Journal of Materials and Environmental Sciences
ISSN : 2028-2508

JMES, 2017 Volume 8, Issue 8, Page 2792-2799

http://www.jmaterenvironsci.com/

2'JP2E, 24-25 Oct. 2016, FP-Taza

Study of the groundwater quality in the irrigated plain of Tadla

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Received 18 Dec 2016
Revised 29 Mar 2017
Accepted 31 Mar 2017

Keywords

- ✓ Perimeter of Tadla,
- ✓ Groundwater,
- ✓ Fertilizer,
- ✓ Quality,
- ✓ aquifer

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Abstract

In the irrigated perimeter of Tadla one of the biggest perimeters irrigated in Morocco, the intensification of agriculture coupled with the increased use of surface and groundwater resources, is considered to be responsible for the diffuse pollution and the deterioration of some parameters of the groundwater quality and soils.
Moreover, the overexploitation of groundwater will cause a lowering of piezometric levels leading to the drought of the wells and drilling. Consequently it's necessary to take rational measurements to control and safeguard the water resources.
In this context, this study was carried out in order to determine the fertilizers use effects on the waters quality of the aquifer of Tadla. The obtained results allowed diagnosing the different polluted zones.

1. Introduction

The Morocco irrigated perimeters are threatened by the nitric pollution of groundwater which decreases the potential of water resources that are good quality thus generates a risk for the population health and for the socio-economic developments in the country [1]. The mastery of this pollution requires sufficient knowledge of the causes and mechanisms responsible for this problem [2]. Furthermore, the abusive use of agrochemical inputs, agricultural intensification and heavy pumping of groundwater reduce the quality and the availability of water.
EL OUMLOUKI et al., [3] reported that overexploitation of these resources, accompanied by the phenomenon of drought, leads to soil and water degradation, resulting problems of solidification, salinization, waterlogging, soil structure deterioration, and the nitric pollution. Recently, the safeguard and protection of the natural environments, especially water quality, became a main concern in the development programs of the country.
Because of the increasing scarcity of water resources in Morocco and the degradation of their qualities, our country has a particular interest in water economics, especially in irrigation and control of different types of pollution.
The nitrates contamination of groundwater has become a major interest of decision makers and researchers in various regions of the world. To protect the groundwater quality, some countries have established networks to monitor nitric water quality [4, 5]. The aim of these monitoring systems is to monitor and to diagnose in the long term the evolution of groundwater quality as a function of soil types and their use, hydrogeological conditions and anthropogenic activities, these systems are also an important tool to help the decision for the improvement of production systems and to better manage the natural resources [6].

2. Materials and methods

2.1. Study area

Located in central Morocco, the Beni-Mellal Khenifra region covers a total area of 2 811 000 ha, [7]. It encompasses five provinces, the capital of which is Béni-Mellal, with a population of 2.52 million in 2014, or approximately 7.4% of the country's total population [7]. The Region of Beni-Mellal Khenifra present three distinct agroecological systems: the plain, the premont and the mountain.

Our study focused on the Tadla plain which lies in the basin of OumErRbia, this last crosses the plain and divided it into two zones: Beni Amir in North and Beni Moussa in South which irrigated areas are 33 000 ha and 69 500 ha respectively as shown in the figure 1. Both perimeters are independent on the hydraulic plan. Indeed, Beni Amir irrigation is provided by the Oum ErR'bia waters, while irrigation of Beni Moussa is assured by the Bin El Ouidane dam's waters [8].

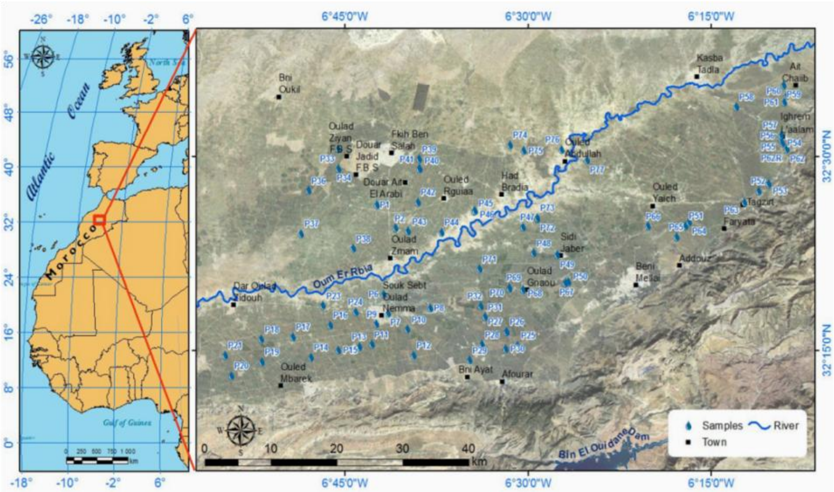

Figure 1: Geographical situation of the study area and sampling points.

In Tadla plain, the main pollution sources are the industrial pollution; which is mainly generated by the agro-food industries effluents, namely sugar factories, canneries, oil mills and the dairy plant, which are located in Beni Amir and Beni Moussa tablecloths, and the domestic pollution generated by the wastewaters directly discharged to OumErrabia without any prior treatment. The agricultural is the most dominant economic activity in the plain; and the agricultural pollution is mainly due to the intensive use of phytosanitary products and fertilizers. This pollution presents the main factor of the increase in rates of organic matter and nitrates. The water used for irrigation in Tadla plain comes mainly from surface waters. While, the proportion of groundwater has become increasingly important in recent decades, because of the general decline of the pluviometric mode [9].

2.2 Climatology

The climate of the plain ranges from Mediterranean type in the semi-arid with cold winter [6]. The annual precipitations are irregular and vary between 250 and 600 mm, the snow appears from 900 m of altitude and the dominant winds blow in East and South East (Chergui). The average annual temperature is around 18 ° C and varies between 3.5 ° C in winter and 40 ° C in summer [7].

2.3 Hydrology

The main water course that passes through the plain of Tadla is Oued Oum ErRbia, Its average flow rate is 38.6 m3 / s with a minimum of 10 m^3 / s and a maximum of 1700 m^3 / s. The waters of Oumer Rbia, used for the irrigation of Beni Amir, are relatively saline (0.7 g / l). This salt load is introduced by wadiSrou, the important tributary circulating on the salt formations of the Triassic. The waters of this wadi have a dry residue average of 1.25 g / l, with a maximum of 6 g / l during a low-water period.

On the other hand, the wadi El Abid, whose waters are used for the irrigation of Béni Moussa, carries water of good quality (0.3 g / l) ([10]; [11]).

2.4 Morphology

The Tadla plain is the witness of a collapse that occurred between the Moroccan Meseta and the chain of the Atlas. This collapse is bordered to the North by the Central Plateau (Cretaceous), to the West by the Rehamna primary massif, to the West and to the South by the limestone folds of the Middle Atlas. In Villa franchian, the Tadla plain was occupied by a large lake which has found an outlet in Imfout by digging a deep throat in the primary rock of the Meseta. Thus, Oum-Er-R'bia was born from the draining of a lake which opened a way to the sea, the Tadla Lake was fed by Wadi El-Abid, wadi Lakhdar, Wadi Derna and another small wadi which takes its sources at about 40 kilometers from Kasba-Tadla [12].

2.5 Hydrogeology

In Tadla plain, the diverse structures of geological formations have given birth to a succession of aquifer layers of variable hydraulic importance and the contrasts of permeabilities between levels. The main tablecloths in the region of the Tadla are:

•the water table of varying depth and salinity circulating in plio-quaternary formations;

•the Eocene limestone water table which is of good quality for irrigation and whose depth is between 80 and 110m;

•The Turonian limestone, with a depth of more than 200 m, constitutes the main resource of good quality water under the Tadla Plain [11].

3. Experimental Protocol

3.1 Physicochemical analyzes

The samples are taken during peak seasons, the summer and the winter period.

The physicochemical parameters likely to vary such as electrical conductivity (EC), pH, and temperature T °C were measured in-situ using specific probes of a portable multi-parameter. Whereas the analysis of the others parameters which are Chemical Oxygen Demand (COD), nitrates, nitrites and ammonia nitrogen were made in laboratory of the environment and agro-resources valorization of faculty of sciences and technics of Beni-Mellal, Morocco, following protocols and procedures defined by AFNOR and RODIER 2009.

The water samples were taken from each well using abucketand then placed in plastic bottles which were previously washed and rinsed several times with distilled water. The samples are stored in coolers and are then transported to the Laboratory for the analysis.

3.2 Statistical analysis

The principal component analysis was performed on the values of the physico-chemical parameters characterizing the 78 wells. This analysis allowed highlighting the correlations between the different water parameters [13].

4. Results and Discussions

Groundwater is an important source of irrigation water and drinking water, therefore it is necessary to deduce the water quality, and the preliminary results allowed deducting the polluted and unpolluted areas.

4.1 pH

The water pH provides important information on the calculation of the elements solubility and of geochemical balance; it is an important indicator of quality. The pH of the water intended for irrigation should be between 6 and 7 because at these values most micro-elements have an optimum solubility, (Peterson 1999). In our study area, pH values are in normal range, they vary between a minimum of 6.03 and a maximum of 8.4 (Figure 2).

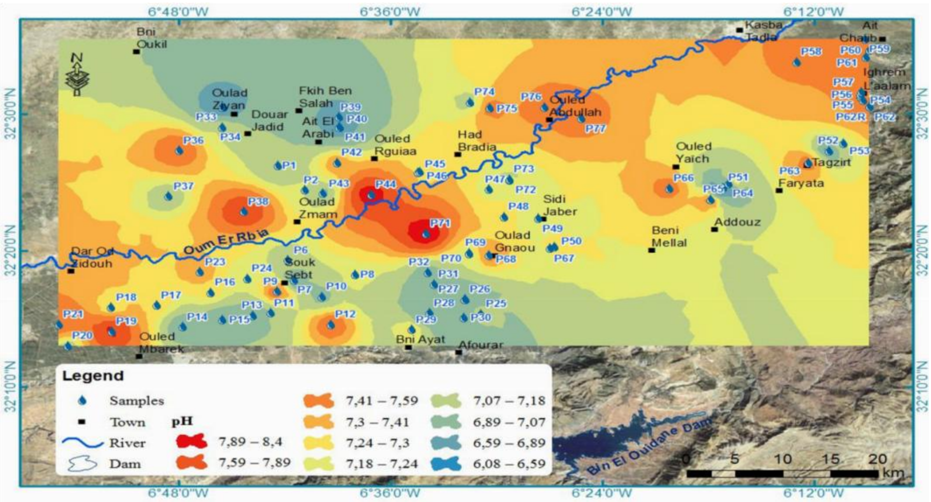

Figure 2:pH variations.

4.2 Temperature

The temperature average value is 20.81; it respects the Moroccan standard norm of water intended for irrigation which is 35°C [14]. In our study area, the temperature values are located in normal range, they vary between a minimum of 17.1 °C and a maximum of 28.5 (Figure 3).

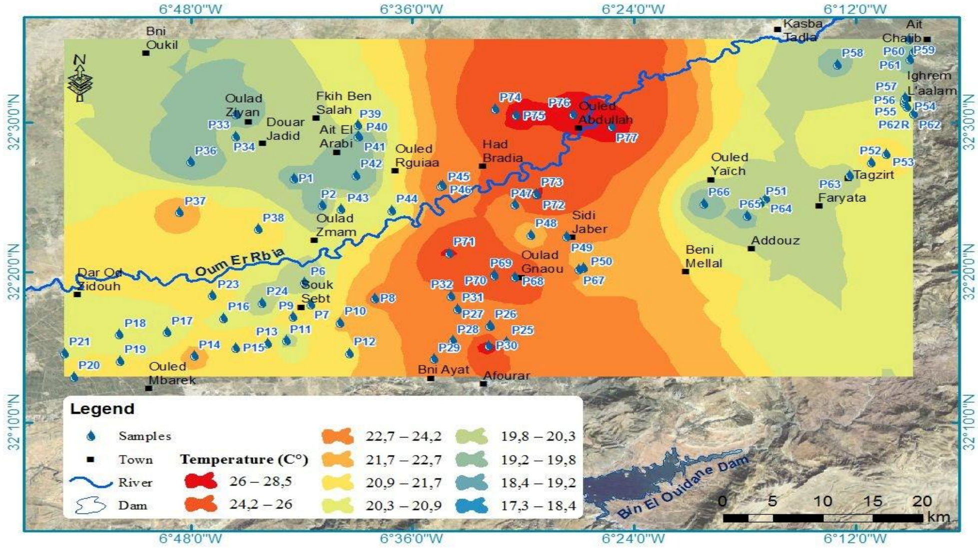

Figure 3: Temperature variations.

4.3 Chemical Oxygen Demand

The analyzes results show Chemical Oxygen Demand (COD) varies between a minimum of 115, 2 mg of O_2/l and a maximum of 595,2 mg of O_2/l (standard < 125 mg of O_2/l), (Figure 4). Indeed, the water quality is poor in some points, whose origin could be related on the industrial activities in the area and also to the use worn water at agriculture. This result is confirmed especially in Beni Moussa where there is installation of the industrial activities (the sugar refinery).

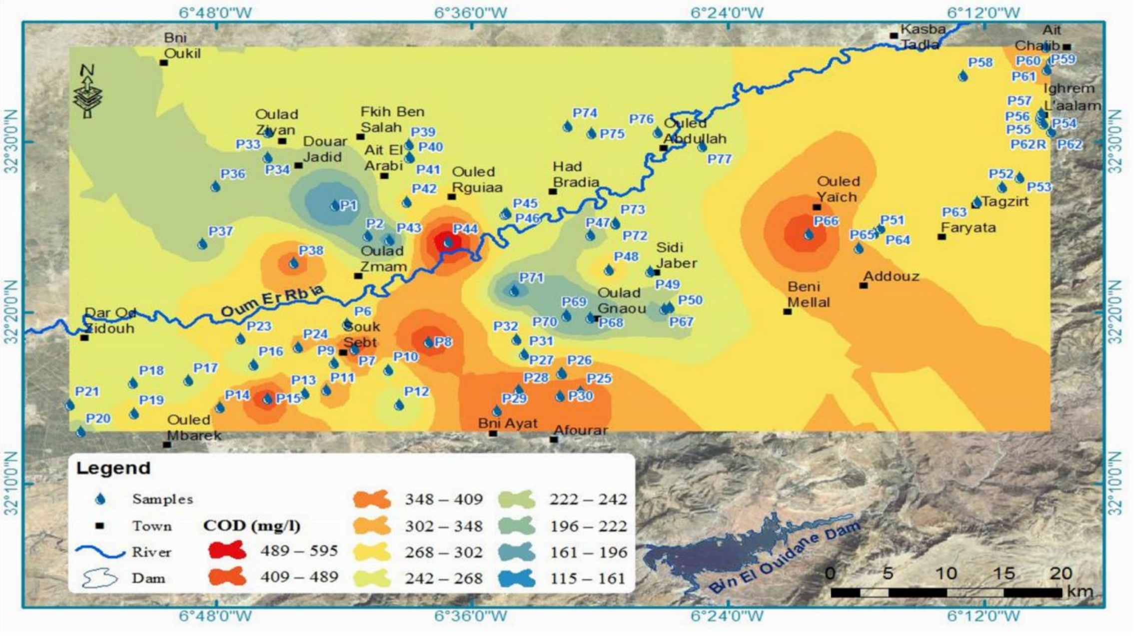

Figure 4: COD variations.

4.4 Electrical Conductivity

The conductivity measurement appreciates the mineralization and gives an indication of the ionic concentration. It depends on the concentration, temperature, and types of present ions [15]. The highest value is remarkable in the areas where irrigation is intense. Thereby, the origin of this mineralization should be the infiltration of irrigation waters charged in minerals. From one well to another there is a wide variation, the electrical conductivity values vary between a minimum of 0.4 ms/cm and a maximum of 6,99ms/cm (Figure 5).

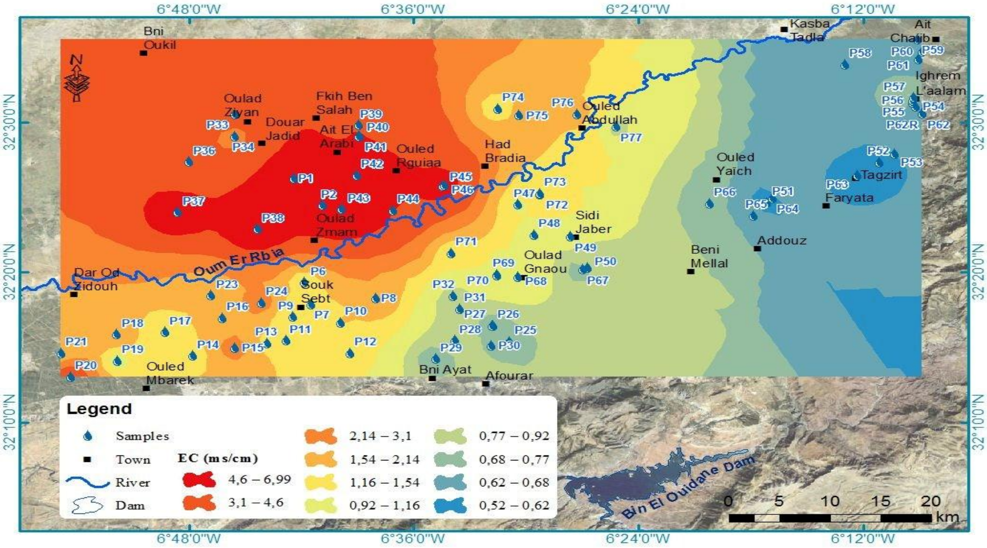

Figure 5: Variations of the Electrical Conductivity.

In the semi-arid zone the salts deposited in the unsaturated zone following the evaporation of rainwater and especially those used for irrigation are taken up by dissolution during the following rainfall phenomenon or by irrigation water, and can reach the saturated zone of the aquifer causing an increase in the salinity of the groundwater [16].

4.5 Nitrates

Nitrates can be found in water and soil, because they have a peculiarity that the other polluting substances do not have, either as a result of fertilization or as a result of natural biochemical processes. In our study area nitrates show the most dominant anions with a concentration that varies from one well to the next, ranging from a low of 24.26 mg / l to a maximum of 140.82 mg / 1 (Figure 6). Those values far exceed the value fixed by the Moroccan standard for drinking water (50mg/l).

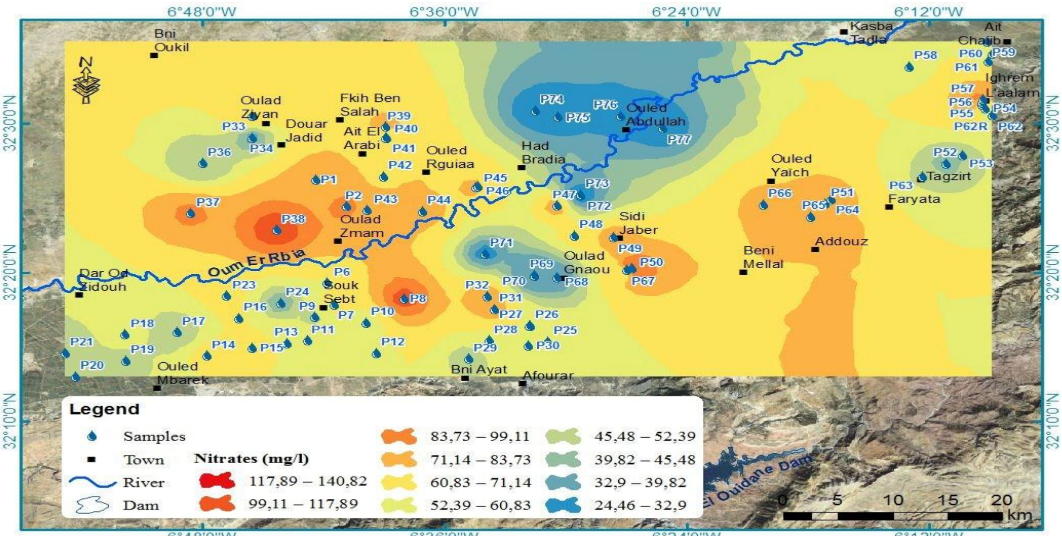

Figure 6: Variation of nitrates.

According to [2, 17, 18], the origin of this pollution is probably related to the nitrites oxidation by the nitrification bacteria following the infiltration of waste waters, also to the excessive use of chemical or animal fertilizers. It is also noted that the irrigation mode coupled with other factors in the physical environment such as the hydrogeological characteristics of the soil and the groundwater level compared to the ground surface can accentuate or limit the training of the nitric pollutants towards the groundwater. In fact, when the irrigation is in the gravity mode, the nitrate content is twice as high as in the case of drip, especially in the presence of a coarse-textured soil. Outside the sampling points, the most responsive irrigation system is gravity irrigation.

4.6 Statistical analysis

After the analysis of the 78 wells water samples, the obtained results (characteristics) are grouped in a mathematical matrix, which is processed by the principal component analysis using the software "The Unscrambler". The results are showing in the following charts:

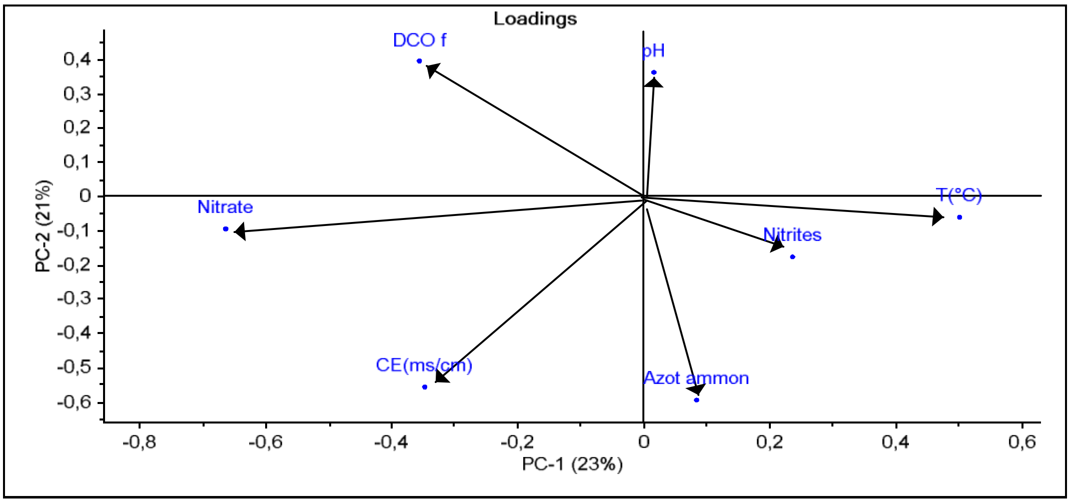

Figure 7: The variables distribution.

Figure 7 represents the laoding graph which describes the variables distribution in the principal components space (PC1 and PC2). We observe that all variables have a loading which is far from the origin and also higher. Then, they are all so important and have a lot of weight which helps us to describe the variation of data at the level of the two PCS.

The nitrate, nitrite and temperature indicate a significant weight on the first principal component.While, pH and ammonia nitrogen are more important on the second principal component.

There is a direct or positive correlation between the nitrite and the temperature, a direct correlation between pH and COD and a direct correlation between the two parameters EC and ammoniacal nitrogen.

There is also a negative or inverse correlation between nitrates and temperature of wells, between ammonium and pH, between nitrites and COD, and there are no correlations between COD and EC, pH and nitrate variables. In order to show the relationship between the various zones and the studied physico-chemical parameters we hadrecourse to the result of the following Bi-stud (Figure 8).

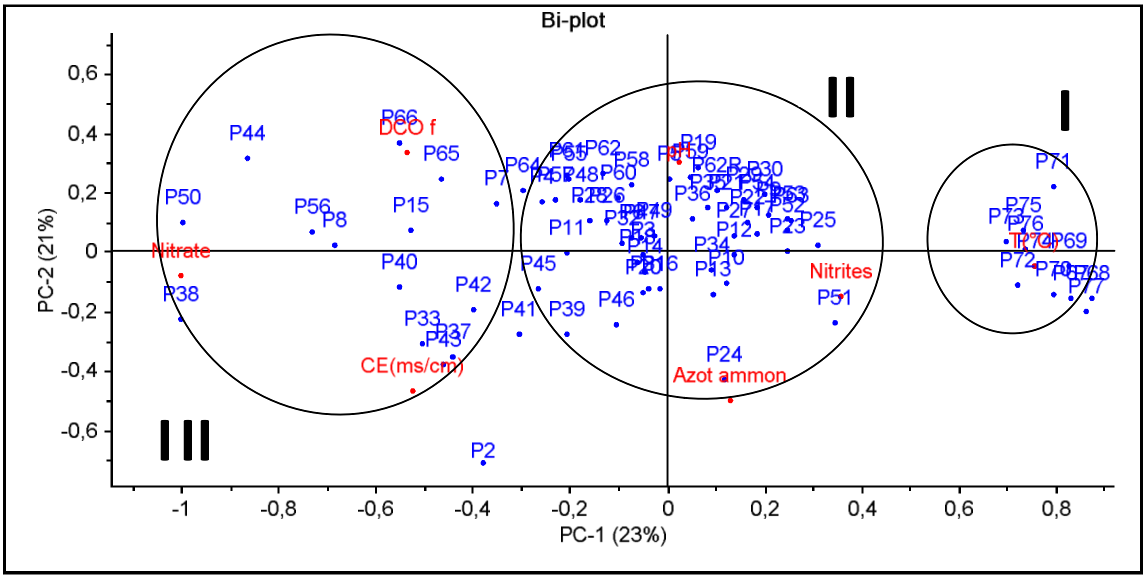

Figure 8: Correlation of samples with variables.

The bi-plot graph allowed interpreting the relationship between the behavior of samples and variables in the same plane, and characterizing 3 groups:

Group I: Regrouped wells with high temperature, lows COD, EC and nitrate content.

Group II: The samples have high pH, nitrogen and nitrite contents.

Group III: Characterized by high COD, EC and nitrate content with low temperatures.

Conclusion

Nowadays, because of depletion of natural resources, the irrigated perimeters are faced with many dysfunctions: dualism of farms, poor efficiency of irrigation, micro-holdings and fragmentation. So, it is necessary to establish a strategy for the management of groundwater resources, which must take into consideration the improvement of the performances of the agricultural holdings while ensuring a sustainable functioning of the underground water.

The study of the wells waters physicochemical characteristics revealed that there is a remarkable pollution by nitrates in the areas where there is a strong agricultural activity generated by the infiltration of irrigation water rich in chemical and organic fertilizers. Moreover, the adoption of gravity system in irrigation accentuates the drainage of this pollution toward the tablecloth.
The use of groundwaters in the food could be the cause of major problems for the consumer, especially converting nitrates into nitrites which cause diseases that are in some cases fatal for newborns.

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