J. Mater. Environ. Sci. 7 (8) (2016) 2852-2860 El Khodrani et al.
ISSN : 2028-2508
CODEN: JMESCN

Study of Physico-Chemical Quality of Groundwater in the Rural Commune of SFAFAA *(Sidi Slimane Gharb, Morocco)*

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Received 23 Feb2016, Revised 04 Jun 2016, Accepted 08 Jun 2016
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Abstract
The aim of this work is to study the physico-chemical quality of groundwater in the water table of the Sfafaa's municipality district (Morocco). We have carried out a qualitative study of the water in different sites of the irrigated perimeter of Sfafaa located in the province of Sidi Slimane Gharb. In fact several measurement campaigns (pH, groundwater depth) and laboratory analysis (ionic balance) were conducted to determine the physico-chemical characteristics of water. We prospected 17 wells distributed into 6 zones: A, B, C, D, E, and F. Data were statistically analyzed using the analysis of variance (ANOVA). The results showed that the depth of water table varies between 9 and 12 m and that 70.6% of the studied wells was highly to extremely saline and then inadequate for irrigation. The studied zones do not have the same salinity level. In fact, the E and F zones represent a significantly higher salinity compared to other zones. This was confirmed by the sodium and chloride rates. Similarly, the difference was statistically significant between zones for calcium, magnesium, potassium, carbonates, nitrates and sulfate. In conclusion, the use of waters of low quality for the irrigation leads to soil degradation by an accumulation of salts. This accumulation is more or less important depending on the quality of water, the nature of the soil, the climate and the way of irrigation. In order to overcome this situation of water degradation in the Sfafaa region, farmers should use efficiently and rationally fertilizers as well as water saving irrigation techniques and salt tolerant crops.

Keywords: Groundwater, quality, physico-chemical, Sfafaa, Morocco.

1. Introduction
Water is an indispensible element for life, socioeconomic and sustainable development of a country. Therefore, it is necessary to have a better knowledge of the existing water resources especially the following information:

- The vulnerability of resources to a possible factor.
- The necessary measures to develop to manage and protect the resources.

All over the world, a lot of studies have stressed the problem of the degradation of soil and groundwater quality which can limit the long-term agricultural production and cause irreversible deteriorations. This deterioration of the quality of these resources is due to the wrong management of irrigation water and agro-chemical inputs. Indeed, the salinization and sodification of agricultural lands, resulting from irrigation with marginal and poor-quality water (mainly groundwater), are increasing rapidly [1].Hence; around 30% of the world irrigated surface is saline. The Mediterranean region registers approximately 16 million hectares [2]. Morocco is highly concerned by this issue. In fact, our country is currently experiencing a situation of water stress (less than 1000 m^3/capita/year) and a shortage of water (less than 500 m^3/capita/year) is expected after 2025 [3.4], because of the periods of extended drought. Also, the zone of productive soil per will decrease due to population growth and deterioration of natural resources phenomena.
Several irrigated perimeters in Morocco are seriously threatened, if no action is taken with the aim of managing water and soil resources in a more sustainable manner [5], [6], [7].
In Morocco the groundwater constitutes an important part of the hydraulic heritage of the country [8], because of its relatively easy exploitation.
The groundwater is traditionally the preferred water resources for drinking, because they are more protected from pollution compared to surface waters [9]. The region of Sidi Slimane Gharb , object of our research work, is a zone with intense farming and agricultural activity ; it plays an eminent socioeconomic role in Morocco. In the studied region, the groundwater has always been an important source of drinking water supply for the local populations, for farming animals and irrigation.
However the water quality represents a growing preoccupation. The challenge which all regions of Morocco and particularly the rural zones face is the protection and the preservation of the quality of groundwater resources. In fact, the use of groundwater with poor quality represents one of the most worrying issues especially when it is used for nutrition exposing this population to health hazards [10].
In this context, the present work is interested in the study of the physicochemical quality of groundwaters of the water table of the Sfafaa's municipality district (Sidi Slimane,Gharb).

2. Materials and Methods

The study zone belongs to the Province of Sidi Slimane, located around the geographic coordinates 34° 15′0" and 6° 9′36", it is limited to the north by the Province of Sidi Kacem (region of the Rabat-Salé-Kénitra), in the south-east by the rural commune of Boumaiz (Province of Sidi Slimane), and to the west by the rural commune of Kecybia (Province of Sidi Slimane), the rural commune of Sfafaa extends approximately 197km^2.
Fertile land, a temperate and humid climate and abundant water resources of the commune of Sfafaa, make of it an agricultural zone of first importance. This commune is a natural collector of surface waters. Its flat morphology (the majority of the plain with a coast lower to 12 m) disfavors the evacuation from flood waters of the river up to the sea.
The irrigated of the zone can be divided into two sub-zones: Those irrigated by the Beht river and those by the Sebou river [11]. The meteorological station of Sidi Slimane [11], records minimum precipitation compared to the other stations in the region of the Rabat-Salé-Kénitra , because of the combination of the effect of the altitude and continentality. The months of most precipitations are November, December and January and the driest are June, July and August. July and August are the hottest months while the coolest are December, January and February. The dry period lasts from May to September.

The prospected wells

We have prospected 17 wells, belonging to the commune of Sfafaa. These wells are divided into 6 zones: A, B, C, D, E and F (Fig 1). The depth of the water table of the commune Sfafaa varies between 9 and 12 m.
The samples of water wells were collected during two seasons (spring and summer) and for two years (2013-2014) with a mean annual precipitation of 386.4 mm. They were conditioned, and then transported in a cooler at 4°C to the laboratory for analysis in the Research Unit on the Environment and Conservation of Natural Resources the National Institute of Agricultural Research in Rabat. Table 1 summarizes the whole physico-chemical parameters measured as well as the methodology followed.

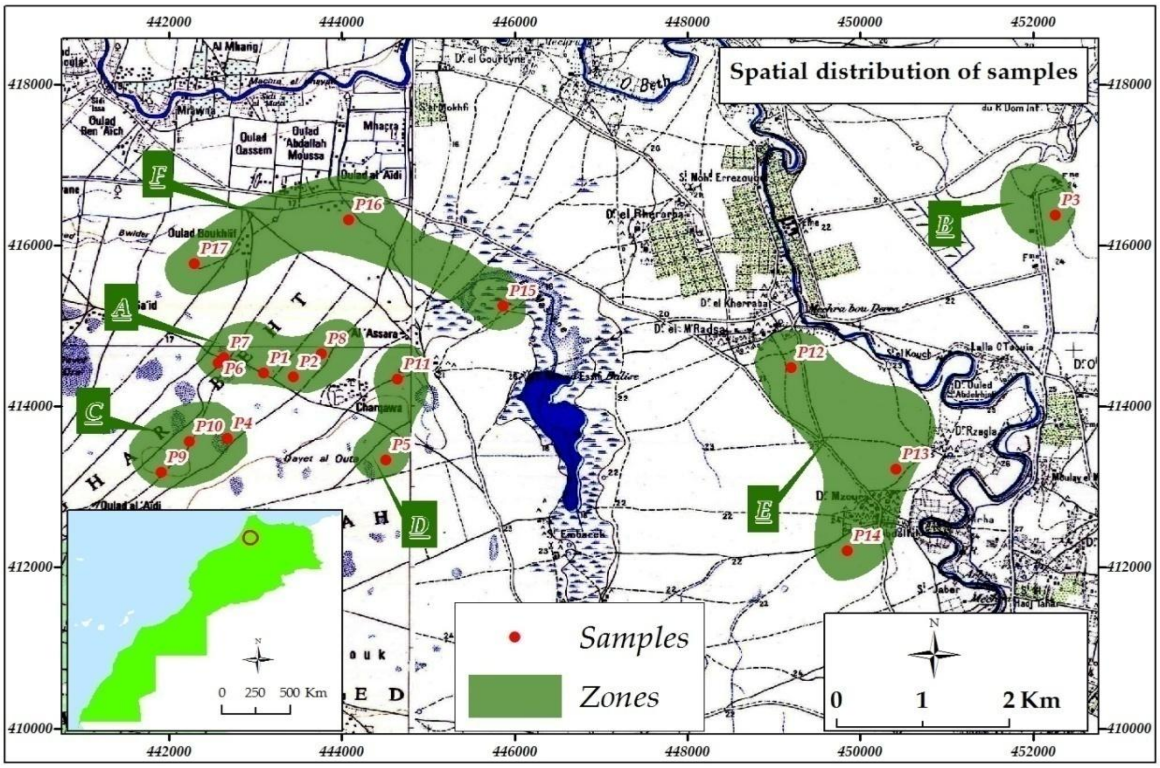

Fig1: Presentation of the study zone and prospected wells.

Table 1: Physico-chemical parameters measured with the corresponding methods used, Rodier [12].

Parameters	Abbreviation	Unit	Methods used
Electrical Conductivity	E.C	mS/cm	Conductivimeter
Hydrogen Potential	pH	-	pH-metre
Calcium	Ca^{2+}	meq/l	Complexometry with EDTA (0.02N)
Magnesium	Mg^{2+}	meq/l	Complexometry with EDTA (0.02N)
Sodium	Na^{+}	meq/l	Flame photometry
Potassium	K^{+}	meq/l	Flame photometry
Chloride	Cl^{-}	meq/l	Mohr's method
Bicarbonate	HCO_3^{-}	meq/l	Acido-basic titration (HCl 0.05N)
Sulfate	SO_4^{2-}	meq/l	Nephelometric
Carbonate	CO_3^{2-}	meq/l	Acido-basic titration (HCl 0.05N)
Nitrate	NO_3^{-}	Ppm	Steam distillation

3. Results and Discussion

The results of measurement of various physicochemical parameters are presented in table 2. In this table, we expressed the levels in means ± standard deviations.

The significance of the difference between the zones is expressed by the F ratio of Fisher-Snedecor as well as the corresponding probability. The difference is considered statistically significant when the probability is less than 0.05.

Table 2: Means ± standard deviations of the physicochemical parameters for the studied zones and the ANOVA significance test.

Parameters	Zones						Signification	
	A	B	C	D	E	F	F value	P value
E.C(mS/Cm)	0.81 ± 0.58	1.24±0.78	0.41±0.18	1.25±0.83	2.79±0.70	3.9±2.41	10.21	<0.001
pH	7.21±0.35	7.4±0.24	7.21±0.25	7.11±0.18	7.33±0.04	6.96±0.37	1.15	0,35
Ca^{2+}	7.92±2.86	5.52±1.32	3.19±1.13	7.23±1.67	5.07±1.70	11.6±9.43	4.24	<0.001
Mg^{2+}	2.95±1.51	4.64±1.44	1.45±1.43	3.9±1.69	3.73±1.14	10.2±9.89	4.37	<0.001
Na^{+}	1.84±0.81	3.95±4.03	0.8±0.50	1.29±1.16	5.16±1.38	10.32±9.05	6.43	<0.001
K^{+}	0.05±0.09	0.06±0.03	0.02±0.01	0.06±0.07	0.09±0.01	0.36±0.48	3.01	<0.001
Cl^{-}	10.24±3.97	12.2±1.82	4.81±3.54	12.68±3.71	19.6±6.13	32.1±22.70	8.04	<0.001
HCO_3^{-}	0.49±0.67	1.43±1.93	0.25±0.71	0.23±0.57	0.8±0.20	1.77±0.65	2.30	0,07
CO_3^{2-}	1.02±0.72	2.58±2.11	1.77±0.72	1.64±1.22	4.7±0.36	1.5±1.66	5.70	<0.001
NO_3^{-}	23.56±6.74	12.2±10.84	11.43±7.32	36.27±13.18	4.23±3.67	19.77±18.31	7.33	<0.001
SO_4^{2-}	1.39±1.13	5.87±0.80	1.67±0.70	5.4±1.35	2.91±0.00	2.91±0.00	25.89	<0.001

We will detail below the results of each parameter as well as the comparison between the different studied zones. Excluded from this analysis are the pH and bicarbonate (HCO_3^-) because they have not presented any significant difference between the zones ($P \geq 0.05$).

3.1 Electrical Conductivity and Salinity of water

3.1.1 Electrical Conductivity of water

Regarding the salinity, we performed a one-way analysis of variance (ANOVA) for the zones studied. The results obtained show a statistically significant difference ($F=10.21$; $p < 0.001$), which explains that the zones studied do not have the same levels of salinity in terms of electrical conductivity (Fig 2).

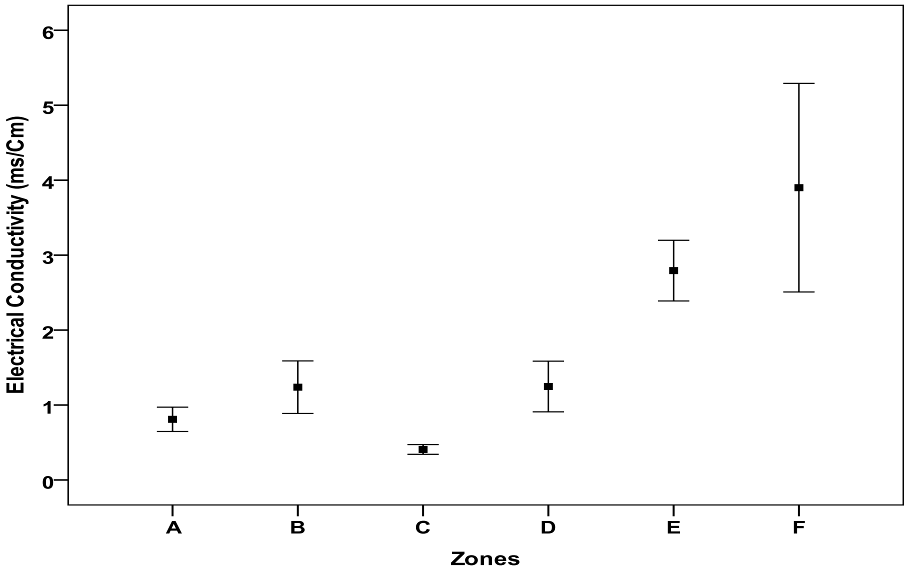

Fig 2: Repartition of means of E.C in function of the studied zones.

Subsequently we have made a comparison of means using the Duncan test [13] which revealed the existence of three groups:

- The first group contains zones C, A, B, D with an average of 0.93 mS/cm.
- The second group corresponds to the zone E with an average of 2.79 mS/cm.
- The third group corresponds to the zone F with an average of 3.90 mS/cm.

The fact that the zones E and F represent a higher salinity compared to the other zones could be explained by the proximity of the Beht river which makes these zones more suitable for crop intensive production. This makes them more exposed to the intensive use of fertilizers and pesticides.
On the other hand, salinity which is significantly higher in the zone F compared to the E zone, would be due to the fact that the zone E is located toward the upstream whereas the zone F is located toward the downstream of Beht river. This implies that the soil in the zone F accumulates in addition to fertilizers used locally, those emanating from the zone E and transported by the river.
The results obtained for the electrical conductivity are confirmed by those registered for the elements sodium Na^+ and chloride Cl^-.

3.1.2 *Salinity of water*
Table 3 presents the classification of waters analyzed according to the U.S. standards for the classification of irrigation water. It is clear from these results that 70.6% of the wells sampled belong to classes C3, C4 and C5. These waters are considered to be extremely saline and therefore, unsuitable for irrigation because they have a higher potential for soil salinization and may cause significant yield reduction, especially for sensitive crops.

Table 3: Distribution of irrigation water salinity of the Sfafaa's region, following the USSLS standards (1954) [14].

Salinity class	symbol	EC (mS/cm)	Number of wells	% wells
Non saline	C1	<0.25	**0**	0.0
Averagely saline	C2	0.25-0.75	5	29.4
Highly saline	C3	0.75-2.25	7	41.2
Very highly saline	C4	2.25-5	4	23.5
Extremely saline	C5	>5	1	5.9

3.2 *Ionic balance*
3.2.1 *Sodium*
The analysis of variance shows that the studied zones differed significantly in terms of the sodium content ($F=6.43$; $p<0.001$). In addition, the comparison of sodium levels, as for conductivity, shows the existence of three groups (Fig 3), with the zone F presenting the higher content of sodium, due to the same reasons as for the electrical conductivity, discussed previously.

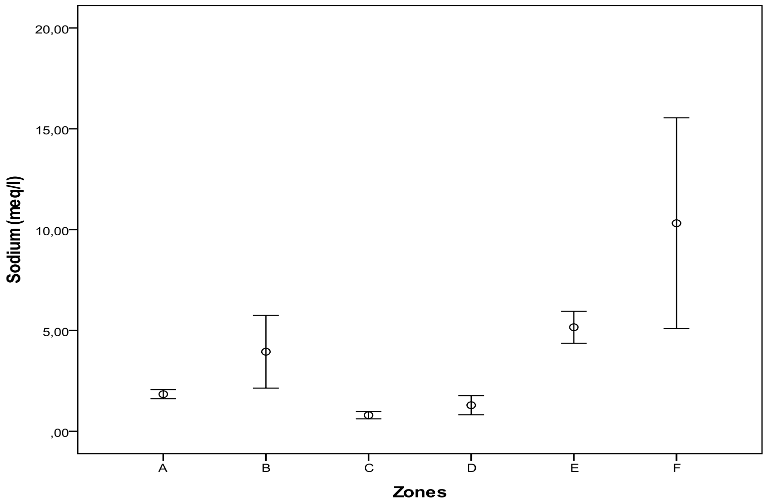

Fig 3: Repartition of means of Sodium in function of the studied zones.

3.2.2 *Chloride*
The analysis of variance shows that the studied zones differed significantly in terms of the chloride content ($F=8.04$; $p<0.001$). In addition, the comparison of chloride levels also shows the existence of three groups (Fig

4). It can be seen that the zone F always presents the higher content in chloride, which is in agreement with the results obtained for sodium and electrical conductivity.

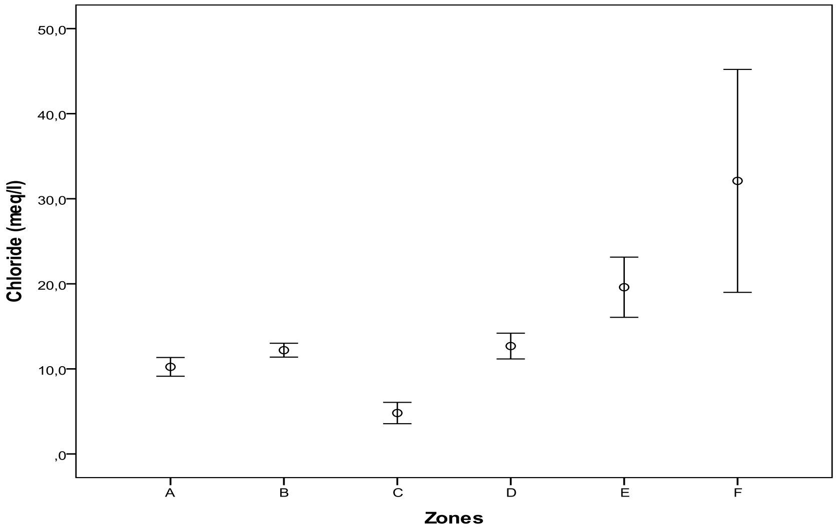

Fig4: Repartition of means of chloride in function of the studied zones.

3.2.3 *Potassium*
The analysis of variance revealed that the studied zones present levels of potassium significantly different (F=3.01; p <0.001). In addition, the comparison of levels shows the existence of two groups (Table 2).
It can be observed that the zone F always presents the highest potassium content that may come in large part from the use of potash fertilizers justified by the intensive agricultural activities carried out in this zone.

3.2.4 *Calcium*
We used the ANOVA to compare the levels of calcium between the different zones. The analysis showed a statistically significant difference (F=4.24; p <0.001). The comparison of these levels shows the existence of three groups (Table 2). It can be seen that the zone F always presents the highest content in calcium.

3.2.5 *Magnesium*
The analysis of variance revealed that the studied zones differed significantly in terms of the magnesium content (F=4.37; p <0.001). According to the comparison of magnesium levels inside the different zones, it has shown the existence of two groups (Table 2). The zone F always presents higher content in magnesium. These results are similar to those obtained for calcium. Generally, calcium and magnesium constitute together the major elements in water minerals.

3.2.6 *Sulfate*
The analysis of variance showed that the studied zones are statistically different in terms of the content of sulfate (F=25.89; p <0.001). The comparison of levels also shows the existence of three groups (Table 2). It can be seen that zones B and D presents the highest content in sulfate, still remaining in the recommended standards for irrigation water [15].

3.2.7 *Carbonates*
The analysis of variance revealed that the studied zones are different significantly in terms of the content of the carbonates (F=5.70; p <0.001).On the other hand, the comparison of levels shows the existence of two groups (Table 2). It can be seen that zone E presents the highest content in carbonates.

3.2.8 *Nitrates*
As in the case of the previous parameters, nitrates levels are significantly different between the studied zones (F=7.33; p <0.001). The comparison of these levels shows the existence of three groups (Table 2). In fact, the D zone is the most concerned by the high content of nitrates. This is due to the massive use of nitrogen fertilizers, livestock and the surface irrigation [16-17]. In fact, one way to stop the nitrate cycle is to use less fertilizer.

Depending on the type of crop and soil conditions, some plants only use half of the fertilizer a farmer applies – leaving the rest to evaporate or percolate into the groundwater. Also, fertilizer and irrigation go hand in hand, and conserving irrigation water cuts down on fertilizer use as well. In addition, the establishment of nitrogen standards for each crop will help farmers to use the appropriate amount of this nutrient. Eventually, regulating the use of commercial fertilizer seems to be a priority to avoid groundwater degradation from nitrate pollution.

3.3 *Water alkalinity*

Table 4*:* Repartition of salinity and alkalinity classes of the studied waters.

Class of salinity(C) and alkalinity(S)	Number of wells	% wells
C2-S1	5	29.4
C3-S1	7	41.0
C4-S1	3	17.6
C4-S2	1	6.0
C5-S2	1	6.0

The use of the Richard diagram (1954) [14] allows to assign to each water a corresponding class of quality in terms of salinization and alkalinisation risks, when this water is used for irrigation (Fig 5). Table 4 gives the distribution of salinity and alkalinity classes of the studied waters. It is observed that the quality classes of waters that dominate are: C2-S1, C3-S1 and C4-S1.
This shows that the waters of irrigation of Sfafaa (Sidi Slimane, Gharb) present a medium danger of salinization and a low to medium risk of alkalinisation.

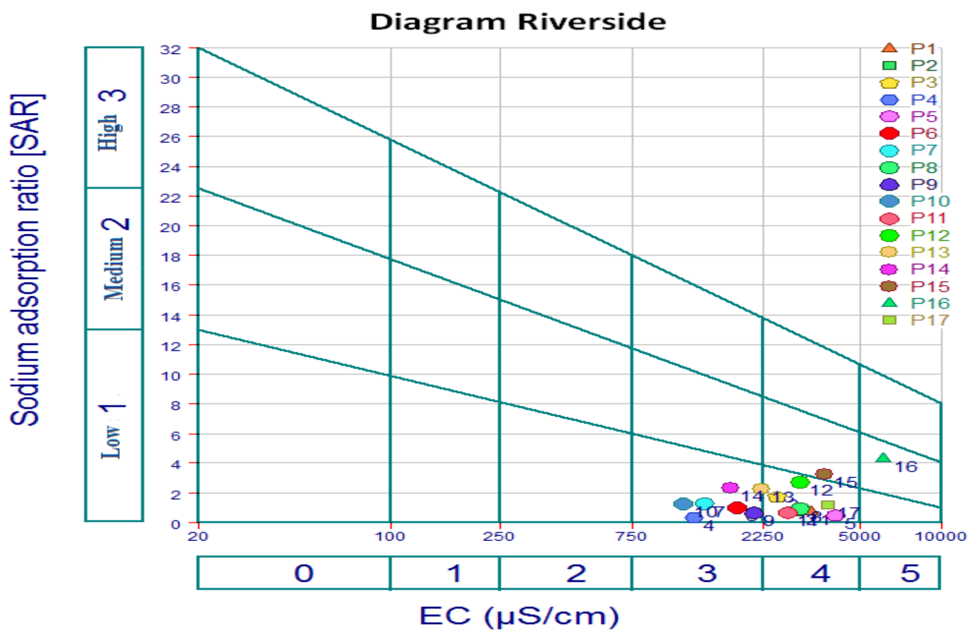

Fig 5*:* Diagram of the determination of the quality of irrigation waters of the region of Sfafaa.

SAR : sodium adsorption ratio (meq/L).
EC : Electrical conductivity to 25 °C (µS/cm).

3.4 *Hydrochemistry*
According to the Piper diagram we distinguish one type of chemical facies that characterize the waters of Sfafaa (Fig 6): Chloride sulphated-and calcium-magnesium facies.
According to the geological map of the study zone, dominant lithological units are formed of Loamy Alluvium of Recent Quaternary (Pleistocene and Holocene), which was confirmed by Hmamouchi et al [18-19].

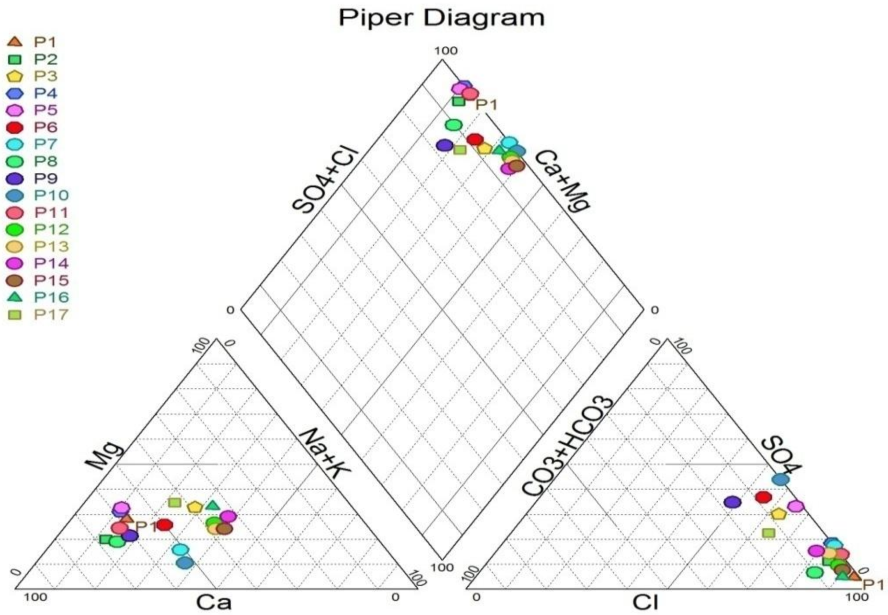

Fig 6: Piper Diagram for water of Sfafaa.

Conclusion

The suitability of water for irrigation is based on many factors like the quality of this water, soil types, grown crops, cropping practices, etc. When dissolved ions are in excess in irrigation water, they affect harmfully plants and agricultural soils, both physically and chemically, therefore reducing the productivity. In fact the study carried out in this work has allowed us to characterize the quality of irrigation waters of the commune of Sfafaa (Sidi Slimane, Gharb). It has shown:

- A higher salinity in the zones E and F compared to the other zones. This high level of salinity was more pronounced in the F zone.
- The groundwaters belonging to upstream and downstream zones in the region (more than 70.6% of water) have a higher potential for soil salinization and may cause significant yield reduction, especially for sensitive crops. This was mainly related to the influence the waters of Behet's river, to the water depth and to the geological nature of the aquifer.
- A concerning level of contamination of groundwater by nitrates was observed in some zones. A rational use of nitrogen fertilizers will contribute to overcome this situation.
- A low to medium risk of alkalinisation. In fact, 100% of the waters studied have values of SAR less than 6.
- A dominance of classes of salinity and alkalinity: C2-S1, C3-S1, C4-S1.
- Chemical facies identified was chloride sulfated-and calcium-magnesium facies.

In order to overcome this situation of water degradation in the Sfafaa region, farmers should use efficiently and rationally the fertilizers as well as water saving irrigation techniques and salt tolerant crops.

Acknowledgements-The present work has the objective to contribute to the enhancement of the sustainable development of agriculture in the region of Rabat-Salé-Kénitra. We want to thank all the people who have helped me in the field and in the laboratory throughout this work.

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