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RESEARCH ARTICLE

A STUDY ON GROUNDWATER GEOCHEMISTRY AND METALLIC PROPERTIES IN THE GUIR BASIN (EASTERN MOROCCO).

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Abstract

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The management and conservation of groundwater of Talssint (watershed of the guir basin), requires a principal components analysis (PCA) of ten physico-chemical parameters. The results visualization showed that Na^+, Ca^{2+} and Mg^{2+} are positively correlated to the F1 axis, unlike conductivity; pH and K^+ which are associated with this axis negatively. The application of the main component analysis to these results shows that we have two groups of wells, a first group of wells in the positive part of the F1 axis, characterized by water with high (Na^+, Ca^{2+}, Mg^{2+}), at well P1 and P2 and a second group of wells in the negative part of axis F1, characterized by water with high K^+ concentration and high electrical conductivity at wells P3 and P4. This enrichment of chemical elements should be related to the geological contexts of the region.

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Introduction:-

Water is a strategic issue principal and a key factor of sustainable development. In a context of climate change and water scarcity, it is important to know the potential water in quantitative terms and qualitatively for the domestic supply in urban and rural areas and a large megalopolis of tomorrow. This knowledge is a prerequisite for the future development in Morocco (Strobl and Robillard, 2008; Taouil, 2013; Bouras et al., 2010), and fits in with the research strategy oriented toward the optimization and the mitigation of environmental problems.

The water balance and water resources in the regionTyikomiyne are conditioned by three main factors: rainfall, the temperature of the air and extreme climate events, in particular the frequent droughts and sometimes dramatic for the local populations.

The population of the village Tyikomiyne, Region of Talssint uses the groundwater for drinking and irrigation but the soil geological nature in the region can risk of lead contamination by major elements because of the increase in the electrical conductivity of the waters of these wells. As well these elements can accumulate in the food chain and

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pose risks to human health (Taouil et al, 2011). A complete diagnostic of the current situation and a rigorous tracking of its evolution are necessary to judge the chemical and physical quality of these waters and its impact on the environment of the area Tyikomiyne. Some studies concerning the evolution of the water quality of this region have been studied by our group (Taouil et al., 2012; Taouil et al., 2013; Taouil et al., 2013). The objective of this work is to study the spatial variations of certain physicochemical parameters Taouil (2013) in May 2011, at the level of the five wells in the Tiykomiyne region of Talssint region, eastern Morocco. The analysis results obtained show that the pH values have oscillated between values close to neutral to basic values, while the values of electrical conductivity exceed the value set by the European standards and also do not meet the standards set by the World Health Organization (WHO).

Geographical Context:-
Our study area concerns the wells of the Tyikomiyne zone (Figure 1), Talssint region, which to our knowledge has not been the subject of any previous academic study and is limited by:

1. The agglomerations of Douars (Ezzaouia) to the south;
2. The neighborhood (Affia) to the north;
3. The regional road RP601 towards (Beni-Tadjit) to the west;
4. JbalAlaajra to the East.

In order to determine the physicochemical quality of the wells of the Tyikomiyne zone, stations consisting of five wells: Faryat, El Masjid, Hadi, Hilla and Deppiz.

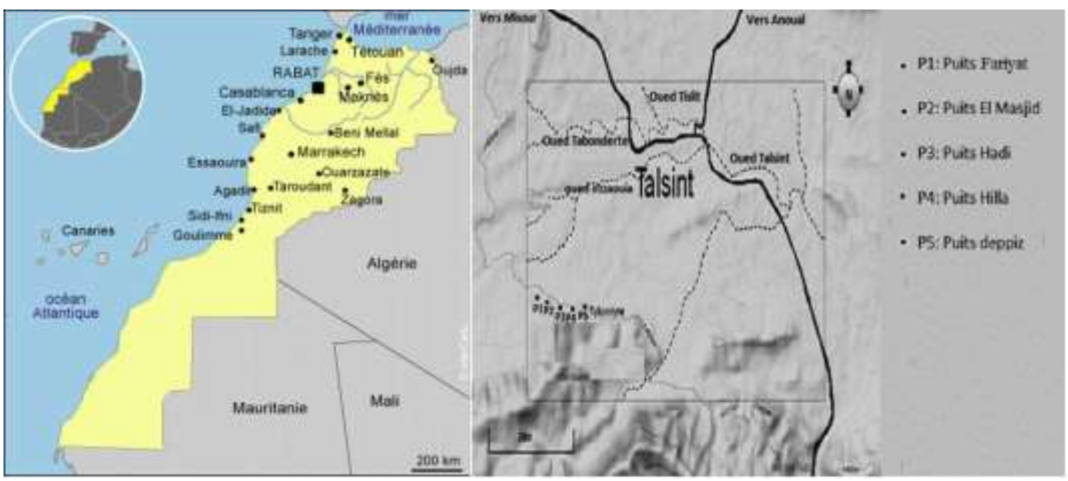

Figure 1:- Geographical location of Tyikomiyne wells, Talssint region.

Data Processing Methods:-
In this study, several principal component analyzes were carried out on two companions during the low water period Taouil (2013) (May 2011), which allows an overall analysis of the physicochemical elements of the groundwater. The objective of the ACP is to present, in graphic form, the maximum amount of information contained in a database, based on the principle of double projection on the factorial axes Lagarde (1995). It explains the structure of correlations or covariances using linear combinations of the original data. The main components are obtained by diagonalizing the matrix of bi-varied correlations. This diagonalization defines a set of Eigen values whose observation for each component determines the number of graphs to be examined (Menció and Mas-Pla, 2008). The final phase of the ACP consists of a graphical representation which gives an overview of the results that the numerical expressions do not provide. Its use reduces and interprets data in a small space Maliki (2000). The correlations between the variables and the axes and the projection of the variables (F1 and F2) were obtained with 'STATISTICA 10'. Indeed, the data of the physicochemical parameters analyzes are processed by this software. Table 1 consists of the values of the ten variables of the five wells (P1, P2, P3, P4 and P5) in the Tyikomiyne groundwater. The aim of this statistical analysis is to highlight the different water points which have high concentrations of chemical elements compared to the whole of the plain. This allows us to give a preliminary idea on the elements and sites of pollution.

Table 1:- Average Concentrations of Some Physico-chemical parameters in waters of Tyikomiyne Wells, Region of Talssint

Variables	Minimum	Maximum	Aérage	St-deviation
pH	7.648	8.425	8.134	0.294
T°	12.432	12.885	12.660	0.182
Cond	1251.167	1428.167	1321.600	65.913
Na^+	19.698	28.018	25.395	3.271
K^+	3.657	4.757	4.326	0.418
Ca^{2+}	251.283	391.498	354.416	59.374
SO4	715.333	1264.833	993.571	257.866
Cl^-	33.417	108.505	65.671	29.975
$Mg2^+$	45.475	80.427	69.115	13.809
$NO3^-$	3.532	42.238	13.856	16.016

Results:-

Matrix of correlation between variables:-

In our case, some variables are positively correlated and others are negatively correlated. Therefore, the physico-chemical parameters which are correlated positively vary in the same direction; which indicates that the increase of the one is controlled by the increase in the other, then the variables which are negatively correlated vary in opposite direction; that is to say the increase of one led to the decrease of the other.

Table 2:- The correlation matrix between the measured variables

Variables	pH	T°	Cond	Na^+	K^+	Ca^{2+}	SO4	Cl^-	Mg^{2+}	$NO3^-$
pH	**1**	0.263	0.339	-0.403	0.903	-0.558	-0.429	-0.804	-0.459	-0.943
T°	0.263	**1**	-0.685	-0.231	-0.070	-0.293	0.422	0.251	-0.117	0.036
Cond	0.339	-0.685	**1**	0.073	0.654	0.096	-0.717	-0.684	-0.151	-0.616
Na^+	-0.403	-0.231	0.073	**1**	-0.474	0.971	0.631	0.557	0.969	0.228
K^+	0.903	-0.070	0.654	-0.474	**1**	-0.556	-0.758	-0.965	-0.606	-0.947
Ca^{2+}	-0.558	-0.293	0.096	0.971	-0.556	**1**	0.565	0.618	0.922	0.367
SO4	-0.429	0.422	-0.717	0.631	-0.758	0.565	**1**	0.856	0.786	0.533
Cl^-	-0.804	0.251	-0.684	0.557	-0.965	0.618	0.856	**1**	0.679	0.871
Mg^{2+}	-0.459	-0.117	-0.151	0.969	-0.606	0.922	0.786	0.679	**1**	0.343
$NO3^-$	-0.943	0.036	-0.616	0.228	-0.947	0.367	0.533	0.871	0.343	**1**

Positive correlation:-

The positive correlations (variation of physico-chemical parameters in the same direction) and after the strong Degrees of correlation between the studied variables, can classify them into seven groups (Table 3):

Table 3:- Classification of the positive correlation of some used Physico-chemical parameters

Correlation degree	0,903 to 0,971	0,856 to 0,871	0,618 to 0,679	0,533 to 0,565	0,339 to 0,367	0,228 to 0,263	0,036 to 0,096
Variables	K^+ / pH Mg^{2+} / Ca^{2+} Mg^{2+} / Na^+ Ca^{2+} / Na^+	Cl^- / SO4 NO^{3-} / Cl^-	Cl^- / Ca^{2+} SO4 / Na^+ K^+ / Cond Mg^{2+} / Cl^-	NO^{3-} / SO4 Cl^- / Na^+ SO4 / Ca^{2+}	Cond / pH NO^{3-} / Mg^{2+} NO^{3-} / Ca^{2+}	NO^{3-} / Na^+ Cl^- / T° T° / pH	NO^{3-} / T° Na^+ / Cond Ca^{2+} / Cond

Negative correlation:-

The negative correlations which vary in two opposite directions where one of the variables increasing led to the decrease of the other and after the low correlations between the groups of variables studied, we can classify them into seven classes (Table 4):

Table 4:- Classification of the negative correlation of some used Physico-chemical parameters

Correlation degree	-0,965 to -0,943	-0,758 to -0,717	-0,685 to -0,606	-0,558 to - 0,556	-0,474 to - 0,403	-0,293 to -0,231	-0,151 to - 0,117
Variables	Cl^- / K^+ NO^{3-} / K^+ NO^{3-} / pH	SO4 / K^+ SO4 / Cond	Cond / T° Cl^- / Cond NO^{3-} / Cond Mg^{2+} / K^+	Ca^{2+} / pH Ca^{2+} / K^+	K^+ / Na^+ Mg^{2+} / pH SO4 / pH Na^+ / pH	Ca^{2+} / T° Na^+ / T°	Mg^{2+} / Cond Mg^{2+} / T°

The diagonalization of the correlation matrix:-

Table 5 and Figure 2 give the diagonalization of the correlation matrix. The second row indicates the Eigen values of the correlation matrix. The third line tells us the percentage explained by each Eigen value.

Table 5:-Diagonalization of the correlation matrix of variables

	F1	**F2**	**F3**	**F4**
Valeurpropre	5.956	2.426	1.419	0.200
Variabilité (%)	59.555	24.260	14.189	1.995
% cumulé	59.555	83.815	98.005	100.000

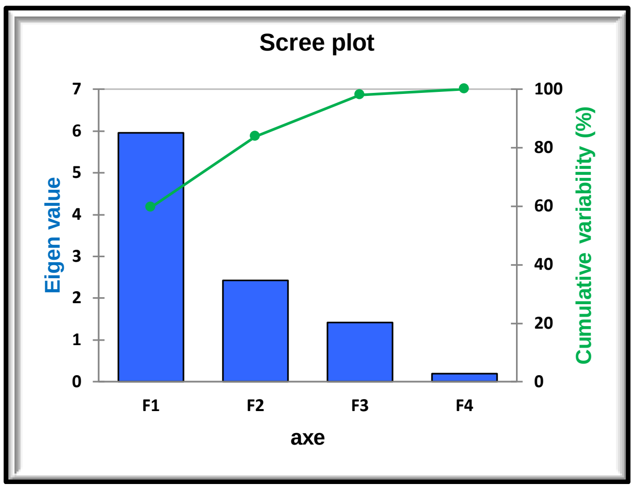

Figure 2:- Graphical representation of the Eigen value and cumulative variability

Variables representation and variables circle:-

The ACP is a factorial method using linear combinations between the variables to analyze the data. This method, which involves the reduction of the data, allows us to present geometrically the variables and the observations. The reduction of the characters number is not achieved by a simple selection of some of them, but by the construction of new synthetic characters obtained by combining the initial characters by the factors. This reduction will only be possible if the initial variables have non-zero correlation coefficients. The results interpretations of the variables are done on the correlation circle, the variables which are close to the circle and which are close to each other have a strong linear relationship between them. On the other hand, the points which are opposite, present an inverse relation. The projection of the variables allows us to interpret the main components and to quickly identify the groups of characters linked together or opposite, provided that the points are close to the circumference. On the other hand, the projection of individuals on the planes allows us to indicate which individuals characterize the most strongly an axis. The variable coordinates with respect to the axial planes F1, F2…. F4 represented in Table 6 show the representation of the variables in the plane (F1, F2) explaining 83.82% of the initial inertia.

For each variable, we associate a point whose coordinate on a factor axis is a measure of the correlation between this variable and the factor (Axis F1 or Axis F2). For example; the coordinate on axis 1 of the potassium concentration variable is -0.951 and that on axis 2 is 0.192 (Table 6) while on axis 3 is 0.240. By projection on a factorial plane, the variables are inscribed in a circle of radius 1. So to facilitate the visualization of the clouds of the points, they have been projected into a 2-dimensional space. The percentage of inertia explained by the two axes forming a plane (F1 and F2) is 83.82% of the total variance (Figure 3). These two axes are taken into account for the description of the variables distribution on the main plane. The first and second axis respectively account for 59.56% and 24.26% of the total inertia.

Table 6:-Correlations between variables and factors

	F1	F2	F3	F4
pH	-0.812	-0.021	0.579	-0.070
T°	0.079	-0.765	0.572	0.284
Cond	-0.552	0.802	-0.138	0.180
Na^+	0.708	0.627	0.323	0.030
K^+	-0.951	0.192	0.240	0.048
Ca^{2+}	0.753	0.622	0.134	0.168
SO4	0.863	-0.189	0.443	-0.155
Cl^-	0.974	-0.206	-0.019	0.094
Mg^{2+}	0.812	0.455	0.348	-0.113
$NO3^-$	0.814	-0.306	-0.490	0.064

According to tests, when the angle between certain variables is less than 90°, the latter are positively correlated. On the other hand, if the angle becomes greater than 90°, these variables are negatively correlated (Harchrassa et al., 2014). According to Figure 3, Na^+, Ca^{2+} and Mg^{2+} are positively correlated to the F1 axis, whereas conductivity, pH and K^+ are negatively correlated.

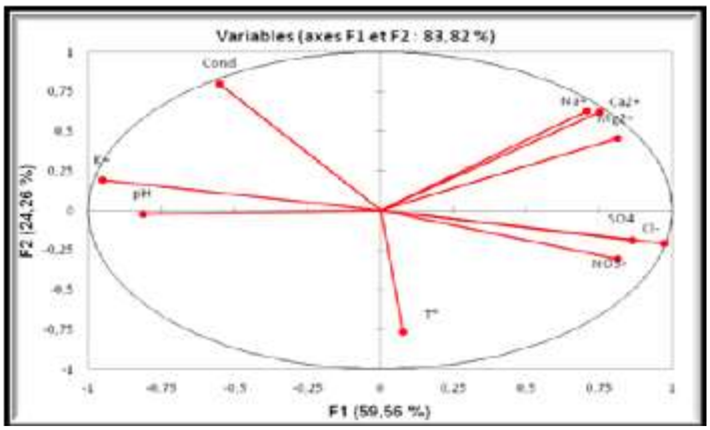

Figure 3:- Circle of correlations represents the projection on the factorial plane F1-F2 of the variables

The projection of the variables on the plane I-II shows two poles (Figure 4):
1. Factor I represents 59.56% of the variance, it is determined by Na^+, $Ca^{2+,}$ Mg^{2+} and K^+.
2. Factor II represents 24.26% of the variance and is determined by the electrical conductivity.

In conclusion, the circle of correlations makes it possible to see, among the old variables, the groups of variables that are highly correlated with each other. So its study is simpler and more informative than the direct analysis of the correlation matrix.

Table 7:-Coordinates of the observations of the five wells

Observation	F1	F2	F3	F4
P1	-0.026	0.818	0.376	-0.850
P2	1.392	-0.237	2.083	0.344
P3	-3.715	-1.970	-0.296	0.064
P4	-1.200	2.505	-0.776	0.386
P5	3.549	-1.116	-1.387	0.056

Representation of wells:-
Study of individuals:-
The arrangement of the wells in the plane defined by the first and second axes (Figure 4) has shown that:

1. A first group of wells in the positive part of the F1 axis, characterized by a water with high (Na^+, Ca^{2+}, Mg^{2+}) concentrations, at the wells P1 and P2.
2. A second group of wells in the negative part of the F1 axis characterized by water with high K^+ concentrations and high electrical conductivity at wells P3 and P4.

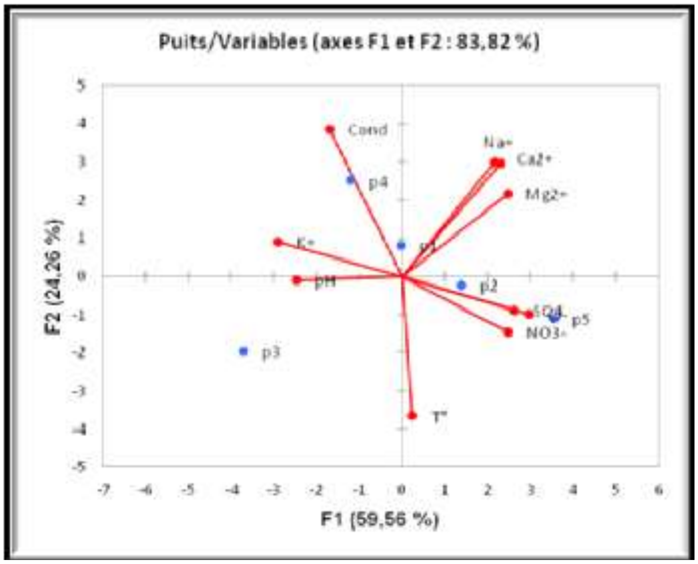

Figure 4:- Projection of the wells and parameters studied on the factorial plane defined by the first two main components F1 and F2.

Conclusion:-

Protecting the environment is a major concern in our societies today. Our results will guarantee the quality of the waters of the Tyikomiyne aquifer. In conclusion, the circle of correlations makes it possible to see, among the old variables, the groups of variables that are highly correlated with one another. Therefore, its study is simpler and more informative than the direct analysis of the correlation matrix.

Thus, we note that the projection of the variables on the plane I-II shows two poles:

1. Factor I represents 59.56% of the variance, it is determined by Na+, $Ca2^+$, Mg^{2+} and K^+.
2. Factor II represents 24.26% of the variance and is determined by the electrical conductivity.

Na^+, Ca^{2+} and Mg^{2+} are positively correlated to the F1 axis, unlike conductivity; pH and K^+ are associated with this axis negatively.

The CPA allowed us to highlight similarities or oppositions between wells and physicochemical parameters. Indeed, the application of the main component analysis on these results shows that we have two groups of wells:

1. A first group of wells in the positive part of the F1 axis, characterized by a water with high (Na^+, $Ca2^+$, Mg^{2+}) concentrations, at the wells P1 and P2.
2. A second group of wells in the negative part of the F1 axis characterized by water with high K^+ concentrations and high electrical conductivity at wells P3 and P4.

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