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Preliminary study of the quality of surface water in El Tarf area for irrigation (Extreme Northeast Algerian)

L. Zaoui *, F.Z. Kahit & M. Benslama

Laboratory Research of Soil and Sustainable Development. Department of Biology. Faculty of Sciences. Badji Mokhtar University - Annaba – Algeria. (****Corresponding author:*** *lilia_zaoui@yahoo.fr*)

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lilia_zaoui@yahoo.fr

Abstract

Wadi Bounamoussa, located in El Tarf (extreme Northeast Algerian) which has an agricultural vacation. During two seasons (winter and summer), the sampling of surface waters of nine stations along wadi Bounamoussa is analyzed. In order to evaluate preliminarily the pollution of surface water, the study methodology carried out in order to check the current state of water chemistry, its evolution over time and in space depending on the variation of physicochemical parameters of water. The results of physicochemical analyses of waters samples of our study area shows that are very poor in soluble and moderately mineralized and accentuated with a neutral appearance require certain precautions such as leaching, which can reduce the yield of sensitive plants and cause slow salinization of soil hence the need for this research. We got the same order of abundance decreasing for both seasons as follows: $\mathbf{Na^+ > Ca^{+2} > Mg^{+2} > K^+}$ and $\mathbf{Cl^- > SO_4^{2} > NO_3^- > NO_2^-}$ with absence of carbonates and bicarbonates. The use of graphical water diagrams made it possible to define the dominant ions responsible for chemical facies of waters and the geological formations at the origin of these facies. The results of statistical analysis confirm those obtained in laboratory and reveal, firstly a variability between intra-period stations (inter-site), and secondly, a potential variability between two periods (inter-period variability). The physicochemical characteristics of this surface water show that it is appropriate to irrigation and agriculture.

1. Introduction:

Worldwide water quality has deteriorated in recent years due to uncontrolled industrial discharges, the intensive use of chemical fertilizers in agriculture and the disorganized exploitation of water resources. These produce a chemical modification of water and make it unsuitable for desired uses **[1].**

Among these cases, was the site of Bounamoussa plain located in El Tarf City (NE Algerian), which is a predominantly rural area and has an agricultural vacation with low industrialization (flour mills, industrial milk production and tomato concentrate canning); where water resources heavily used for agricultural activities. The burden of these discharges is growing with the socio-economic development of study area **[2].** The chemistry of water resources (surface waters at wadi Bounamoussa level, surface waters and deep aquifer) often influenced by the effect of the dissolution of geological formations, domestic, industrial and agricultural activity. The use of fertilizers in intensive agriculture, the unsewered sanitation in densely populated areas irrigation of land by sewage effluents are considered the main polluting factors. Wadi Bounamoussa is the principal source of irrigation and drinking water for the majority of the population **[3-5].**

Several studies in El-Tarf region reported various degradations levels of surface and ground waters as one of the major concerns among the public and governmental decision makers **[3],** but these studies did not include an evolution of inorganic pollution of surface waters especially Bounamoussa river.

The main objectives of this study were to evaluate surface waters quality of wadi Bounamoussa in El Tarf city, Algeria by using the Physico-chemical analysis and to discuss the major ions chemistry of in this case the methods proposed by correlation and PCA and their allocation under both intense urban development and agricultural activities in two periods of season (winter and summer). Suitability of water for irrigation can assessed not only from the total concentration of salt, but also from the type of salt and ions constituting it. It is then essential to study the parameters defining the characteristics of waters intended to irrigation **[4].**

2. Materials and Methods

The development of agriculture and fertility of soils plain have created dense human settlements in the studied area particularly in North. Research has indicated that agricultural practices may cause nitrate, chlorides and sulfates contamination to be high to exceed the maximum acceptable level for water **[5].**

The experimental study carried out on surface water. The work done was the broadest possible physicochemical characterization of the waters. The objective was to arrive at a thorough knowledge of the environment for allowing a good understanding and a relevant analysis of the results.

To achieve this objective, two (02) campaigns of sampling and analysis periods were carried out, the first related to month of April 2016 (end of wet season, beginning of irrigation season) and the other concerned month of September 2016 (end of dry season, after the release of Chaffia dam). Nine (09) stations spread across the Bounamoussa plain have been chemically analyzed in the laboratory.

2.1. Presentation of study area:

The area of El Tarf is along the littoral and fact part of the most sprinkled areas the Algerian Northeast (**Fig. 1**). The climate of El Tarf is wet Mediterranean type, characterized by two six months seasons each one **[6].** The study region subjected to a Mediterranean climate characterized by two different seasons: one wet, marked by high rainfall and low temperatures from October to May, and other dry and warm with high temperatures reaching their maximum in August with low rainfall. Prevailing southerly winds blow off the sea during the winter; and in summer, the hot Sirocco blows in a south-south-westerly direction, carrying with it a drying effect that is strongly felt during a one month period of time **[7].**

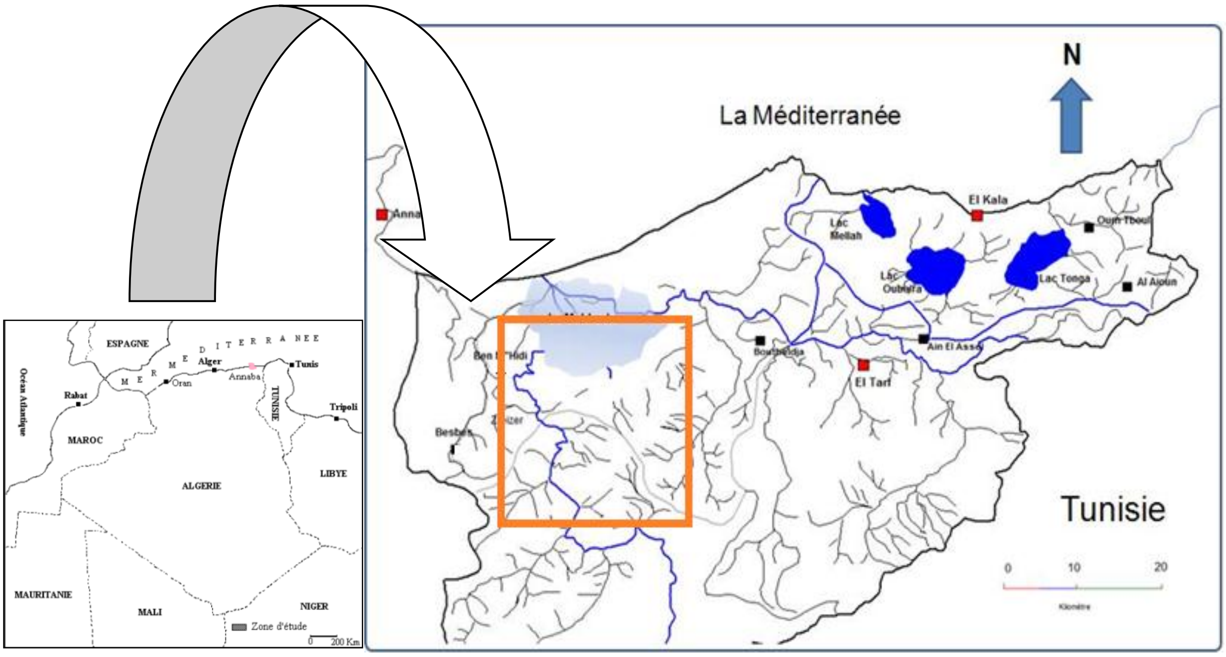


Figure 1: Map of the location of the study area **[8].**

The geology of the study area is part of the geology of Algerian north-eastern Tell which extends from the Constantine region on the Algerian-Tunisian border. Thus, it is distinguished by the Secondary (Marls and Marl calcareous), the Tertiary (Formations, sandstone and clay) and at the end of the Quaternary (alluvial deposits).

The study area is located in two catchment areas, namely the Seybouse wadi and the East Kebir wadi **[3].**
It is characterized by different geomorphological units, whose more widespread Quaternary formations occupy the lower part (Northwest and Northeast) of study area. These several forms are as follows:
The Marshes of the Mekhrada which constitute a particular environment where during the winter a lake and during the summer of the pastures, the Grabbens which are represented by different plains, the Horests which are represented by the sandstones and clays of the numidien, the Massif Dunaire and the Massifs Rocky, Terraces and different lakes, mountains, hills, wadis such as El Kebir East, Bounamoussa and Seybouse and finally the plains are those of Annaba, El Tarf, Bouteldja, El Asfour and Oum Teboul **[2, 22].**
The presence of numidian sandstones forms the whole of the massifs. Only the basins show outcrops of soft rocks from tellian or maritime and massylienne units **[2, 4].**
A plan adopted to achieve this objective; it consists in the beginning of carrying out a sampling grid with a complete analysis of the physicochemical parameters of waters.
Nine (09) sites or stations were selected across the study area from upstream to downstream of Bounamoussa wadi; according to their good accessibility even in winter, their locations in the plain, their types of use (agricultural land, residential or fields etc ...), and the nature of pollution that affects them and especially depending on the presence superficial waters.
The surface waters were sampled in nine (09) stations spread out in the space between Ben M'Hidi and the Cheffia dam: Six at the level of agricultural lands crossed or near wadi Bounamoussa, two stations at the bridges crossing the wadi (Ben M'Hidi Bridge and Zerizer Bridge) and the last distance from the Cheffia dam.

2.2. Sampling and analysis protocol

2.2.1. Sampling

The samples taken from the running water, that is to say, the most at canal center, about 10cm below surface, using seal and the rope according to places. Until overflow in 1.5 L polyethylene bottles (at least for each sampling station) rinsed before filling with water to be analyzed and corked.
Upon return to the laboratory, samples were immediately stored in a refrigerator at a temperature below 4° C protected from light. Due to lack of time in the field, filtering done in laboratory the day after the sampling campaign. The samples filtered to a porosity of 0.45µm, in order to eliminate as much as possible colloids, which increase the apparent solubility of certain ions.

2.2.2. Choice of Physicochemical parameters

The study concerned analysis of physicochemical parameters, namely: pH, EC, SM, DR, DE, Ca^{+}, Mg^{+}, CO_3^{2}, HCO_3^{-}, Cl^{-}, SO_4^{-2},NO_2^{-}, NO_3^{-}, NH_4^{-},K^{+}, Na^{+} **[9]** of waters samples taken at 09 study sites along wadi Bounamoussa in order to establish a diagnosis of state of surface water pollution in our study area. Dry Residue (DR), Dry Extract (DE) par evaporation and determined by weight, finally suspended matter (SM) by filtration, pH were evaluated by pH Meter and electrical conductivity (EC, TDS) were measured in the field using a Conductivity Meter. These analyses performed at laboratory level by colorimetric method. Concentrations of Ca^{2+} and Mg^{2+} were estimated titrimetric ally using 0.02 N EDTA and concentrations of HCO_3^{-} and Cl^{-} by H_2SO_4 and $AgNO_3$ titration (0.02 N), respectively. Concentrations of Na^{+} and K^{+} were measured using a Flame photometer.

2.2.3. Statistical data analysis

The Principal Components Analysis (PCA) results are a descriptive statistical method whose purpose graphically represented the maximum amount of information contained in a data table **[10].** This statistical method makes it possible to transform the initial quantitative variables, all more or less correlated with each other, into new quantitative, uncorrelated variables called main components. The PCA made using the Statistical software (version 6). PCA conducted from the correlation matrix. The eigenvalues sought make it possible to access the factorial axes presenting a maximum of inertia. The use of PCA for the study of water chemistry makes it possible to differentiate groups with similar chemical characteristics, their variations (factor) along the main axes but especially the modes of acquisition of the mineralization **[24].**

3. Results and Discussion

The results of the physicochemical analyses showed that all surface waters of our study's area were free of carbonates (CO_3^-) and bicarbonates (HCO_3^-). The statistical results of other physicochemical parameters of 09 sites for dry and wet period were show in Table 1. The statistical study of spatial distribution of chemical elements presented the minimum, average and maximum values, as well standard deviation (SD), (Tables 1).

Seasonal variation in the concentration of chemical elements is related to the effect of region's climatic conditions (precipitation, evaporation), and to the exploitation of resources by pumping and irrigation. All surface waters of our study's area are high values during the dry period.

Table 1: Descriptive statistics for water chemistry

	Wet season				Dry season				
Variables	**Minimum**	**Maximum**	**Average**	**SD**	**Minimum**	**Maximum**	**Average**	**SD**	**Algeria Standards**
pH	7.20	7.80	**7.548**	0.177	7.72	8.39	**7.924**	0.190	**6 – 8.5**
EC (µS/cm)	212	631	**347.333**	128.540	245	523	**314.444**	87.414	**/**
DR (mg/l)	0.13	0.33	**0.230**	0.065	0.07	0.40	**0.230**	0.109	**1500**
SM (mg/l)	0.027	0.110	**0.059**	0.032	0.001	0.020	**0.010**	0.005	**25**
DE (mg/l)	0.051	0.104	**0.066**	0.019	0.010	0.017	**0.013**	0.003	**50**
Ca^{++} (mg/l)	13.067	27.733	**19.644**	5.166	13.867	33.333	**24.741**	5.549	**200**
Mg^{+2} (mg/l)	11.858	21.384	**14.785**	3.374	14.483	25.855	**19.818**	3.459	**50**
TH (mg/l)	24.925	47.517	**34.430**	7.927	31.071	53.843	**44.559**	7.692	**150 à 200**
Na^+ (mg/l)	27.49	107.80	**51.407**	22.417	27.50	93.32	**40.50**	21.394	**200**
K^+ (mg/l)	2.42	6.98	**3.712**	1.381	2.350	10.27	**4.192**	2.447	**12**
NH_4^+ (mg/l)	0.005	0.041	**0.020**	0.015	0.007	0.060	**0.029**	0.019	**0.5**
Cl^- (mg/l)	24.815	332.048	**139.043**	89.604	11.817	177.250	**73.526**	55.039	**250**
SO_4^- (mg/l)	39.529	87.569	**57.373**	14.149	47.255	68.235	**54.314**	7.030	**250**
NO_3^- (mg/l)	3.708	18.958	**11.148**	4.758	5	43.75	**15.694**	11.624	**50**
NO_2^- (mg/l)	0.033	0.153	**0.071**	0.048	0.023	0.349	**0.080**	0.103	**0.1**

pH appears to be controlled by the precipitation and the solution of various minerals .The laboratory analytical results (Table 1) indicated that pH values ranged between 7.20 to7.80 and 7.72 to 8.39 respectively for wet and dry season in all water samples, with a mean value of 7.548 ± 0.177 and 7.924 ± 0.19 according to Algeria standards of irrigation, most of water samples have a good quality for irrigation, where optimal limits of 6 and maximum permissible limit of 8.5 **[3, 17].**

Conductivity reflects the mineralization of water, therefore, the high values of electrical conductivity is high values of the concentration of dissolved salts. This parameter is directly related to salinity the mean is recorded in the order of 347.333 ± 128.540 µS/cm and 314.444 ± 87.414 µS/cm, also the range from a minimum of 212 and 245 µS/cm and a maximum of 631 and 523 µS/cm respectively for both seasons (table 1). Higher values of these parameters characterize wells located in the agricultural areas which suggest a large contribution of saline return flow waters and the dissolution of evaporate sediments **[16].**

Water samples are very poor in soluble salts and presents no immediate risk for its use in irrigation; the means values of salt are respectively for both season 0.230 ± 0.065 and 0.230 ± 0.109 for dry residue, 0.059 ± 0.032 and 0.010 ± 0.005 for suspended matter, 0.066 ±0.019 and 0.013± 0.003 for dry extract.

Ca^{+2} and Mg^{+2} content means of water samples are 19.644 mg/l, 14.785 mg/l and 24.741 mg/l, 19.818 mg/l respectively for both seasons (Table 2). Ca^{+2} and Mg^{+2} were dominant in surface water. Na^+ content of water samples ranged from 27.49 to 107.80 mg/l and 27.50 to 93.32 mg/l respectively. The concentrations of Ca^{+2}, Mg^{+2}, K^+ and Na^+ in water samples were suitable for irrigation **[20].**

The surface waters characterized by the evolution of the contents of cations and anions which present the same order of decreasing abundance for both seasons as follows: Na^+> Ca^{+2}> Mg^{+2}> K^+ for cations and Cl^-> SO_4^{-2}> NO_3^-> NO_2^- for anions conferring to water a sodium chloride facies. Calcium, sodium and chloride are major constituents of natural water in this area. Chloride source is the dissolution of evaporate rocks forming the study's area soil, and the main anthropogenic sources are urban, and agricultural wastewater **[5].**

The chloride value is found in the range of 24.815 to 332.048 mg/l for wet season and 11.817 to 177.250 mg/l for dry season with a mean value of 139.043 - 89.604 mg/l and 73.526 ± 55.039 mg/l respectively for both seasons. (Table 1). Results shows that all most of samples are of good quality for irrigation according to Algeria standards for irrigation (optimal limits of 250 mg/l) and Rodier (2009).

Certains parameters like nitrates, nitrite and suspended matter inform us about organic pollution of water. Contamination by these elements mainly related to soil leaching and anthropogenic activities (waste releases). Na^+ ions exchangeable can replace alkaline earth ions (Ca^{2+} and Mg^{2+}) clays, thus causing clogging of soil pores and thus waterproofing **[11].** Calcium and magnesium can be tolerated, even in relatively great amounts in irrigation waters. High values of these parameters indicate sodium is not in excess in dam waters and that hazard of defoliating sensitive crops by a sprinkling system is very low **[4].** During high water mark, low chloride content explained by dilution by rainwater's. Since chloride ions have a high concentration in low water levels periods, where the sources of this element were essentially constituted by wastewater discharge, notably urban waste **[5].**

In spite of efforts made to raise awareness to nitrate surface water pollution, nitrate fertilizer use has not decreased, but has increased due to surface tilling practices linked to increased crop production and progressive agricultural development **[3].**

The hardness of water is reduced to its concentration of calcium and magnesium ions. In the waters studied (Table 1), this parameter shows a large variation, it increases in dry period and decreases in rainy period, This variation would be related to the lithological nature of the aquifer formation and in particular to its composition in magnesium and calcium **[22].**

The measured values of nitrates (respectively 11.148 mg/l and 15.694 mg/l) and nitrites (0.071 mg/l and 0.080 mg/l respectively) for both seasons through wadi Bounamoussa were low (Table1). The concentrations found in analysed water do not exceed the standard accepted by the WHO [2008] (50 mg/l for NO_3^- and 0.1mg/l for NO_2^-) furthermore the natural limit is greatly exceeded **[5].**

Slim et *al.*, **[12]** found that a trace amount of nitrate in surface water related to either algal growth in these sites, or the joint phenomenon of denitrification, which transforms nitrates NO_3^- into nitrogen N_2 thanks to the presence of organic matter.

The increase in winter levels linked to the increase of soil-leaching phenomenon and their decrease in summer contents could explained by the decrease in diffuse pollution **[13].** These seasonal changes are consistent with those recorded in rivers **[14].**

According **MEDJANI [3]** results shown that the degree of pollution varies by zone, as well as by month to month with contents often exceeding recommendations made by World Health Organization (WHO). The protection of water quality and the reduction of risk contamination are of great importance in the region to a reliable and sustainable development. The evaluation of physical chemical parameters measured in surface waters of wadi Bounamoussa shows a degraded water quality. **[2]** and **[15]** reached this conclusion, indicating the alteration of waters of our study area whose has a very high organic pollution class.

3.1. The mineralization

The concentration of Total Dissolved Solids, salinity or total dissolved load **[17].** This parameter represents the total concentration of substances dissolved in water. TDS is composed of inorganic salts and some organic matter. These elements can come from a number of natural sources as well as from human activities. *TDS* calculated by summing the main ionic species (Na^+, Ca^{+2}, Mg^{+2}, K^+, Cl^-, SO_4^{-2}, NO_3^- , NO_2^- and NH_4^+ **), [5, 16].**

It is more important from south to north of our study area. Figure 2A and 2B for cations and Figure 3A and 3B for anions illustrate the variations of dissolved salts (TDS, or total concentration of dissolved salts) for both seasons. The rate of TDS in surface waters of our study area generally increases during dry season and decreases at the beginning of winter season **[16, 18].**

The salinity varies in notables proportions in the zone of study. Altogether, it is rather high on borders of the North of the wadi Bounamoussa and it decreases in the South. The spatial evolution of average concentrations of dissolved salts of surface waters follows an increasing gradient upstream downstream of wadi Bounamoussa, it is important in site S9 or it noted that concentrations of sodium, chloride and sulphates were also importants; thus The high chloride concentrations can cause toxicity to sensitive crops at high concentrations **[21].** While nitrites, nitrates and potassium have no determining role in the mineralization of waters.

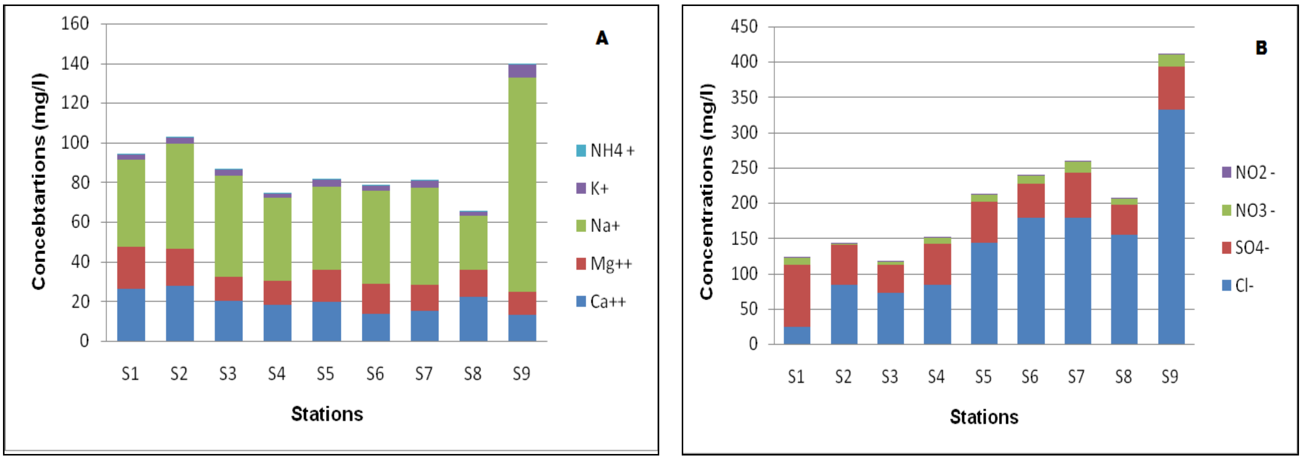


Figure 2(A and B): Concentrations of cations and anions of samples waters (wet season)

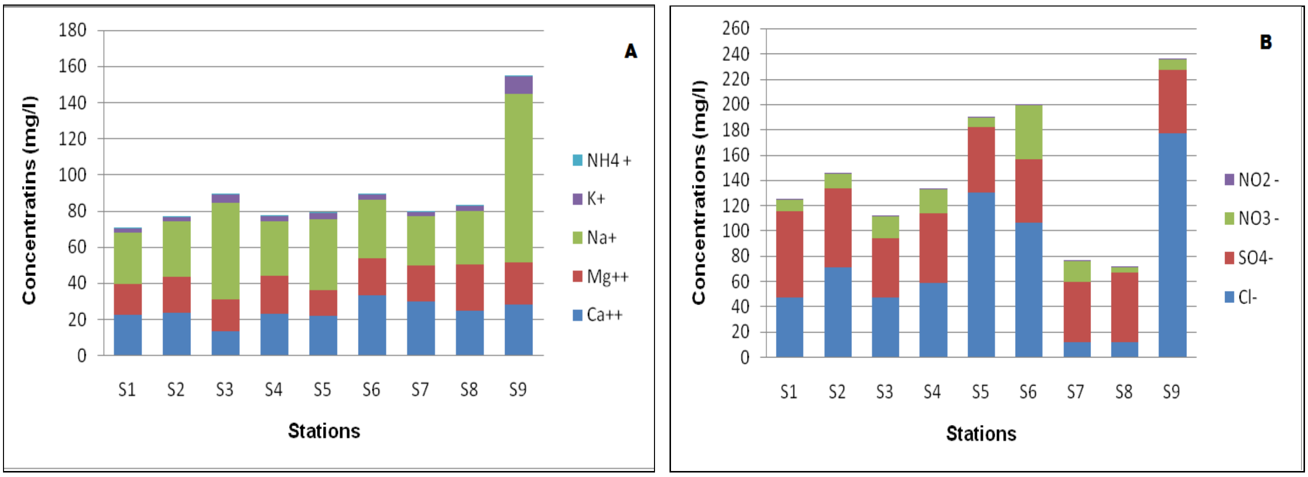


Figure 3(A and B): Concentrations of cations and anions of samples waters (dry season)

3.2. Principal Component Analysis (PCA)

In order to study the chemistry governing surface waters of area study and correlations between elements and different variables, we opted for the main component analysis method. The Principal Component Analysis (PCA) which is a method complementary to classical approaches of hydro-geochemical research provides quick visualization and shows correlation among different water quality variables **[21, 25].** The aim of the analysis is to obtain a small number of linear combinations that account for most of the variability of data.

The values in bold show the correlation coefficients of strongly correlated variables between them (negatively or positively). This remark is valid for all correlation matrices.

fifteen variables : pH, EC, MES, DR, DE, Ca^+, Mg^+, TH, Cl^-, SO_4^{-2},NO_2^-, NO_3^-, NH_4^-,K^+, Na^+ and nine individuals from S1 to S 9 used by PCA treatment. The PCA results on a data matrix; which consisting of nine stations during wet campaign (high water mark) and nine stations during dry campaign (low water levels).

Table 2 given correlation matrix of chemical elements during wet season. The NH_4^+ / NO_2^-, NH_4^+ / NO_3^- and NH_4^+ / SO_4^{-2} couples appear to be without a direct link between them and with all elements during winter. Their degree of correlation with other ions is not significant.

A strong correlation is observed between the TH/Ca^{+2} and TH/Mg^{+2} pairs with correlation coefficients equal to 0.954, 0.889 respectively. The K^+/Na^+ pair has an excellent correlation coefficient of 0.922. The relationships between the different cations indicate the existence of ion exchange reactions between soil solution and adsorbent complex **[15, 16].** The strong correlation of chlorides and the electrical conductivity of water is excellent, hence a great influence of chloride on the salinity of water, the correlation coefficient between CE / Cl^- = 0.935, pH / Cl^- = **-** 0.896. The high chloride concentrations can cause toxicity to sensitive crops at high concentrations **[21].**

For wet season, three factorial axes F1, F2 and F3 alone represent 86.86% of total variance (respectively 48.01%, 25.49% and 13.36%) and are representative of variance of the set of data. F1-F2 and F1-F3 factorial designs respectively represent variances equal to 73.50% and 61.36% (Figure 4).

The projection of the individuals shows that these are the surface waters of stations S1, S8 which are located upstream of the study area (near the Chaffia dam), and site S9 marked by the high concentrations of all the chemical elements, therefore the most polluted (Figure 5).

Table 2: Correlation matrix of different parameters in wet season

Variables	pH	EC	DR	SM	DE	Ca^{++}	Mg^{++}	TH	Na^+	K^+	NH_4^+	Cl^-	SO_4^-	NO_3^-	NO_2^-
pH	**1**														
EC	**-0.941**	**1**													
DR	-0.440	0.423	**1**												
SM	-0.676	0.722	0.292	**1**											
DE	-0.133	0.184	0.684	0.169	**1**										
Ca^{++}	0.739	-0.824	-0.178	-0.512	0.174	**1**									
Mg^{++}	0.434	-0.550	0.183	-0.389	0.489	0.711	**1**								
TH	0.666	-0.771	-0.038	-0.499	0.322	**0.954**	**0.889**	**1**							
Na^+	-0.684	0.731	0.327	0.412	0.506	-0.460	-0.261	0.411	**1**						
K^+	-0.714	0.767	0.254	0.545	0.348	-0.522	-0.283	-0.461	**0.922**	**1**					
NH_4^+	0.045	-0.006	0.117	-0.035	0.703	0.352	0.307	0.360	0.634	0.481	**1**				
Cl^-	-0.896	**0.935**	0.199	0.835	0.105	-0.753	-0.523	-0713	0.717	0.809	0.053	**1**			
SO_4^-	-0.077	-0.011	0.823	-0.112	0.684	0.220	0.635	0.414	0.133	0.097	0.252	-0.185	**1**		
NO_3^-	-0.788	0.838	0.671	0.755	0.307	-0.726	-0.293	-0.598	0.513	0.639	-0.126	0.761	0.333	**1**	
NO_2^-	-0.195	0.130	0.005	0.479	-0.237	-0.378	-0.116	-0.296	-0.305	-0.210	-0.597	0.244	-0.169	0.341	**1**

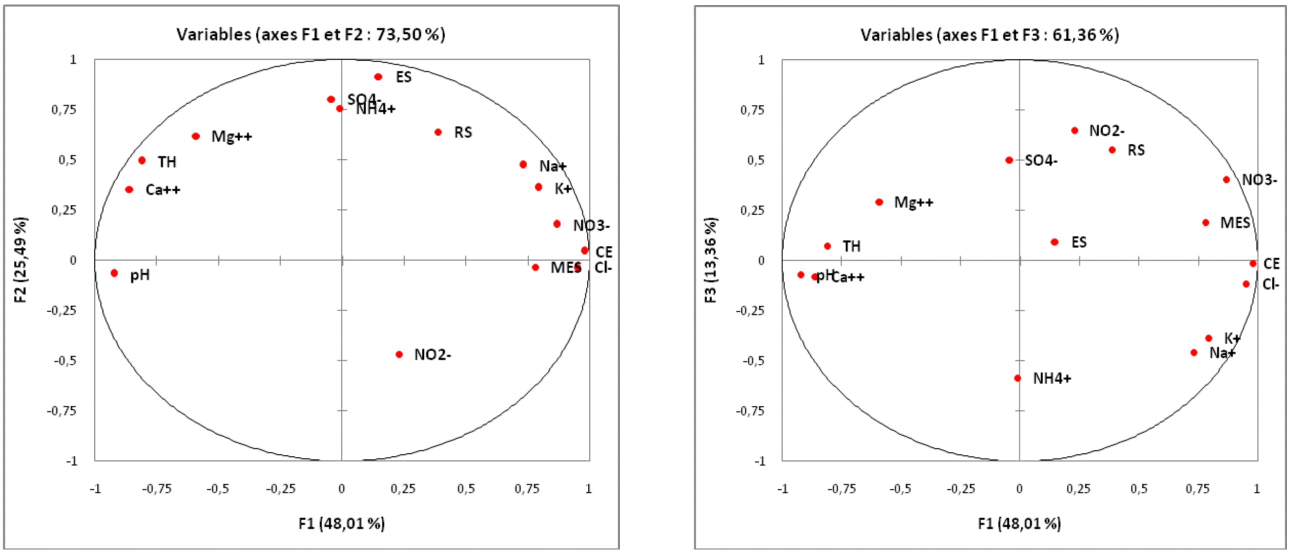


Figure 4: Factorial chemical distribution (wet season)

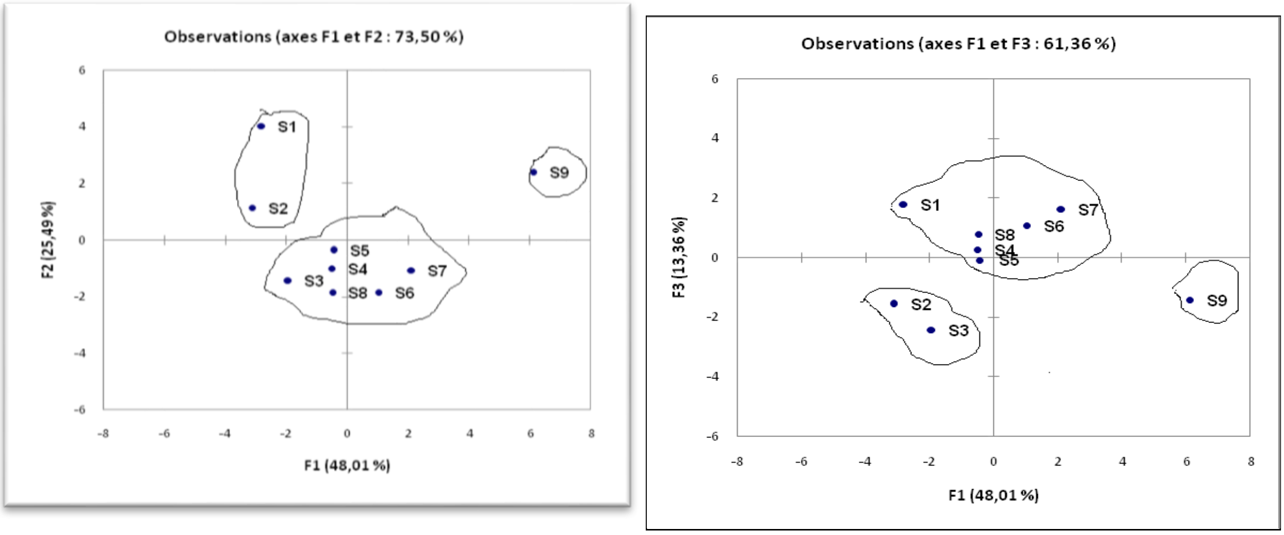


Figure 5: Factorial distribution of samples (wet season)

Table 3 shows the correlation matrix of various parameters of dry season. The majority of correlation coefficients are positive, which indicates a direct and significant link between the majorities of physicochemical parameters of surface waters of our study zone.

Table 3: Correlation matrix of different parameters in dry season

Variables	pH	EC	DR	SM	DE	Ca^{++}	Mg^{++}	TH	Na^{+}	K^{+}	NH_4^{+}	Cl^{-}	SO_4^{-}	NO_3^{-}	NO_2^{-}
pH	**1**														
EC	**0.866**	**1**													
DR	0.311	0.483	**1**												
SM	0.463	0.615	0.730	1											
DE	0.628	0.490	0.446	0.529	1										
Ca^{++}	0.184	0.268	0.612	0.427	0.647	**1**									
Mg^{++}	0.401	0.315	0.519	0.205	0.153	0.428	**1**								
TH	0.313	0.335	0.675	0.400	0.536	**0.914**	0.758	**1**							
Na^{+}	0.844	0.744	0.413	0.680	0.518	-0.050	0.196	0.052	**1**						
K^{+}	0.818	0.721	0.480	0.712	0.532	-0.001	0.250	0.112	**0.990**	**1**					
NH_4^{+}	0.518	0.640	0.675	0.494	0.158	0.475	0.760	0.684	0.377	0.398	**1**				
Cl^{-}	0.556	0.582	0.373	0.736	0.675	0.212	-0.098	0.109	0.716	0.753	0.052	**1**			
SO_4^{-}	-0.021	-0.017	-0.503	-0.668	-0.143	-0.116	-0.149	-0.151	-0.383	-0.394	-0.243	-0.177	**1**		
NO_3^{-}	-0.168	-0.277	0.074	0.128	0.482	0.453	-0.028	0.314	-0.195	-0.190	-0.344	0.079	-0.318	**1**	
NO_2^{-}	**0.893**	**0.903**	0.652	0.705	0.560	0.312	0.496	0.448	**0.864**	**0.874**	0.742	0.604	-0.241	-0.277	**1**

However, it observed that the Cl^- / SO_4^-, Cl^- / NO_3^-, Cl^- / NO_2^- and SO_4^- / NO_3^- pairs appear to have no direct link between them and with all the elements during this companion. Their degree of correlation with other ions is not significant. The K^+ / Na^+ pair has an excellent correlation coefficient of 0.990 for dry season. The relationships between different cations during both seasons indicate the existence of ion exchange reactions between solution and the adsorbent complex **[15, 16].** pH with EC and NO_2^- (respectively 0.866 and 0.893) shown a strong positive correlation. These strong correlations shown that the variations of the dissolved ionic charges related partly to variations in the contents of these ions. During September campaign, the FI axis expressed 49.26% of total variance, F2 axis expressed 18.76% and F3 axis expresses 13.74% of total variance (81.76% of total variance). The factorial F1-F2 and F1-F3 represented respectively 68.02% and 63% variances (Figure 6).

The F1 factor groups all the chemical elements in the positive pole except SO_4^-. The F1 factor therefore characterizes the mineralization (influenced mainly by evaporates) in its positive part and the less mineralized waters in the negative pole. In the individual plane (Figure 7) the FI axis distinguishes between slightly to moderately charged waters and highly mineralized waters.

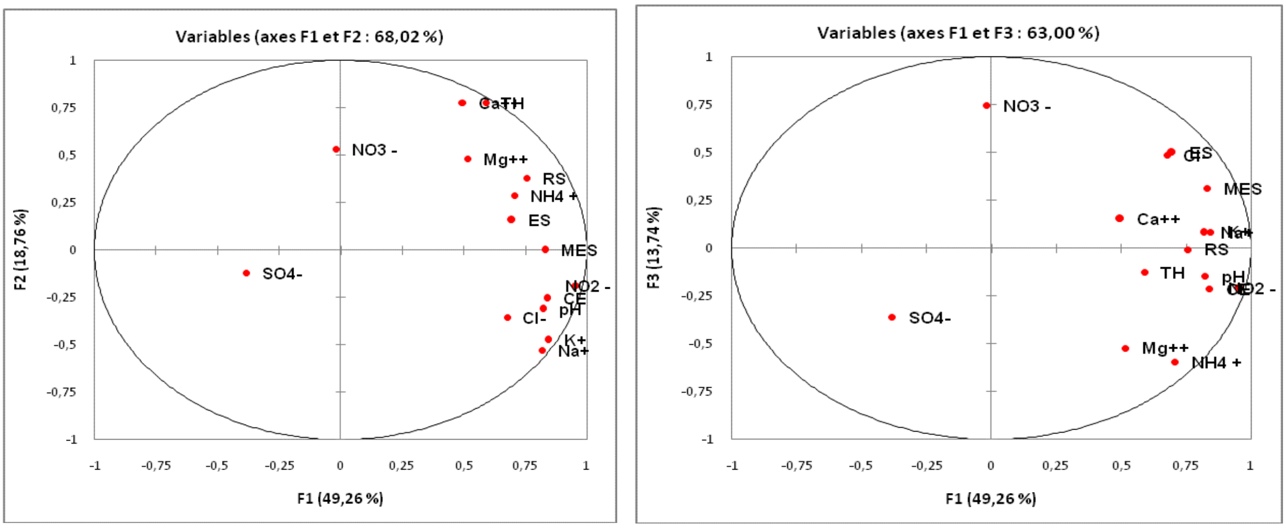


Figure 6: Distribution of chemical elements on the factorial plane (dry season)

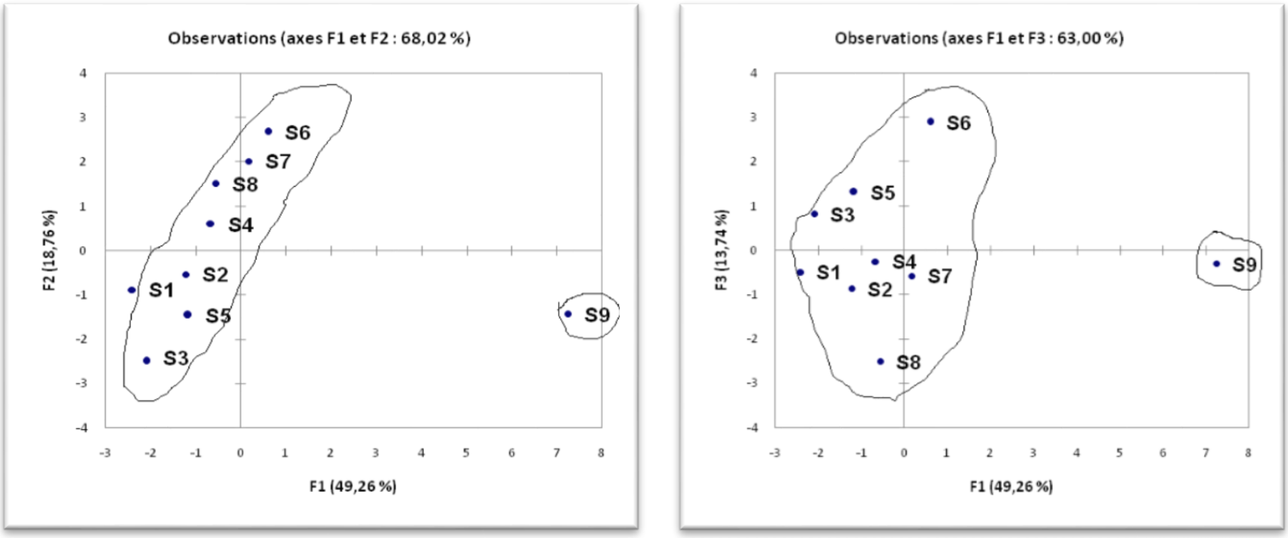


Figure 7: Factorial distribution of samples (dry season)

Our results are consistent with the conclusions of Jerônimo et al **[23]** who showed that wet season is strongly correlated with electrical conductivity, chlorides, sulphates and sodium. While the dry season is strongly correlated with ammonium, alkalinity and nitrates.

3.3. Chemical facies

In order to better identify the chemical facies and to have an indication of the qualitative aspect of surface waters of study's area, the graphical representation of the analysis results is a valuable tool. To achieve this goal, the Piper, Riverside and Schoeller-Berkaloff diagrams were used. The realization of these diagrams made using the Diagram software, designed by *Ronald Simler* (hydrogeology laboratory, University of Avignon, 2004).

3.3.1. Piper diagram: this diagram has the particularity to represent several samples on same plane. It is composed of two triangles, to determine the chemical facies (cationic and anionic). The global facies obtained by intersection on a rhombus synthesizing the chemical facies of the sample considered **[21, 24].**

The Piper diagram established by surface waters of our study area (Fig 6) shows three families of facies during both wet and dry seasons:

- A chlorinated and sulphated calcium and magnesian family.
- A sodium chloride family.
- A sulphated calcium and magnesian family.

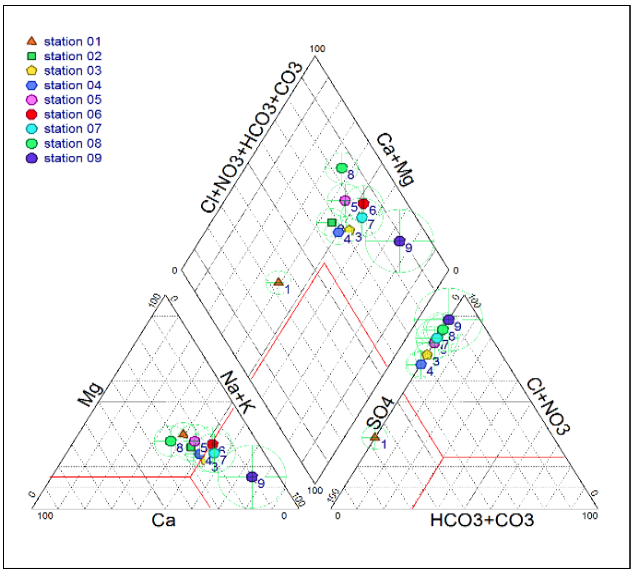


Figure 8A: Piper Diagram of Waters Wet Season

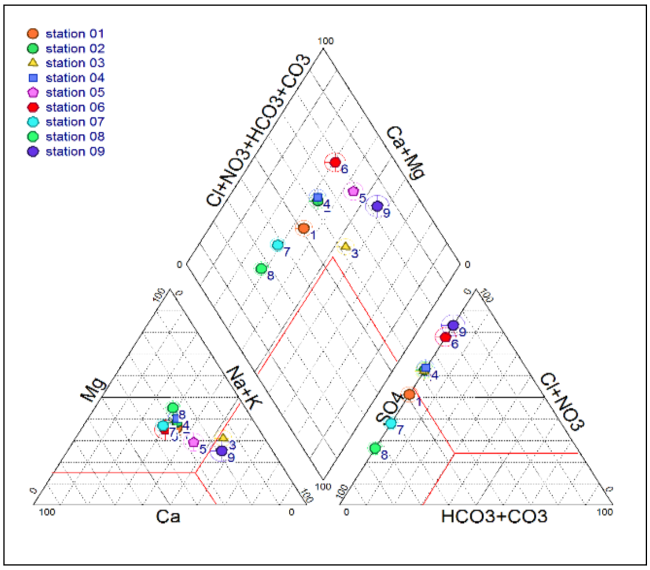


Figure 8B: Piper Diagram of Waters of Dry Season

Figures 8A and 8B illustrated the predominance of Na^+ ions with respect to Ca^{2+} and Mg^{2+} among cations, as well as the abundance of Cl^- and SO_4^{2-} ions among anions in waters of this period. This explains the predominance of sodium chloride facies observed on both diagrams **[24].**

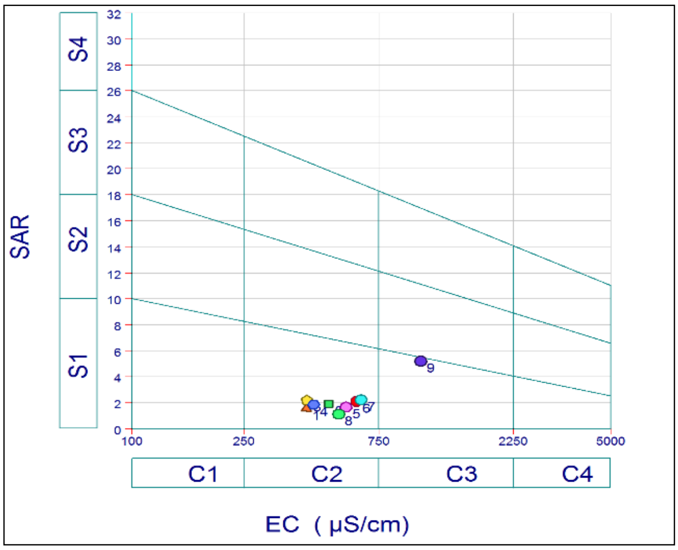
3.3.2. Riverside Diagram

The Riverside diagram, which based on electrical conductivity (EC) and Sodium Absorption Ration (SAR), taken into account the balance between these two variables, one of which influences the other. . The risk of sodicity due to SAR attenuated in the presence of high salinity **[25].**

According to Riverside diagram established by surface waters of study area collected during April (Fig 9A) which shown that they belong to classes (C2-S1) and (C3-S1). These classes classified as medium to good, poor quality and water used with caution in poorly drained soils and only for irrigation of salt-tolerant crops. Drainage is necessary and during September (Fig 9B) which shown that they belong to classes (C1-S1) and (C2-S1). These classes were as medium to good quality for irrigation and as water for use with sensitive plants and in poorly drained soils and for sensitive plants (fruit trees) **[25].**

3.3.3. Representation on the Schoeller-Berkaloff diagram

A semi-logarithmic diagram gives indications on certain chemical parameters of water. The representation of the chemical content of the water points on the Schoeller-Berkaloff diagram has the same appearance as the Piper diagram, and it is constant that the dominant facies is the sodium chloride facies (Figures 10A & 10B) respectively for wet and dry seasons. It reported that the content of bicarbonates and / or carbonates were absents, compared to that of the other anions, which explained the very low distribution of the bicarbonate facies.



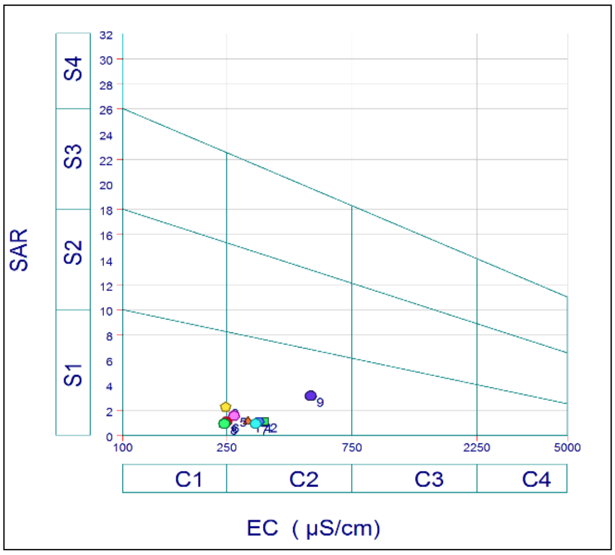


Figure 9A: Wet season **Figure 9B: Dry season**

Figure 9A and 9B: Salinity diagram for classification of irrigation waters

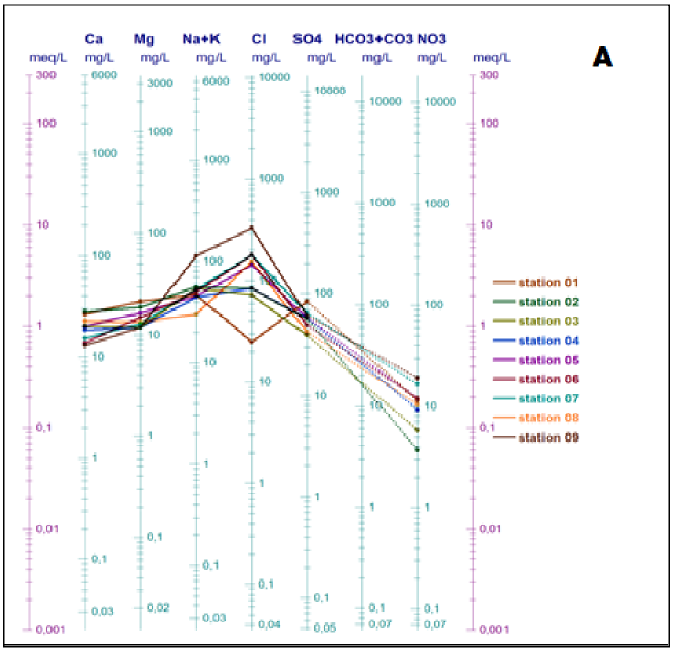


Figure 10A: Schoeller-Berkaloff diagram (wet season)

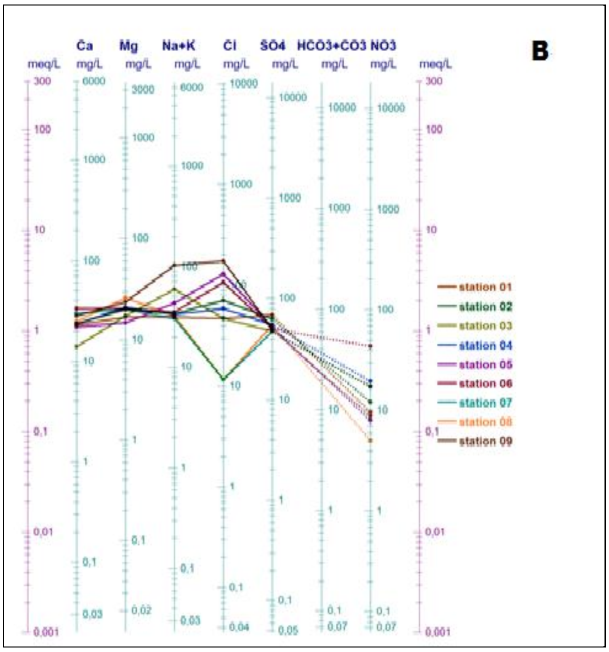


Figure 10B: Schoeller- Berkaloff diagram (dry season)

Conclusion

Before using water for irrigation, its quality, which is equally important to its quantity, should be assessed so that it could not create any health hazard. If low quality of water is utilized for irrigation, soluble salts and /or other toxic elements may accumulate in the soil thus deteriorating soil properties and crop quality.

Seasonal variation in the concentration of chemical elements is related to the effect of the region's climatic conditions (precipitation, evaporation), and to the exploitation of resources by pumping and irrigation.

Wadi Bounamoussa constitutes a privileged area in humid region, characterized by a clay and sandy-clay filling of which piezometric levels are very close to those of soil generally very fertile. The study of chemical quality of surface waters made it possible to determine that the ionic balance of surface waters of our study area were characterized by a dominance of sodium then calcium among cations, and chlorides then sulphates among anions. This study has also shown the importance and utility of multivariate analysis techniques to obtain information on water quality, to identify the dominant typology of water and thus prevent any kind of pollution.

The chemical facies of the surface waters of wadi Bounamoussa made it possible to understand the relationships that exist between chemical parameters of these waters and their origins. The most predominant facies of these waters is sodium chloride facies.

The spatiotemporal variation of several physicochemical parameters gave us an idea of a relatively intense pollution which results in a significant polluting load and a deterioration of the water quality, particularly in the area of Ben M'Hidi located partly upstream of wadi Bounamoussa, subject to urban, agricultural and industrial discharges (Station S9 presents a risk of occasional accidental pollution).

Salinity can lead to significant adverse effects due to the fixation of sodium chloride by soil colloids. In addition, salts cause changes in soil structure (permeability and aeration) that directly affect crop development. Irrigation with raw water that is too rich and rich in salt will result in an increase in soil salinity after enrichment with chloride, sodium and calcium. These waters are generally acceptable for agricultural use without any alkaline or bicarbonate and magnesium hazards.

The release of Cheffia dam plays an important role in improving surface waters quality of wadi Bounamoussa, with caution in irrigation areas. These discharges contained in water have adverse effects on the soil and agriculture and can create health risks for farmers who come into contact with these waters and for consumers of agricultural products.

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