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Assessment of groundwater quality in Khouribga region, Morocco

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- ✓ Water quality
- ✓ Groundwater
- ✓ physico-chemical analysis
- ✓ Piper and Berkallof diagram.
- ✓ analysis by main component.
- ✓ Phosphate region.

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Abstract

The Khouribga region is world widely known by the activity of OCP Group. The first phosphate basin is the "Basin of OuledAbdoun" which can be the source of groundwater contamination of the "wells" in the region and especially the douars located near the factory. This contamination causes health problems for the population, animals and the environment degradation as a whole for the region. The region is constituted by several Douars. But, this study was done only in the areas near the locations of OuledAbdoun phosphate exploitation, Ouled Azouz, Fassis, Fokra, Ouled Brahim, Gufaf, Lhamri, and BNI Amir", where the dwellers of these douars use wells water as the main drinking water. In a physico-chemical quality control of the groundwater in the region of Khouribga. Multiple analyzes were performed on 14 elements of each of the 90 samples collected from the 90 wells, 10 wells for each Douar. These analyzes are carried out at the laboratory of Hydrology in National Institute of Hygiene of Rabat (NIHR). These analyzes have been treated by the chemical Hydro method which uses Piper and Scholer-Berkallof diagram to determine the type of facies that exists in the region, and by the ACP statistical method using the software XLSTAT to know the level of correlation between the different elements dissolved in the studied groundwater.The groundwater of this region are characterized by heterogeneity of hydro-chemical facies. The diagram of Piper shows the dominance of two types of chemical facies, a calcium sulfate magnesian and and another calcium bicarbonate magnesian. The principal components analysis (PCA) has allowed corroborating the results obtained by the physico-chemical analysis.

1. Introduction:

Water is the basic element for the life of all living beings in the planet. Thus, it plays a very important role for the development of the world countries. [1]. Ground water is one of many water sources, it is a renewable resource due to rain precipitation to ensure an aquatic equilibrium, from where comes the obligation to preserve their quality as well as their renewal. [2]

The quantity and quality of available water resources currently pose problems of more and more complex and difficult to resolve particularly in the under-developed countries. [3]

The groundwater is of capital importance in most regions of the world. However, this resource that was once of good quality, is currently threatened by a variety of point and nonpoint sources of contamination. [4]

Morocco is part of many developing countries characterized by an arid climate, with an excessive exploitation of its aquatic water (less than 1 000 m3/hab/year) [4], which could lead to a serious shortage of water especially after the year 2025 (less than 500 m3/hab/year). Where the importance to preserve and control groundwater becomes vital and should be our main concern. [4. 7. 8. 9]

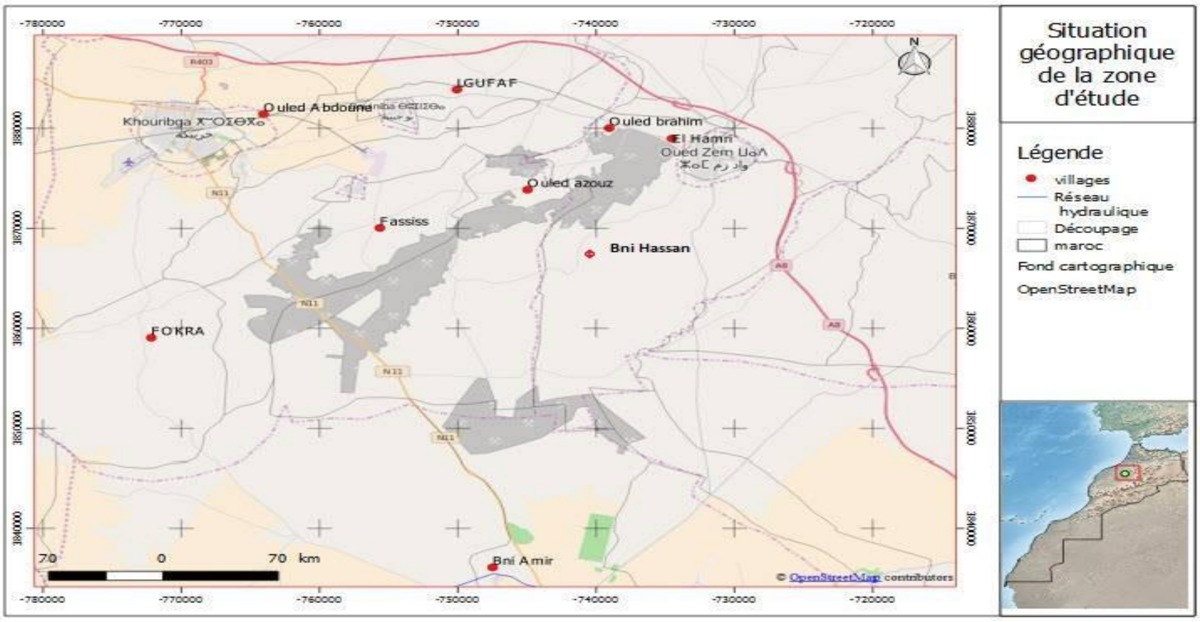
In Morocco, groundwater is the main source of water supply for inhabitants and especially in the rural areas [2. 5], it is the case for the region of Khouribga that contains the Great Phosphate Basin in Morocco, which can threaten the quality of these groundwater.

To know the quality of groundwater and the types of facies in the region of Khouribga, a physico-chemical study was performed on 90 samples collected from the various wells distributed across the area where there is a phosphate exploitation. Physico-chemical analysis according to experimental methods were done on the 90 samples. These methods are used by several researchers: Haoua Amadou, Mahaman Sani Laouali for the Characterization chemical hydro of groundwater in the region of Tahoua (Niger) [4], and Mr. Ben Abbou, Mr. El Haji In their study on the determination of groundwater table quality in the province of Taza (Morocco) [5].

2. Materials and methods:

2.1. *Study area:*

The province of Khouribga is limited in the north by the province of Khmisset, to the south by the province of Beni Mellal, to the east by the province of Khnifra and to the west by the province of Settat. It is the 1st exporter of phosphate in Morocco, and is characterized by a dry continental climate, and aridity semi-endured by cold in winter and summer warmth and fall of irregular rain according to conditions geological, climatological, geomorphologicals. Water resources in the region of Khouribga are influenced by the conditions geological, climatological, geomorphological and the Hydrological nature which leads to intense exploitation of groundwater, influence directly on the hydraulic deficit of the region.



Map 1: Geographical situation of the area studied

2.2. *Sampling:*

All samples of well water are collected at the level of the douars on uled Abdoun, Ouled Azouz, Fassis, Fokra, Ouled Brahim, Gufaf, Lhamri, and BNI Amir", the main douars of the region of Khouribga recognized by a phosphate activity. 90 samples with a frequency of dis Samples For everybody, are collected manually in polyethylene bottles of capacity of 1.5 liters, well washed with distilled water and three times with water has collect, with in situ measurements of pH, temperature and conductivity, the samples have been transported in coolers at 4°C to the hydrology laboratory within the National Institute of Hygiene in Rabat for the result of the analyzes.

2.3. *Analytical method:*

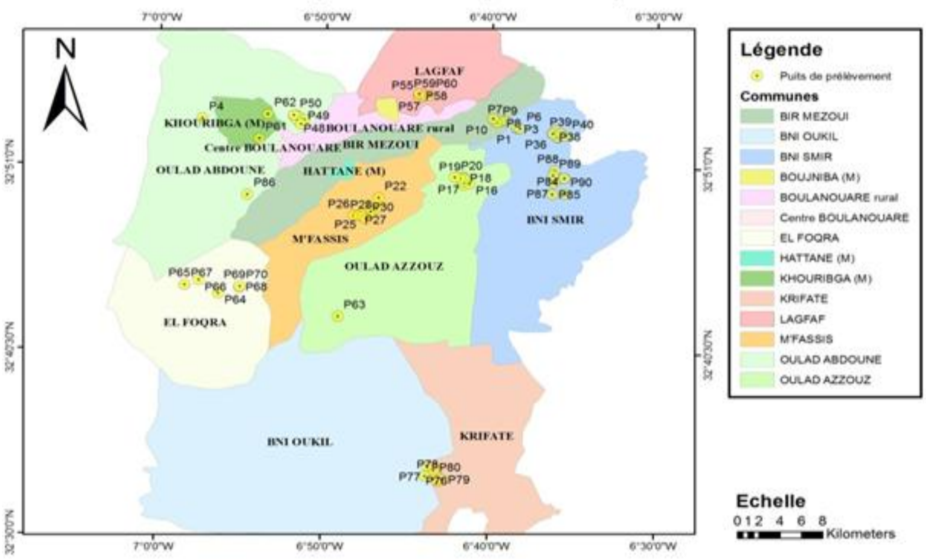
During the collection of samples there is of the measures carried out in situ "pH, temperature, and Conductivity" by the pH-meter and the conductivity meter, after we have transported the 90 samples to the laboratory of Hydrology of the National Institute of Hygiene in Rabat for the following Analyzes physico-chemical, the collection, transport, and conservation are according to the Protocol and the procedures defined by the hydrology laboratory. Other physico-chemical parameters are determined by the methods laid down themselves by the laboratory, whose total hardness calcium and by the complexation by titration with the acid ethyl-diamine-tétracéique EDTA"". The chlorides by the method described by Rodier, 1984. The sulphates, nitrates and ammoniums by the reading of the absorbance at $\lambda = 420$ nm. The sodium and potassium are dosed by the Spectrometry with Flame.

3. Results and Discussion:

According to our study the results exposed represent the average values relating to physico-chemical parameters measured insitu and to its own of the hydrology laboratory at the National Institute of Hygiene of Rabat.

pH:

The pH represents the activity of the ions H3O, it conditions the balance physico-chemical groundwater, and for those in the region of Khouribga the pH average varies between 7.08 and 7.55, which reflects a slight alkalinity, the results have all been within the national standards for water quality. Where the maximum permissible value is entre 6.5et 8.5 (NM03.7.001, 2006) (Figure 1).



Map 2: Distribution of the sampling points of Groundwater "sinks" in the region of Khouribga.

Table 1: Average values of the physico-chemical analysis of groundwater in the region of Khouribga.

NOM	PH	TEMP	COND	TAC	TH	CA2+	MG2+	CL-	NO3-	SO42-	HCO3-	MO	K+	NA+
O BRAHIM	7.15	18.78	922.4	21.45	46.09	69.05	69.33	83.31	72.79	25.11	258.79	1.05	2.42	42.82
O AZOUZ	7.35	16.96	1217.9	21.1	45.92	76.55	62.68	206.6	96.49	25.37	263.5	2.75	8.01	35.13
FASSIS	7.17	20.09	612.4	17.5	31.18	54.03	43.04	131.71	32.39	15.89	219.63	1.97	1.64	17.89
ELHAMRI	7.43	16.74	621.1	23.55	43.48	63.21	69.18	215.45	57.56	13.12	283.41	4.67	1.1	36.27
O ABDOUN	7.25	16.47	996.6	23.4	50.44	102.93	60.35	287.55	37.25	0.09	291.58	3.90	1.21	53.84
LGUFAF	7.08	16.7	151.7	2769	57.66	144.53	52.53	423.54	37.37	0.09	370.27	2.64	1.82	79.44
FOKRA	7.56	19.42	602.1	25.6	44.76	62.52	70.97	452.27	5.46	0.02	1561.6	3.09	3.47	79.44
BNIAMIR	7.24	19.21	1008.9	27.05	50.36	77.19	76.85	283.29	7.29	0.11	1644	3.61	8.18	33.28
BNIHASSAN	7.21	18.85	577.9	23.35	53.04	108.61	77.67	412.87	45.45	15.63	550.83	4.09	4.56	40.06

Temperature:

The mean values of the temperature measured in groundwater in the region of Khouribga vary between 16.45C° and 20.09°C, these values are acceptable by Report The standard marocaineNM03.7.001, 2006.In a general way, the temperature of the water is influenced by the origin from which it is derived (Superficial or Deep). (Rodier. 1984) (Figure 2).

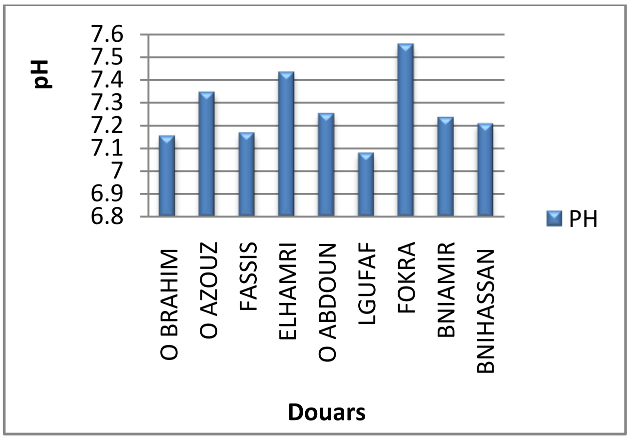
Conductivity:

The conductivity allows to know the quantity of dissolved mineral salts in the waters, and after the results are : the average conductivity of our wells varies between 151.7 µs/cm and 1217.9 µs/cm, which all these values are lower than 2700 µs/cm fixed by the national standard (NM03.7.001. 2006).

Of this fact, and concerning this parameter as well discussed, the quality of the water at the level of the study area is excellent (Figure 1).

Meaning of chemical facies of the region of Khouribga:

In the aim of studying the chemical quality of the region and its mineralization, the results of the analyzes for the major elements are presented in the form of diagrams that allow easy interpretation, the use of these diagrams is therefore quite common and useful in hydrochemistry, software very convenient to represent these different diagrams have been designed by Simler (Simler, 2012).For our study only the two graphic representations, which have been selected and used: the diagram of Piper and Schoeller_BerKaloff.



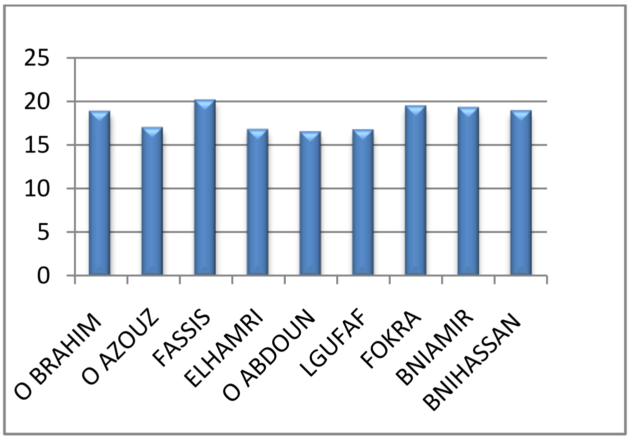


Figure 1: the pH value of groundwater in the region of Khouribga

Figure 2: Temperature value of groundwater in the region of Khouribga in °C.

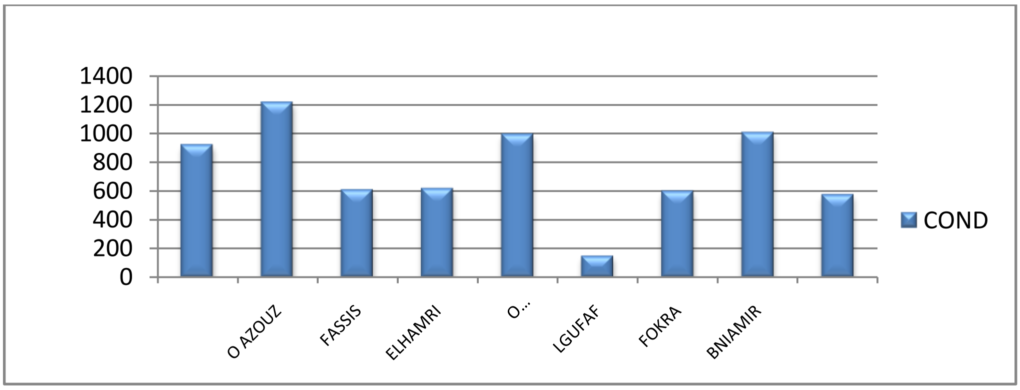


Figure 2: Conductivity value of groundwater in the region of Khouribga in °C.

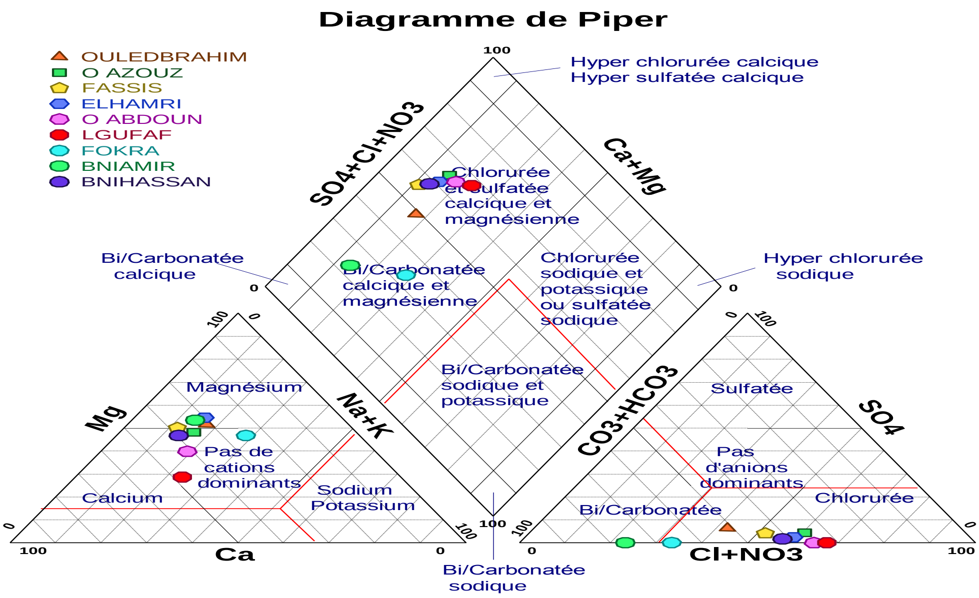


Figure 4: Representation of diagram of Piper of groundwater in the region of Khouribga

The representation of Piper, shows that there are two types of chemical facies for the region of Khouribga: sulfated facies Classic and magnesian for the douars Ouled Brahim, Ouled Azouz, Fassis, Elhamri, bicarbonate Calcium Carbonate magnesian for the douars Fokra and BniAmir. The triangle of the cations indicates that the majority of groundwater are loaded in $Mg2+$ and $Ca2+$, which the cloud of points is located between the Pole calcium and magnesium, on the contrary for the triangle of anions is a trend toward chlorides and nitrates on approximating to the bicarbonate.

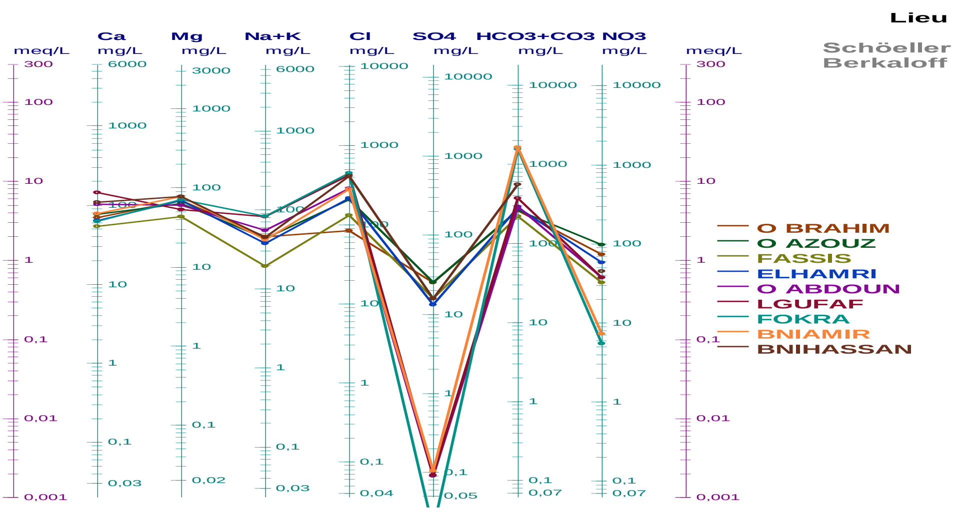


Figure 5: Representation of diagram of SchoellerBerKaloff of groundwater in the region of Khouribga

The previous results are confirmed by the representation of Schoeller BerKaloff, which indicates that the chemical faciesis the chloride sulfated, calcium and magnesium for Groundwater of douars Ouled Brahim, OuledAzouz, Fassis, Elhamri, OuledAbdoun, and Bni Hassan, followed by e bicarbonate facies calcium carbonate magnesian, and for the Fokra douars and Bniamir.

Application of the principal components analysis:

The treatment of physico-chemical data via the method of the ACP gives several results that are presented in Tables 1, 2 and 3, Table 1 represents the values own, variability and the accumulation, whose first three factors totaling 52.43% and accumulation of 116. 39 %, the first two axis totaling 41.30% they constitute the main axis has selected for the projection of data studied. Table 2 shows the contribution between the different variables and principles factors, and after the results given it is found that F1 as defined by TH (r = 0.80), Ca2+ (r= 0.71), Cl- (r=0.66), TAC (r=0.64), and Na (r=0.60) which render him the more important factor.

Table 2: Own values with an inertia of 41.30 %.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
Valeur propre	3.172	2.609	1.559	1.181	1.070	1.031	0.866	0.581	0.573	0.456	0.358	0.295	0.201	0.047
Variabilité (%)	**22.658**	**18.639**	**11.133**	8.436	7.643	7.368	6.186	4.152	4.091	3.256	2.554	2.110	1.436	0.339
% cumulé	**22.658**	**41.297**	**52.430**	60.866	68.508	75.876	82.062	86.215	90.306	93.562	96.116	98.225	99.661	100.0

Table 3: Correlation between the variables and the factors.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
PH	-0.060	0.268	0.240	-0.299	-0.385	0.621	0.403	-0.210	0.149	-0.040	0.112	0.007	-0.028	-0.008
TEMP.	-0.309	**0.625**	0.161	0.070	-0.177	-0.497	0.255	0.000	-0.144	-0.146	0.109	0.234	-0.176	-0.002
COND.	0.213	-0.281	**0.637**	-0.306	0.311	0.201	0.018	0.121	-0.385	-0.221	-0.153	0.014	-0.057	-0.025
TAC	**0.640**	0.251	-0.032	-0.320	0.116	-0.017	-0.335	0.044	0.453	-0.242	-0.074	0.117	-0.114	0.002
TH	**0.796**	-0.316	0.198	0.129	-0.356	-0.111	-0.044	-0.167	-0.114	-0.049	-0.006	-0.032	-0.017	0.155
Ca2+	**0.711**	-0.444	-0.155	0.090	-0.223	-0.233	0.067	-0.336	-0.061	-0.144	-0.001	-0.022	0.038	-0.135
Mg2+	0.439	0.180	**0.560**	0.190	-0.409	0.039	-0.278	0.273	0.020	0.308	0.039	0.005	-0.056	-0.066
CL-	**0.656**	0.127	-0.239	0.202	0.075	0.000	0.443	0.409	0.050	-0.141	0.089	-0.231	-0.059	-0.003
NO3-	-0.224	-0.774	0.254	0.076	0.118	0.007	-0.115	0.092	0.109	-0.143	0.453	0.078	0.032	0.002
SO42-	-0.455	-0.468	0.331	0.335	-0.236	-0.084	0.237	0.155	0.284	-0.159	-0.284	0.093	0.118	0.001
HCO3-	0.365	**0.806**	0.241	0.002	0.087	-0.070	-0.031	0.014	-0.044	-0.119	0.091	0.041	0.346	0.004
MO	0.315	0.119	-0.272	0.666	0.167	0.502	-0.062	-0.025	-0.113	-0.054	-0.020	0.259	-0.039	-0.002
K+	0.187	0.136	0.553	0.311	0.551	-0.124	0.208	-0.301	0.222	0.174	0.003	-0.086	-0.067	0.002
Na+	**0.576**	-0.399	-0.149	-0.363	0.149	-0.099	0.358	0.118	0.023	0.307	-0.009	0.284	0.067	0.009

The correlation matrix defined the links between the different physico-chemical variables according to the coefficient of correlation (r=0.64), it is represented by the Table 3.

Table 4: Correlation Matrix.

Variables	PH	TEMP	COND.	TAC	TH	Ca2+	Mg2+	CL-	NO3-	SO42-	HCO3-	MO	K+	Na+
PH	**1**													
TEMP	**0.069**	**1**												
COND.	**0.080**	-0.225	**1**											
TAC	-0.010	-0.156	**0.074**	**1**										
TH	-0.055	-0.277	**0.243**	**0.309**	**1**									
Ca2+	-0.191	-0.325	**0.051**	**0.261**	**0.839**	**1**								
Mg2+	**0.109**	**0.030**	**0.173**	**0.242**	**0.509**	**0.095**	**1**							
CL-	-0.037	-0.068	-0.031	**0.303**	**0.355**	**0.361**	**0.136**	**1**						
NO3-	-0.190	-0.356	**0.275**	-0.258	**0.063**	**0.099**	-0.098	-0.249	**1**					
SO42-	-0.003	**0.022**	**0.040**	-0.439	-0.077	-0.093	-0.026	-0.235	**0.468**	**1**				
HCO3-	0.158	**0.424**	**0.028**	**0.418**	**0.063**	-0.114	**0.361**	**0.275**	-0.562	-0.457	**1**			
MO	-0.037	-0.226	-0.130	**0.056**	**0.145**	**0.132**	**0.080**	**0.339**	-0.147	-0.165	**0.134**	**1**		
K+	-0.049	**0.090**	**0.251**	**0.076**	**0.085**	-0.003	**0.166**	**0.092**	**0.021**	**0.040**	**0.301**	**0.102**	**1**	
Na+	-0.078	-0.357	**0.222**	**0.256**	**0.404**	**0.500**	-0.012	**0.395**	**0.080**	-0.175	-0.141	-0.065	**0.022**	**1**

At the level of the circle of correlation, there is a set of variables such as the organic matter, HCO_3-, K, TAC, Cl-, and Mg^{2+} are correlated positively on the F axis1 with a variability of 22.66% Conversely there will be a negative correlation between the variables SO_4^- and NO_3^- . On the F axis 2 with a variability of 18.64%, it was a positive correlation between the variability of conductivity, TH, CA2 and Na, has the opposite the variable temperature and pH.The above graph represents the distribution of the various sampling points studied (90 wells) in the region of Khouribga on the factorial plan F1 x F2, which will be stalled automatically with the one of the variables to provide us with an idea on the regions most affected by the polluting material.

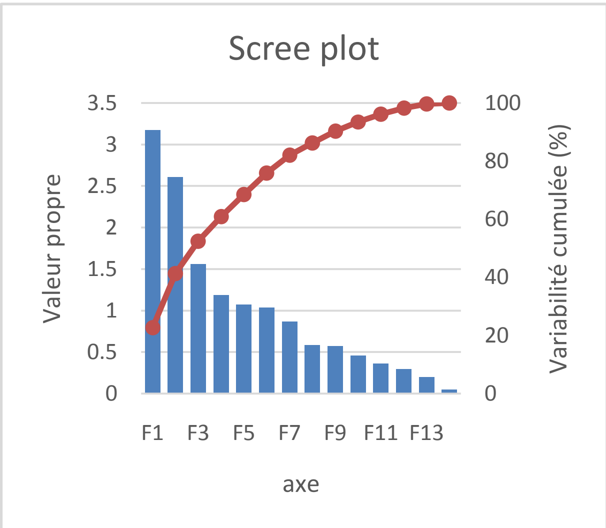


Figure 6 : Projection of the variables on thefactorial plan F1 x F2 (41.30%).

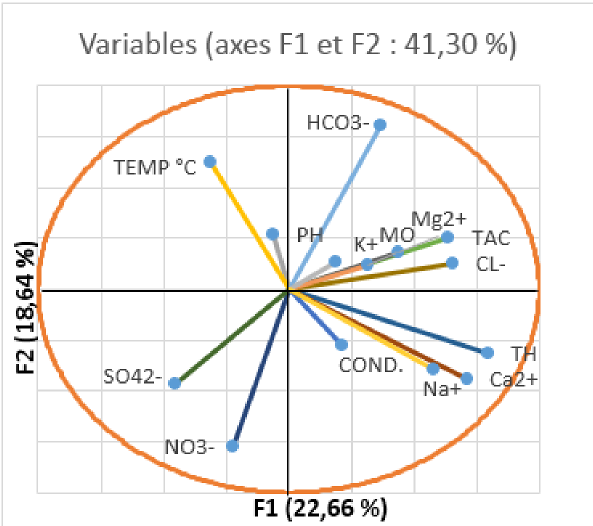


Figure 7 : Graphical presentation of own values with inertia of (41.30%).

This chart relates to the allocation of the various sites studied (90) in the region of Khouribga on the factorial plan F1 and F2, which will be stalled automatically with the one of the variables to provide us with an idea on the most affected regions in polluting material.

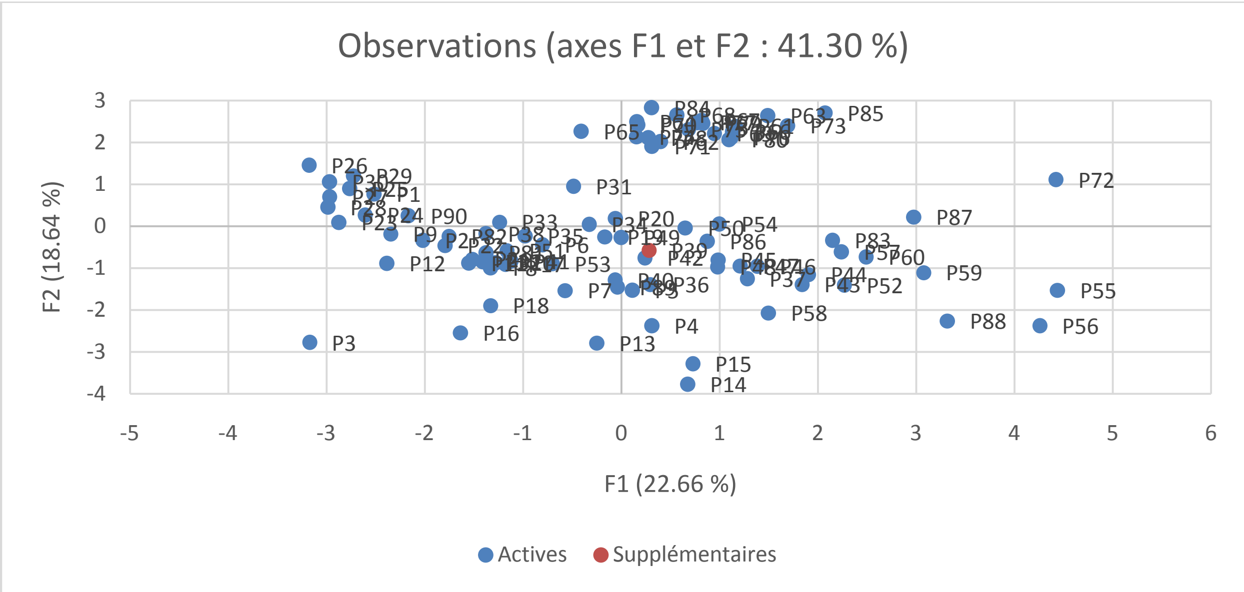
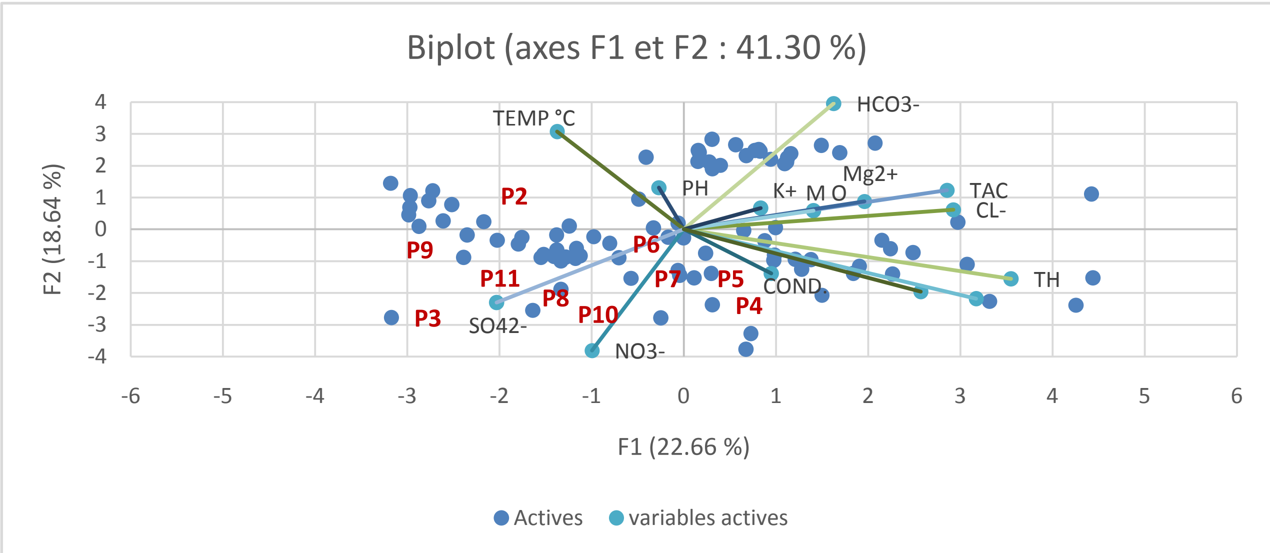
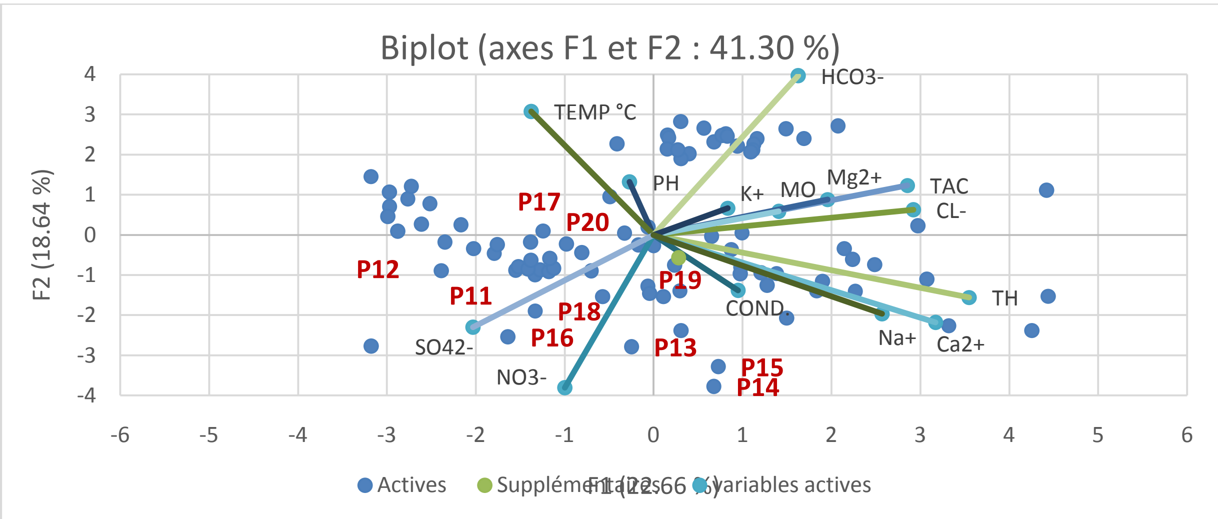


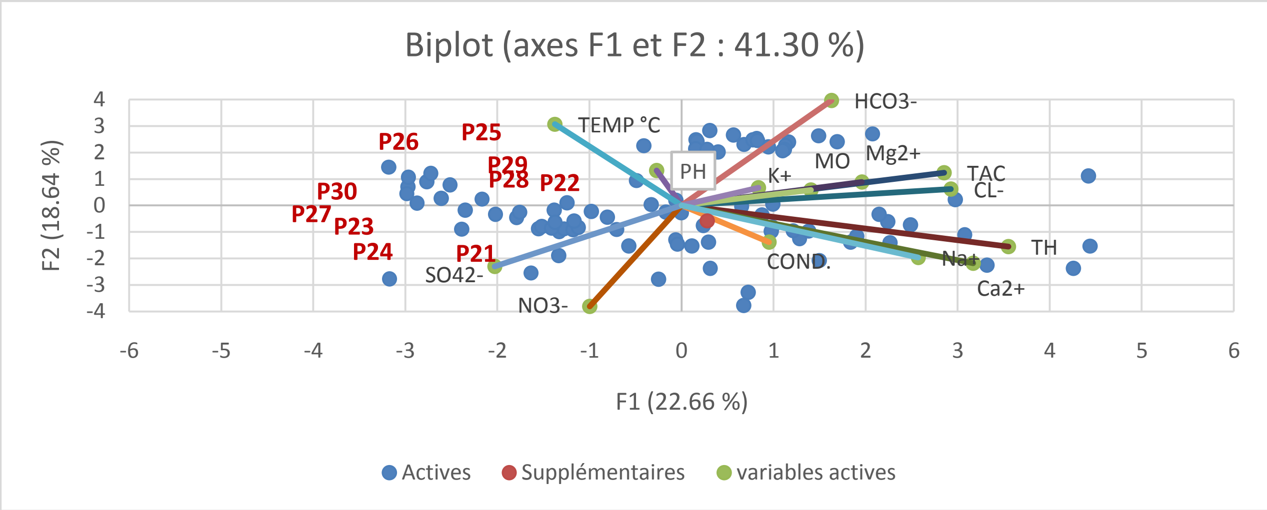
Figure 8: Projection of the individuals on the factorial plan F1 x F2 (41.30%).



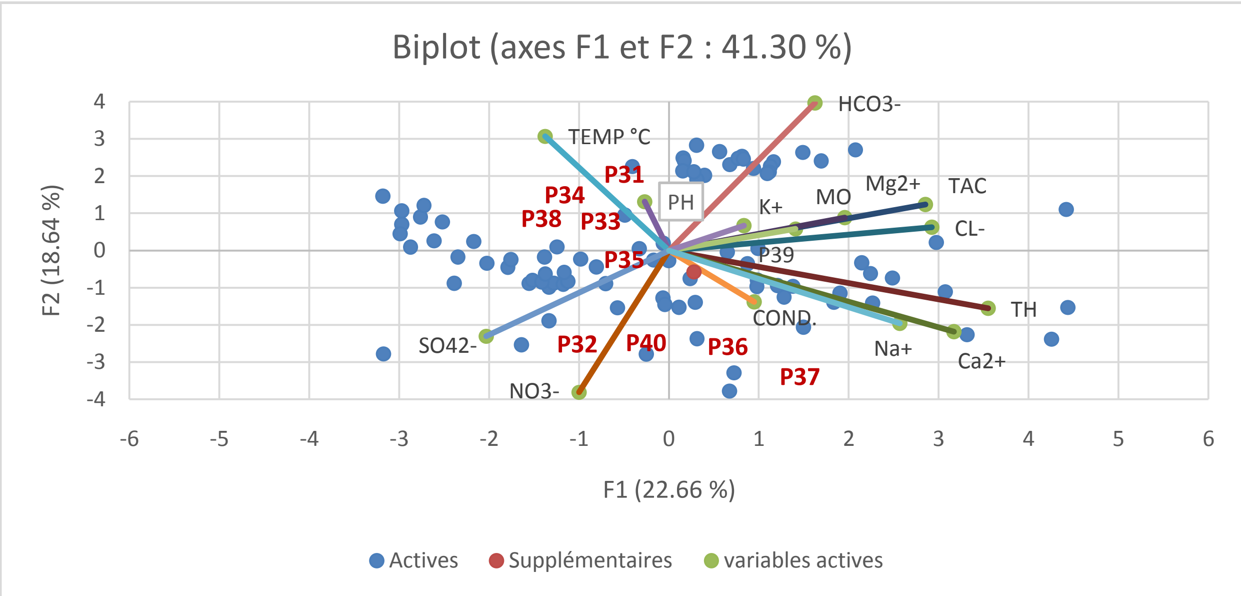
A: Projection of individuals of Douar Ouled Brahim on the factorial plan F1xF2 (41.30%).



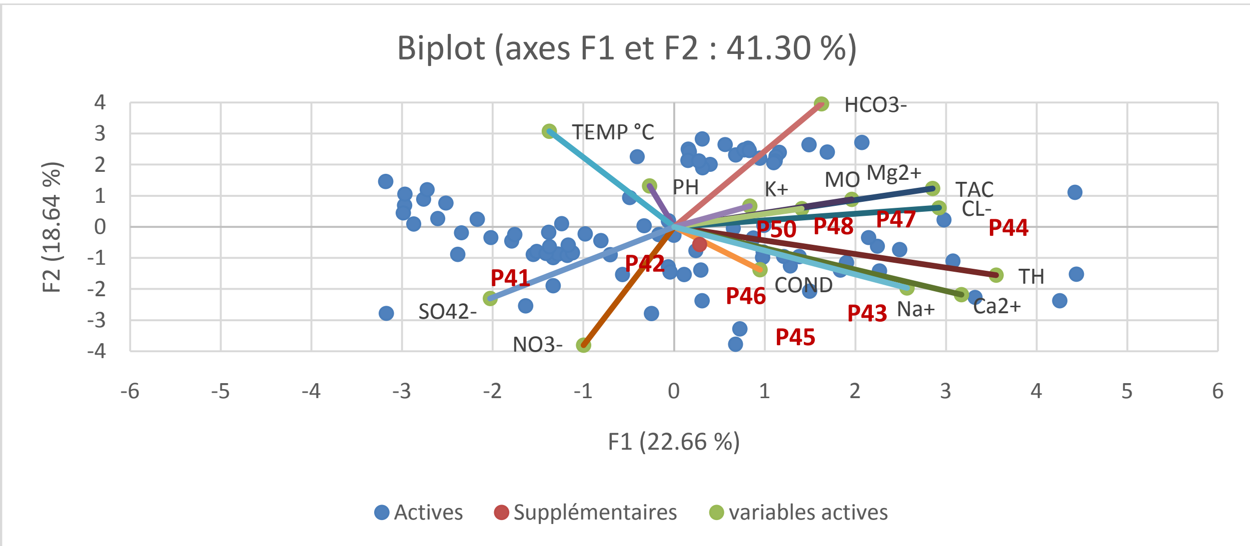
B: Projection of individuals of Douar OuledAzouz on the factorial plan F1xF2 (41.30%).



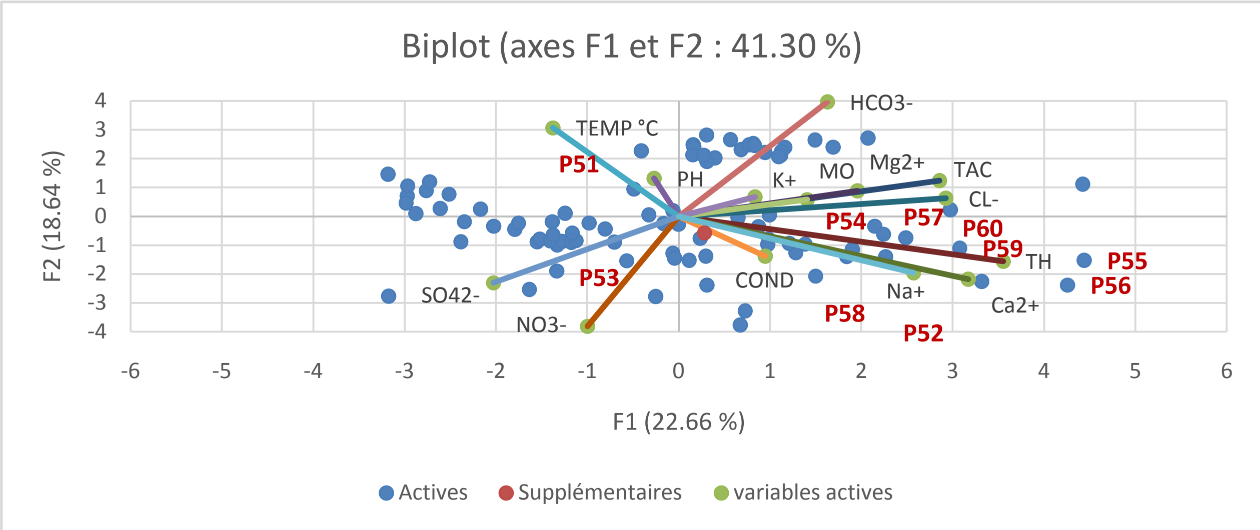
C: Projection of individuals of Douar Fassis on the factorial plan F1xF2 (41.30%).



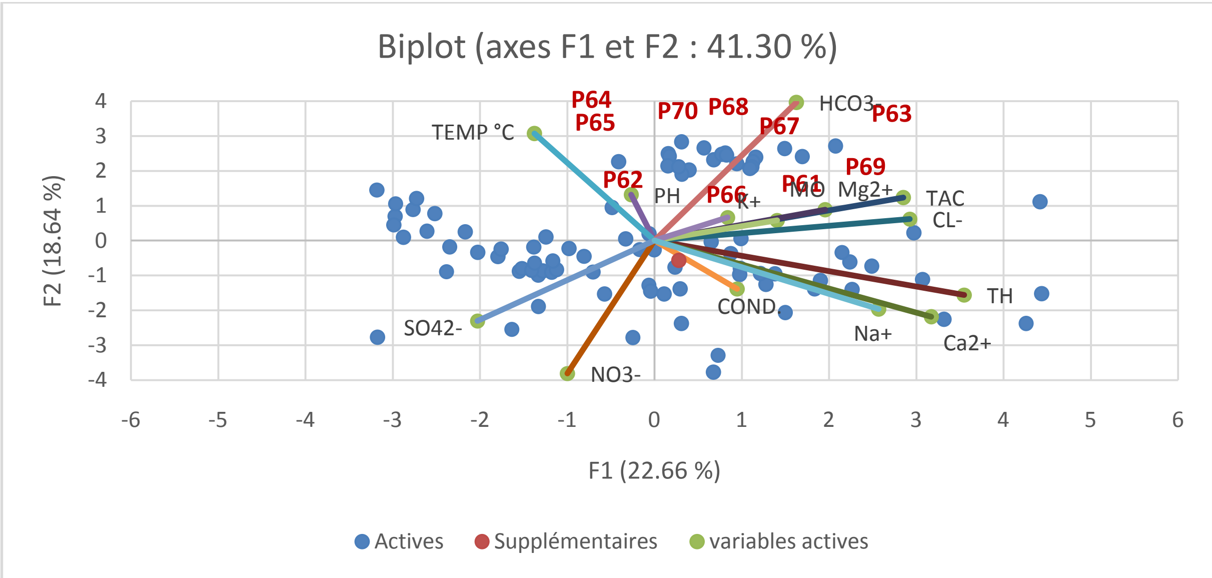
D: Projection of individuals of Douar Lhamri on the factorial plan F1xF2 (41.30%)



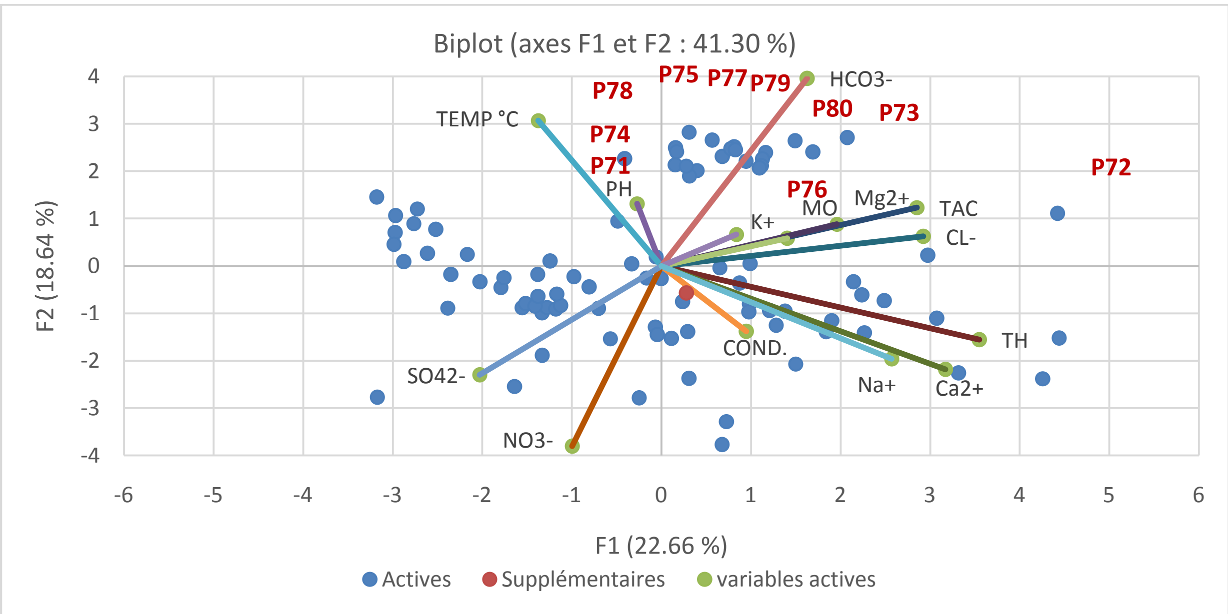
E: Projection of individuals of Douar OuledAbdoun on the factorial plan F1xF2 (41.30%).



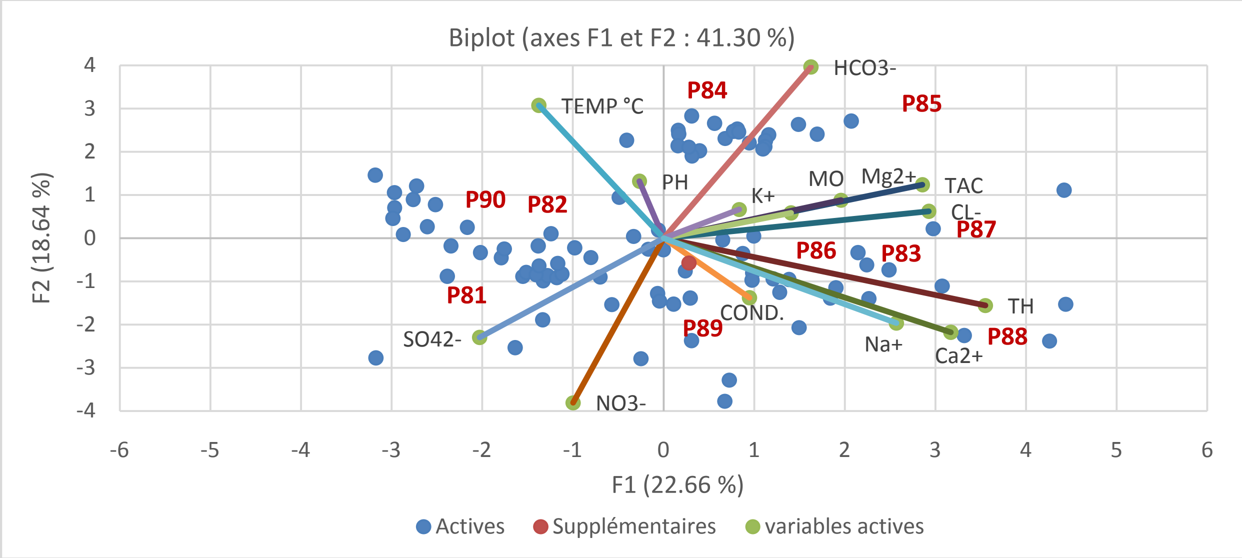
F: Projection of individuals of Douar Lgufaf on the factorial plan F1xF2 (41.30%)



G: Projection of individuals of Douar Fokra on the factorial plan F1xF2 (41.30%)



H: Projection of individuals of Douar BniAmir on the factorial plan F1xF2 (41.30%)



I: Projection of individuals of Douar BniHassan on the factorial plan F1xF2 (41.30%)

At the level of the chart on which there has been a projection of variables and of the individuals on the factorial plan F1 x F2 of variability of 41.30%, there is a progression or evolution of the concentrations of the variables of the organic matter MB and the mineral matter such as Na and Cl- in all regions on the F axis1 except the Douar of Fassis which has a low mineralization. At the same time, the concentration of the hardness (TH) important enough in the study sites of BniHassan (I.) and Lgufaf (F). Similarly, the regions of O Brahim (A) and Bni Hassan (I) are aware of the very high concentrations of sulphate, SO_4^{2-} and Nitrate NO_3^- in relation to the other study sites.

On the F axis2, there is a decrease in the temperature, electrical conductivity and pH (it is still close to the neutrality) regions of BniAmir (H) and Fokra (G) toward the region of Lgufaf (F), with the same way as for the concentrations of Mg^2, K, and HCO_3^-; and vis-versa as regards the concentration of Ca^{2+} by decreasing from bottom to top on the axis F2.

The regions of Lgufaf (F) and Bnihassan (I) are more mineralized, by against that the douars of Fokra (G) and Bnihassan (I) are the most bicarbonated (TAC, HCO_3^-), compared to the other regions studied, more regions of Ouled Brahim (A) and Ouled Azouz (B) are more sulphated Nitrated and that the other regions.

At the level of the Regions Fokra (G) and BniAmir (H), we know a high concentration of HCO_3^-, Mg^{2+}, K, and the electrical conductivity in relationship with the influence of the temperature relative to the other regions of study.

Conclusion

Groundwater is a major source of water for the rural population in Khouribga region.These watersare always exposedbydifferent domestic or anthropogenic source caused by Office Chérifien phosphate factory, which requires the physico-chemical analysis of groundwater in the region in order to properly assess the quality of these waters.

The results obtained in this study, by the analyzes of these waters in the hydrology laboratory, shows that the majority of the samples collected in the region are generally of good quality in terms of pH, conductivity, temperature, chloride, magnesium, calcium, sodium, potassium, sulfate, bicarbonate, and organic matter.

However, the problem of the excess of nitrate for most of the samples "sinks" which exceeds the maximum value set by the Moroccan standard NM 03-7-001 (50 mg/L), which strictly prohibits the consumption of these waters by infants and pregnant women which the organization cannot adapt to an overload in nitrate and nitrite in the presence of nitrates in great quantity in the groundwater of Khouribga caused by the difference of the depths also of the geological structure of the region.

The groundwater of this region are characterized by heterogeneity of hydro-chemical facies. The diagram of Piper shows the dominance of two types of chemical facies, a calcium sulfate magnesian and and another calcium bicarbonate magnesian and.

The principal components analysis (PCA) has allowed corroborating the results obtained by the physico-chemical analysis.

References

1. M.L Belghiti, D. Bengoumi, *Larhyss J.*, 14 (2013)21-36.
2. W. Ayad, M. Kahoul, *J. Mater. Environ. Sci.*, 4 (2016) 1288-1297.
3. N. Nouayti, D. Khattach , M. Hilali, *J. Mater. Environ. Sci.*, 4 (2015) 1068.
4. M. Ben abbou, El hajim, *Larhyss J.*, 16 (2013) 77.
5. J. El Asslouj, S. Kholtei, *RSE / J. Water Sci.*, 3 (2007)309.
6. M. Bahir et A. Mennani, *Estudios Geol.*, 58 (2002) 103.
7. F. Bouchemal, S. Achour, *Larhyss J.*, 22 (2015) 197.
8. L. Matini, M.S. Kongo-Mantono, *Afri Sci.*, 05 (2009) 82.
9. S.G. Eblin, G.M. Soro, A.P. Sombo, N. Aka, O. Kambiré, N. Soro, *Larhyss J.*, 17 (2014) 193.
10. K. Soncy, B. Djeri, K. Anani, M. Eklou-Lawson, Y. Adjrah, D.S. Karou, Y. Ameyapoh, C. Souza, *J. Appl. Biosci*, 91 (2015) 8464.
11. B. Legube, R. Desjardins et M. Doré, *J. Water Sci.*, 11 (1998) 87.
12. N. Aghzar, H. Berdai, A. Bellouti et B. Soudi, *J. Water Sci.*, 2 (2002) 459.
13. S. Amrani, S. Hinaje, *Eur Sci J.*, 20 (2014) 1857.
14. N. Tabouche, S. Achour, *Larhyss J.*, 03 (2004) 99.
15. O. B. Yapo, V. Mambo, A. Seka, M. J. A. Ohou, F. Konan, V. Gouzile, A. S. Tidou, K. Kouame, P. Houenou, *Int. J. Biol. Chem. Sci.*, 4 (2010) 289.
16. H. Amadou, M.S. Laouali, A.S. Manzola, *J. Appl. Biosci.*, 80 (2014) 7161.
17. N.C. Amin, K.S. Lekadou, A.R. Attia, J.S. Claon, K. Agbessi, K.L. Kouadio, *J. Sci. Pharm. biol.*, 1 (2008) 22
18. L. Matini, J.M. Moutou, M.S. Kongo-Mantono, *Afri Sci.*, 05 (2009)82.
19. M. Ben Abbou, F. Fadil, *Eur Sci J.*, 5 (2014)1857.
20. N. Nouayti, D. Khattach, M. Hilali, *J. Mater. Environ. Sci.*, 4 (2015) 1068.
21. A. Sadek, *HSJ*, 56 (2011) 334.
22. N. Nouayti, D. Khattach, M. Hilali, *J. Mater. Environ. Sci.*, 6 (2015) 1068.
23. K. E. Ahoussi, Y. B. Koffi, A. M. Kouassi, G. Soro, J. Biemi, *J. Appl. Biosci.*, 63 (2013) 4703.
24. F. Bouchemal, S. Achour, *Larhyss J.*, 22 (2015)197.
25. H. Haddad, H. Ghoualem, *Larhyss J.*, 18 (2014)155.
26. F.X. Nshimiyimana, S. El Blidi, A. El Abidi, M.E. Faciu, J.C. Udahemuka, F. Benammi, G. Lazar, A. Soulaymani, M. Fekhaoui, *J. Mater. Environ. Sci.*, 7 (2016) 2760.

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