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Research Article

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Underground Risk Study by Principal Component Analysis: Case of Groundwater Application of the Groundnut Basin of Senegal

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Abstract To establish a relationship between the different physicochemical parameters and to better evaluate the effect of pollution on the groundwater quality of groundnut basin, a principal component analysis process was applied to all parameters. The general objective of this paper is to estimate the probability distribution of the chemical data obtained. The principal component analysis (PCA) applied to the data showed that the variables can be grouped into several main components. The interpretation of the results using these processing tools made it possible to understand that the parameters responsible for water quality are connected in several components. The results obtained in this search for statistical treatment of groundnut basin water clearly showed the most vulnerable groundwater levels in each locality.

Keywords underground waters, pollution, groundnut basin, main components

1. Introduction

Water is a precious and essential natural resource for multiple uses (domestic, industrial and agricultural). Its quality is a factor influencing the state of health and mortality in both humans and animals [1-4]. Water pollution, defined as a physical, chemical or biological degradation caused by human activity, disrupts the hydrochemical, hydrodynamic and aquatic equilibrium conditions thus compromising their multiple uses. The statistical method makes it possible to transform the initial quantitative variables, all more or less correlated with each other, into new quantitative variables, called principal components [5-6].

2. Material and methods

2.1. Study zone

The study area concerns the groundnut basin which is located towards the center of Senegal. It consists of five (05) regions: Diourbel, Fatick, Kaolack, Kaffrine and Thies [7]. Groundnut Basin is characterized by a precarious hydraulic resources. This situation is linked, on the one hand, to the scarcity or even the lack of surface water resources (non-perennial watercourses, lower rainfall), and on the other hand to the problems of availability of groundwater resources (hydrodynamic characteristics or poor quality) [8].

2.2. Sample

Among the five regions, we randomly selected a total of fifty-six sampling sites, or 11 samples per zone. The water samples were placed in well labeled 500 ml vials indicating origin and date of collection. After sampling, the samples were stored in a cooler and immediately sent to the laboratory of the Polytechnic School of Thies for analysis.

2.3. Physicochemical and statistical analyzes

The main component analysis approach was obtained thanks to the characterization of the groundnut basin of Senegal (Kaolack, Kaffrine, Fatick, Diourbel, Thiès) This characterization was made using an AL 800 spectrophotometer for the complete identification of chemical parameters [9]. The data obtained from this analysis were processed by the xlstat software. This treatment makes it possible to classify in a factorial plan by identification the most representative elements and possibly the layers more vulnerable to pollution [10]. It should be recalled that the data are geochemical analyzes taken at the five (05) sites of the groundnut basin intervention zone.

3. Resultats and Discussions

3.1. Physico-chemical typology of PCA waters of Kaolack and Kaffrine regions

The figure 1 and 2 respectively represent the graphical approach of the PCA according to the correlation circle and according to the F1 and F2 plane.

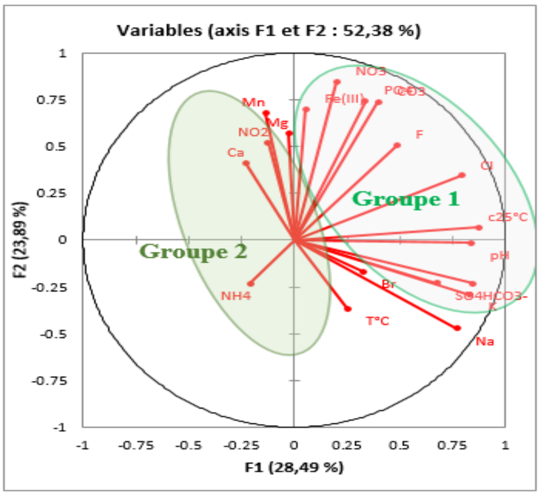

Figure 1: Distribution of the inertia between the axes for the Kaolack and Kaffrine waters, the correlation circle of the variables

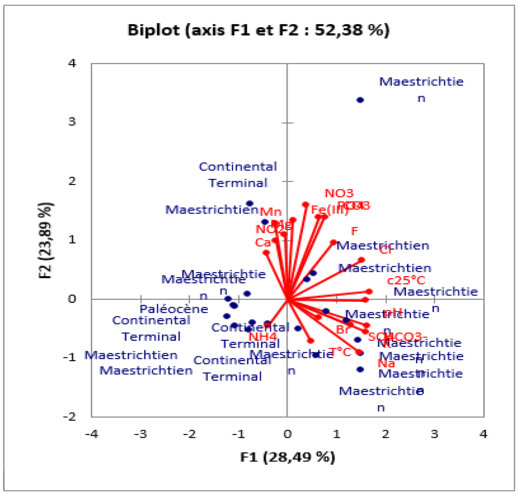

Figure 2: Distribution of the inertia between the axes for the Kaolack and Kaffrine waters, factorial map in the plane

In the factorial plane F1 and F2, the correlation circle formed by the axes F1 and F2 giving 52.38% of the total information. This plan also shows, on the F1 axis (28.49%), the highly mineralized waters rich in fluorides and chlorides, on the F2 axis 23.89% of the weakly mineralized waters. These weakly mineralized waters are associated with variables such as the ammonium ionNH_4^+, which is an indicator of domestic pollution.

The F2 axis (23.89%) is associated with variables such as nitrite (NO_2^-), ions, nitrate (NO_3^-), and phosphates (PO_4^{3-}). It defines a faecal pollution axis that is well relative to our percentage scale.

We can deduce from the correlation circle reading that fluoride and chloride contents are strongly positively correlated. As for the other parameters, very close to the origin, are weakly correlated because the angle which separates them from the origin is close to 90 °.From the observations, the global analysis makes it possible to define a typology dominated by the individualization of two (02) groups of follow-up G1 and G2:

- A group G1 located in areas where salinization and the presence of fluoride ions are strongly noticed. Moreover, this is the case for almost half of the samples studied in these two localities;
- A group G2 where we observe a weak mineralization close to the origin. We can say that these areas are in good quality tablecloths.

3.2. Physico-chemical typology of the PCA waters of the Diourbel region

The Figures 1 and 2 respectively represent the graphical approach of the PCA according to the correlation circle and according to the plane F1 and F2. They also tell us about the distribution of the inertia between the axes for the waters of Diourbel.

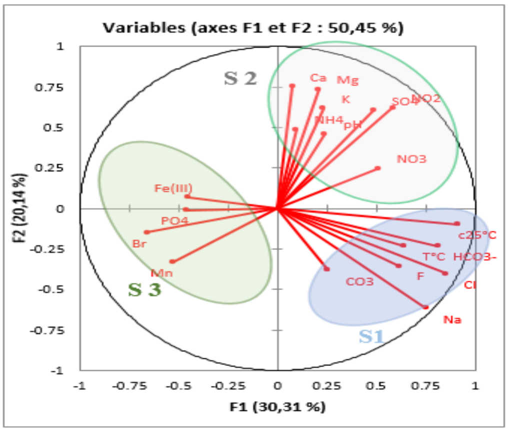

Figure 3: Distribution of inertia between axes for Diourbel waters, the correlation circle of variables

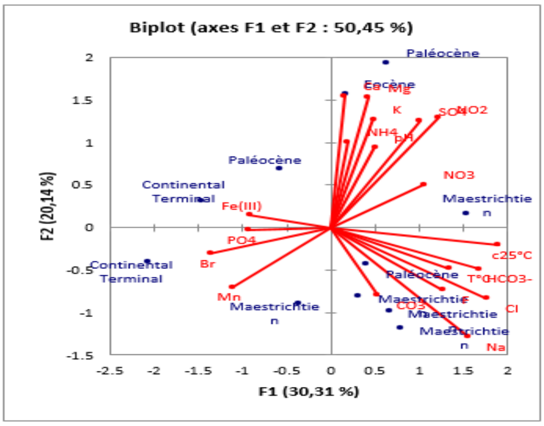

Figure 4: Distribution of inertia between the axes for Diourbel waters, factorial map in the plan

In this factorial plane F1 and F2, the correlation circle formed by the axes F1 and F2 gives 50.45% of the total information. At the level of the axis F1, we have 30.31% of information of the total inertia of this model. Whereas at the F2 axis, we have 20.14% of information. Observations with respect to the degree of pollution and mineralization, we have the same similarities with the two previously studied regions. These observations allow us to divide this model into three distinct groups S1, S2, S3, represented at the level of figures 3 and 4:

- Group S1 represents a highly mineralized zone with high fluoride and chloride contents;
- Groups S2 and S3 are poorly represented because close to the origin. These two groups therefore have a low correlation.

3.3. Physico-chemical typology of the PCA waters of the region of Fatick

The figures 1 and 2 respectively represent the graphical approach of the PCA according to the correlation circle and according to the F1 and F2 plane. They also tell us about the distribution of the inertia between the axes for the waters of Fatick.

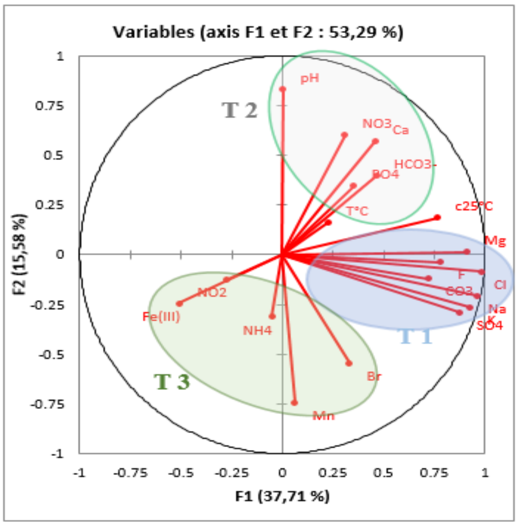

Figure 5: Distribution of the inertia between the axes for the Fatick waters, the correlation circle of the variables

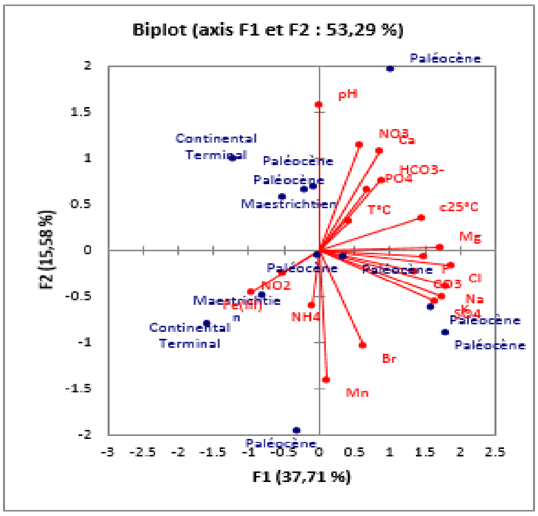

Figure 6: Distribution of the inertia between the axes for the Fatick waters, factorial map in the plan

In this factorial plane F1 and F2 of the Fatick region, the correlation circle formed by the axes F1 and F2 gives 53.29% of the total information. At the axis F1 we have 37.71% information of the total inertia whereas at the level of the axis F2, one obtains 15.58% of information. According to this information obtained, we can say that our representation is of good quality. The observation of the factorial map in the plan shows that the Paleocene aquifer is the most affected by pollution. Indeed it is a tablecloth very far from the origin. From these observations we can divide this model into three (03) separate respectively T1, T2 and T3.

The T1 group is the group where the pollution is much more significant because the elements involved in this study are closer to the correlation circle. In some areas of this region, we have noted dropping out due to fluoride and salt levels that are largely within the guidelines for drinking water distribution.

With regard to the T2 group, we can deduce directly from the reading of the correlation circle that this group contains a specificity with a significant correlation of the PH. This important correlation of the pH means that for this group there is a reduction in the amount of CO_2.This reduction in the amount of carbon dioxide causes the effect of dolomites on this group to have little influence on the geochemistry in this area.

3.4. Physico-chemical typology of the PCA waters of the region of Thiès

The figures 1 and 2 respectively represent the graphical approach of the PCA according to the correlation circle and according to the F1 and F2 plane. They also tell us about the distribution of the inertia between the axes for Thiès waters.

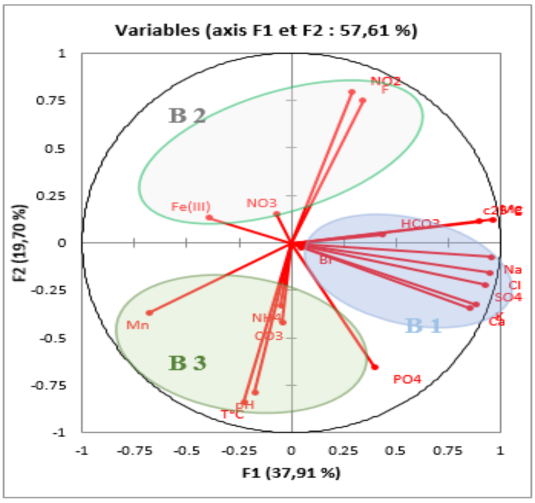

Figure 7: Distribution of inertia between axes for Thiès waters, the correlation circle of variables

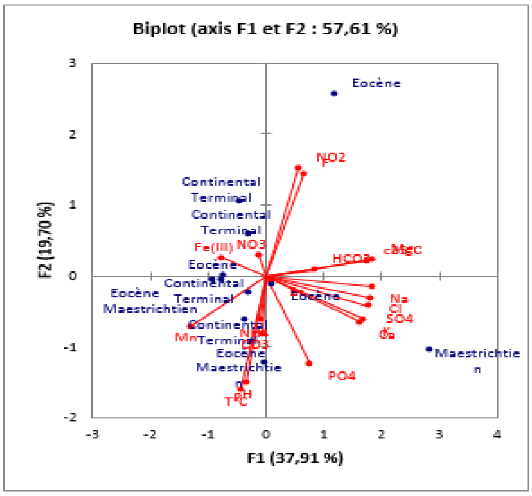

Figure 8: Distribution of the inertia between the axes for Thiès waters, factorial map in the plan

The factorial plane F1 and F2 of the Thiès region shows a total percentage of inertia, the correlation circle formed by the axes F1 and F2 gives 57.61% of total information. This information is respectively for the F1 axis 37.91% of information and 19.70% for the axis F2.We also note here three (03) groups of components B1, B2 and B3.This region shows a particularity at the level of the groups B1 and B2 which constitute a band of pollution being towards the zone of Mbour going towards Fatick where the contents in chlorides and in fluorides are important.

But also at group B3, we have a temperature angle close to the origin that is negatively correlated. As a result, it can be deduced that the increase in temperature has an effect on the quality of the groundwater. In fact, the quality of the water sometimes depends on the temperature and the nature of the rock.

4. Conclusion

The results obtained in this search for statistical treatment (PCA) of groundnut basin water clearly showed the most vulnerable water tables at the level of each locality.

In the factorial plane F1 and F2 of the area of Kaolack and Kaffrine respectively shows strongly mineralized waters (F1) rich in fluorides and chlorides and waters weakly mineralized (F2).

With regard to the Diourbel region, the same similarities are observed with respect to the degree of pollution and mineralization compared with the two Kaolack and Kaffrine regions. The observation of the factorial map of the Fatick region shows that the Paleocene aquifer is the most affected by pollution. Indeed it is a tablecloth very far from the origin.
The region of Thiès has a particularity. It has a band of pollution located towards the Mbour area towards Fatick where the chloride and fluoride contents are important, but also a temperature angle close to the origin and which is negatively correlated.
The PCA is therefore a tool that offers the possibility of simplifying the study of groundwater and to reduce the number of variables to be taken into account in order to better study underground pollution.

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