the Quaternary. The Jurassic series form the major part of Mesozoic terrains of the High Atlas; they are based conformably on the red clastic formations of lower Triassic-Liasic. Their lithology consists essentially of dolomite, limestone, calcareous marl alternations and silico-clastic detritus. The Trias is constituted of detrital deposits, doleritic basalt with evaporite levels, in angular unconformably above the deformed Paleozoic basement and structured by several tectonic phases. The Jurassic series rest conformably on the red formations Triassic-Lower Lias [5, 6].

* ***Hydrogeologically***, the water resources in the Ziz watershed consist of a share of aquifers located along the valleys and characterized by their small size and their direct dependence on weather conditions. Moreover, The Ziz watershed contains a set of interconnected hydrogeological units (Lias and Dogger): The Lias is forming a relatively continuous system and Aalenien and Dogger aquifers form networks, fragmented into separate basins [1, 2 and 3].

Climate

The Ziz watershed is located in a semi-desert bioclimatic stage. Temperatures have significant seasonal variations with a very hot summer and a very cold winter. The annual rainfall regime is characterized by the existence of two rainy seasons: autumn and spring [1, 2 and 3].

3 MATERIAL AND METHODS

3.1 SAMPLING POINTS :

We took samples from twenty water points (wells, boreholes, and springs) chosen so as to have an overall picture of the waters of the Jurassic aquifers of the Upper Ziz basin.

The heavy metals contents of these waters (Lead, Zinc, Nickel, Iron, Copper, Cadmium, Cobalt) were determined at the Oriental Center for Water Sciences and Technologies (COSTE) laboratory.

3.2 GEOSTATISTICAL STUDY

For any hydrochemical study, the separate study of each of the parameters is an important step when analyzing and interpreting the geochemical behavior, but it is often insufficient. Data must, therefore, be analyzed and interpreted taking into consideration their multi-criteria nature. To study the sources of water pollution, we carried out a statistical technique, particularly the analysis of principal components (PCA) [1, 2 and 7].

4 RESULTS AND DISCUSSION

4.1 Results of the identification of explanatory variables by the ACP

PCA is a descriptive multi-criteria technique whose objective is to present in matrix form the maximum of information contained in a statistical database . This statistical database is made up, in rows, of "individuals" (boreholes and springs) on which are measured "quantitative variables" (metal elements) arranged in columns. It allows the number of variables to be reduced in order to project the point cloud into a two-dimensional (F1*F2) subspace generated by pairs of factor axes [1, 2 and 3].

The results of this statistical study (ACP) are presented in tabular or graphical form to realize information and facilitate their analysis. This technique of interpretation and analysis of an array of data can be used to identify similarities between water points related to the studied parameters (metal elements).

* Choice of Eigenvalues (selectable number of factors)

The eigenvalue table and graph show that the first two factors represent 63.48% of the variances expressed. These factors combine the maximum of the variances expressed and are enough to accurately analyze and interpret the information sought (Table 1 and figure 2).

Table 1. The table of eigenvalues.

Factors	Eigenvalue	% Total variance	Cumulative Eigenvalue	Cumulative %
Factor 1	2,98	37,28	2,98	37,28
Factor 2	2,10	26,20	5,08	63,48
Factor 3	0,98	12,20	6,05	75,69
Factor 4	0,89	11,19	6,95	86,87

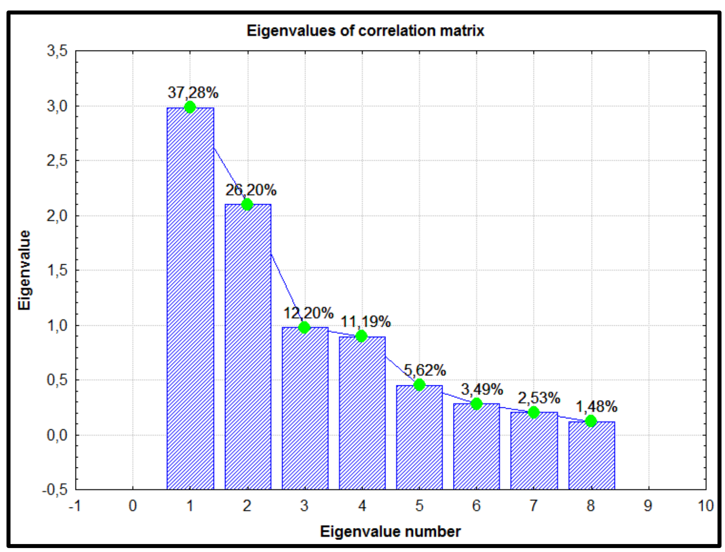

Fig. 2. Eigenvalues of correlation matrix

The factor F1, with a variance of 37.2%, is the most important factor. Then comes the factors F2, F3 and F4 with respectively 26.20%, 12.20% and 11.19% of the variance expressed. The factors selected are those whose eigenvalues are greater than or equal 1. Given these different conditions, the first three factors can be retained. Indeed, the eigenvalues of these factors vary between 2.10 (F2) and 2,98 (F1). Also, the cumulative variance calculated is 63.48%. The factorial axes F1 and F2 selected for this statistical study are representatives of the variance of the data set hydrochemical. The factorial design F1 -F2 thus represent cumulative variance equal to 63.4%. In view of this percentage expressed, it can be considered that the mechanisms that control the variation of the contamination of groundwater with the metal elements are largely contained in these two factors.
The correlation matrix presented in Table 2 shows the correlations between the variables studied. These correlations are necessary for understanding the phenomena of contamination of the region's waters by heavy metals.
This matrix of correlation shows an average correlation between Cu-Pb (0.676); Pb-Tp- (0.559); Fe-pH (0.515) and Cu-Tp (0.408). It also shows a strong correlation between the CE-Tp variables (0.860). These different correlations reflect the influence of each metal elements in the contamination and pollution of groundwater in the basin of Ziz.

Table 2. Correlation matrix of physico-chemical variables.

	Cu	Fe	Ni	Pb	Zn	CE	Tp°	pH
Cu	1							
Fe	0,343	1						
Ni	-0,048	0,327	1					
Pb	0,676	0,194	-0,032	1				
Zn	-0,356	-0,101	-0,265	-0,027	1			
CE	0,232	-0,192	-0,179	0,441	0,140	1		
Tp°	0,408	-0,128	-0,170	0,559	0,049	0,860	1	
pH	0,064	0,515	0,238	-0,187	-0,225	-0,643	-0,574	1

* *Analysis of the distribution of parameters in the plan F1xF2*

The matrix of correlation presented in the figure 3 shows the principal results of this statistical study (PCA) in factorial plane F1-F2. The first factor F1 is defined by a grouping situated in its positive part and constituted by the Fe, Ni, and pH with a variability of 37.28%. Conversely, the second factor F2 is presented by a group consisting of the temperature, Pb, +, Cu, Fe, Ni and pH in its positive part with a variability of 26.20%.

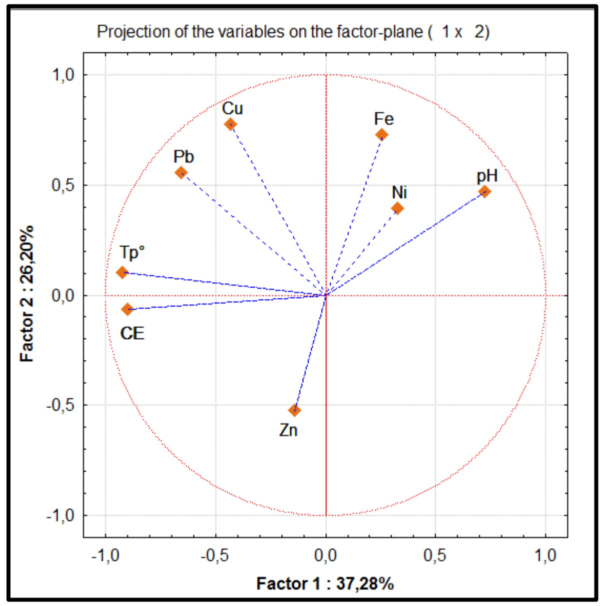

Fig. 3. Projection of the statistical variables in the factorial plane F1-F2.

In fact, the principal component analysis (PCA) was done to identify trends, correlations and phenomena that may influence the distribution of heavy metallic elements in groundwater of the basin of Ziz.

Figure 4 presents the projection of the individuals (water points) in the factorial plane F1 * F2, this matrix allows the identification of three groups (GI, GII and GIII), depending on the nature (heavy metals) of pollutants and their degree of contamination of groundwater in the region.

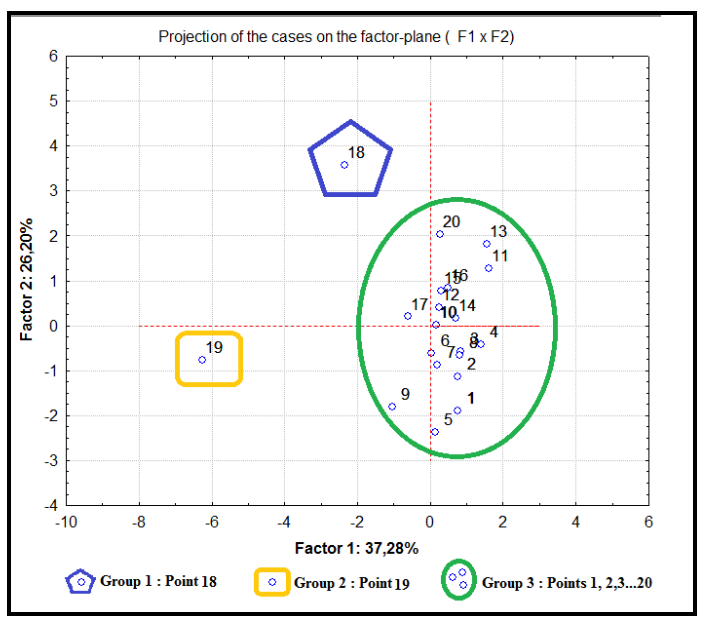

Fig. 4. Representation of water points of the factorial plan F1×F2

Group I: These water points are characterized by pollution Cu and Pb. It is represented by point 18. This contamination is due to the contact of these waters with the deposit (Pb-Zn) and the hydrolysis of iron ores at depth. This heavy load on these metals Cu and Pb, occupies the positive part of the axis F2 and negative part of the axis F1[7]. .
All the point waters register values exceeding the Moroccan standards of drinkability (10µg / l).

Group II: These water points waters occupies the negative parts of F1 and F2. It is represented by point 19. This area shows a high degree of contamination by a high concentration of Zinc (Zn). This very high concentration of Zinc 23.4µg /l has a negative correlation with the axis F1 and F2.
This contamination is due to the contact of these waters with the deposit (Pb-Zn) and the hydrolysis of iron ores at depth.

Group III: This group represented by a water point cloud at the center of the F1 and F2 axis. It is characterized by a large load in metals (Ni, Fe, Zn). This area has a wide distribution of these metals, precisely in all water points except points 18 and 19[8].

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This pollution is mainly of geological origin: it is due to the contact of these waters with the deposit (Pb-Zn), the ores of chalcosine, magnetite, hematite and gabbro which are dispersed in the zone, the extraction-treatment of ores at the deposits of galena (Pb- Zn), basic and utrabasic magmatic rocks (gabbros and peridotites) and by natural emissions (erosion of volcanic rocks). Iron could possibly come from the oxidation and hydrolysis of iron ores at depth.

5 Conclusion

The application of hydrochemical and statistical tools in the study of the underground waters of the upper Ziz basin made it possible to specify its functioning according to the nature of the pollutants and their degree of pollution. In fact, the results of this study have shown that this pollution is essentially of geological origin; it is due to the contact of these waters with the deposit (Pb-Zn), the ores of chalcosine, magnetite, hematite and gabbro which are dispersed in the zone, the extraction-treatment of ores at the deposits of galena (Pb- Zn), basic and utrabasic magmatic rocks (gabbros and peridotites) and by natural emissions (erosion of volcanic rocks). Iron could possibly come from the oxidation and hydrolysis of iron ores at depth. The application of the statistical tool made it possible to show significant connections between electrical conductivity and the different metals, which made it possible to show a strong participation of Pb, Cu, Ni, Fe and Zn in the pollution of Jurassic aquifers. .
The application of the principal component analysis has shown that two factors explain almost 63.48% of the variance. Factor 1 is that of pollution by Pb and Fe, while factor 2 is that of pollution by Cu, Fe, and Zn. Hydrochemical and statistical tools have, therefore, shown that pollution of groundwater is controlled by metals in conjunction with deposits (Pb-Zn).

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