CONTRIBUTION TO THE STUDY OF THE DEGRADATION OF THE BOUNAMOUSSA PLAIN (EL TARF-ALGERIA) BY IRRIGATION WATER AND CHEMICAL FERTILIZERS

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Abstract. Modern agriculture has become a real source of pollution; the systematic use of chemical fertilizers and pesticides at high levels often has multiple consequences on the environment, as in the case of the Bounamoussa plain “El Tarf-Algeria” (which is highly productive and is known for the diversity of its crops and for cultivation practices that call for the use of chemical fertilizers and phytosanitary products, as well as the use of irrigation water from different sources and of often unknown quality. The lack of evaluation of the state of soil fertility and the risks generated by cultivation practices justifies such a study and proposes a follow-up by the services concerned. The approach adopted consists of an analysis of the soil and drainage water collected at the end of the summer season. The aim is to evaluate in a preliminary way the pollution of surface waters and soils of the plain of Bounamoussa. The results of the physico-chemical analyses of the soil and water reveal the existence of excessive levels of phosphates and chlorides, which becomes a risk of salinization of the soil. The presence of high levels of nitrites and nitrates can be a potential risk of pollution of groundwater.
Keywords: *soil, pollution, contamination, salinization, modern agriculture*

Introduction

The increase in population and the development of urban areas, agricultural and industrial units as well as cultivated land have resulted in a degradation of water quality which leads to a very significant decline in the reserves that represent the water resources and soils for the feeding of populations (Belalite and al., 2021).

Pollution represents a serious problem for the environment because of the discharges into the rivers (Belouanas and Menani, 2019). The problems related to pollution are currently a source of concern that requires universal interest. This pollution, generated by anthropogenic activities, can, by reaching critical levels, present a serious danger to public health (Amharref et al., 2007).

Vulnerability to water pollution makes it possible to identify areas at high risk of contamination, regardless of the type of pollutant. It should in principle condition land use plans or at least allow targeting of areas where rigorous protection measures should be adopted (Belouanas and Menani, 2019).

Soil is a finite resource, which means that its loss and degradation are not recoverable in a human lifetime. Soil pollution affects the food we eat, the water we drink, the air we breathe, our health and the health of all organisms on the planet.

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Without healthy soils, we cannot produce our food. In fact, an estimated 95% of our food is directly or indirectly produced in our soils (FAO, 2019).

The Bounamoussa plain is a highly productive agricultural plain located in the North of the willaya of El-Taref (North East of Algeria), it is drained by the Oued Bounamoussa which extends from the commune of Ben M'Hidi, then it of Asfour, crossing the Chafia dam to the commune of Bouhadjar, crossing a significant area of agricultural land (Zaoui, 2020).

The watershed of Bounamoussa which presents a rugged relief is part of the watersheds strongly affected by water erosion and other anthropic factors in Algeria (Bouhadeb, 2019), That is why we conducted this research to assess the current situation of the plain of Bounamoussa and specifying the origin and nature of pollution that affect the waters and soils of this plain via certain parameters that influence.

The objective of this research is the characterization and evaluation of the current situation of the Bounamoussa plain, by specifying the origin and the nature of the pollution which affects the waters and soils of this plain via certain physicochemical parameters which influence on this plain.

Material and methods

Experimental site

The plain of Bounamoussa is located in the North-Eastern part of Algeria in the territory of the wilaya of El Tarf. This plain includes very important agricultural lands such as: the lands of the commune Ben M'Hidi, Asfour and Bouhadjar whose Oued of Bounamoussa drains these agricultural lands. And this is the site of our research where we made the sampling of the soils in the three grounds quoted previously with the sampling of the waters of the Oued Bounamoussa which crosses these grounds. These three sampling sites are representative of the area in question (*Fig. 1*).

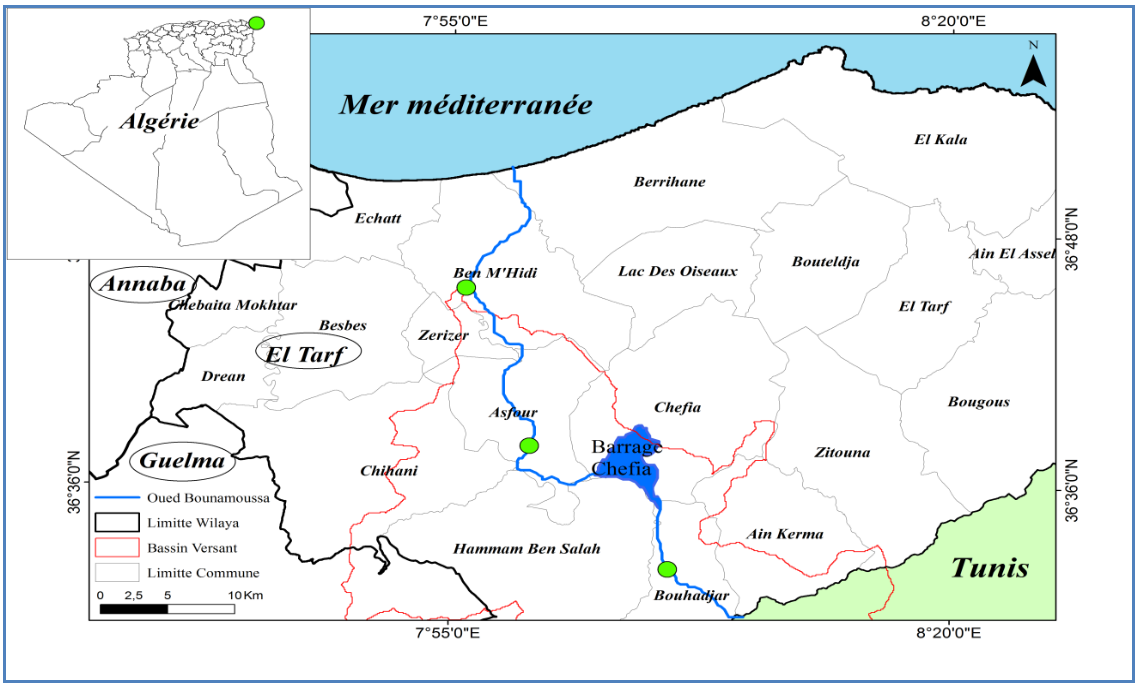

Figure 1. *Presentation of the sampling sites*

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A work plan has been adopted to achieve our research goal. It consists in carrying out a sampling grid with a complete analysis of the physico-chemical parameters of water and soil to explain the origin and nature of pollution that degrade our plain.

Three sites (stations) have been selected across the study area of upstream, central and downstream of the Oued Bounamoussa (*Fig. 2*); according to their good accessibility even in winter, their locations in the plain, their types of uses (agricultural land, residential or fields etc.) and the nature of the pollution that affect them.

Surface water and surface soils are sampled in three stations (the month of January 2021) that are spread in space between Ben M’Hidi, Asfour and Bouhadjar: So we sampled a sample of soil and water of the commune of Bouhadjar which corresponds the upstream of the plain of Bounamoussa, then a sample of soil and water of the commune of Asfour which corresponds the center of the plain and finally a sample of soil and water of the commune of Ben M’Hidi which corresponds the downstream of our plain.

Figure 2. *Oued Bounamoussa (El-Tarf-Algeria)*

For the water, the following physico-chemical analyses were carried out:

The hydrogen potential (pH) and electrical conductivity (CEC) were determined by direct reading in situ using a multi-parameter (Type: WTW pH/Cond 340i/SET), Suspendedolids (SS) by filtration; other physico-chemical parameters such as: Nitrate (NO^-_3), Nitrite (NO^-_2), Chlorides (CL^-), Phosphate (P_2O_5) are recommended by the standards of (AFNOR, 1977), and by the protocols of (Rodier, 1996).

For the soil, the following physico-chemical analyses were carried out:

On the fine fraction of the soil the following physico-chemical analyses were carried out:

The granulometry → international method with a pipette (Baize, 2000).

The pH → pH meter (Baise and Girard, 1995).

The electrical conductivity → conductometer (Bonneau and Souchier, 1979).

Hygroscopic humidity → oven drying (24 h at 105 °C) (Delcour, 1981).

The organic matter → incineration in muffle furnace (4 h at 450 °C) (Morel, 1986).

The real density → pycnometer (Delcour, 1981).

And on the fraction of the not crushed soil, we made only one analysis:

The apparent density → with kerosene (Baize, 2000).

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Statistical analysis

Results were applied by using ANOVA followed by Tukey test (MINITAB 18 Software). Results were expressed as mean ± standard deviation.

Results and discussion

The results obtained have been grouped in the histograms below.

Water results

Hydrogen potential (pH)

The pH is a measure of the acidity of water, that is, the concentration of hydrogen ions (H^+). The pH of a natural water can vary from 6 to 8.5 depending on the acidic or basic nature of the soil (Devillers and al., 2005).

The results of the surface water analyses of Oued Bounamoussa show that the water of the three stations have a pH between 7.15 and 7.75 (*Fig. 3*). We note that the pH values are within the norms, which means that the water has a neutral aspect (Seghir and Khérici, 2008).

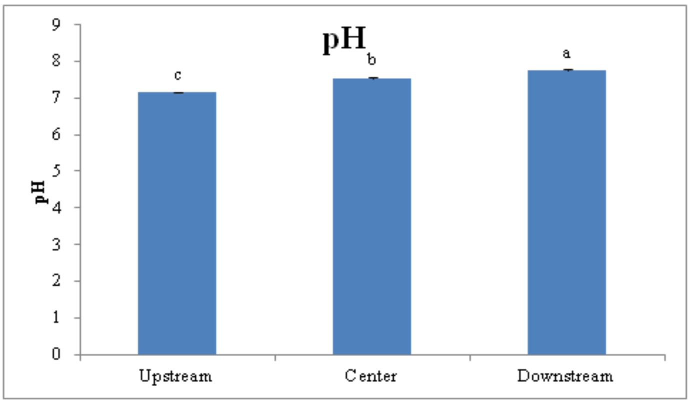

Figure 3. *Spatial variation of pH*

Electrical conductivity (EC)

The electrical conductivity of a water is the conductance of a column of water between two metal electrodes (Arouya, 2011; Rodier, 2009). The measurement of conductivity allows to assess the amount of dissolved salts (degree of mineralization) in water (Elafri, 2009). The electrical conductivity recorded average values that increase from upstream to downstream (379 µS/cm and 410 µS/cm) (*Fig. 4*).

This increase can be explained by the effect of intense industrial and agricultural discharges. It is found according to Rodier (2009) that surface waters are moderately mineralized and accentuated.

Suspended solids (SS)

Suspended solids include all mineral or organic materials that do not solubilize in water. They include clays, sands, silts, organic and mineral materials of small size, plankton and other microorganisms in water (Devillers and al., 2005). Suspended solids

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as they are can be a vector for the absorption of toxic substances by the organism in high concentrations that can lead to a warming of the water, which will have the effect of reducing the quality of the habitat for cold water organisms (Hébert and Légaré, 2000). At a pH between 6 and 8.5, the TSS standard for fresh and natural water is 25 mg/l to 70 mg/l (O.C. 11-125 Water Quality).

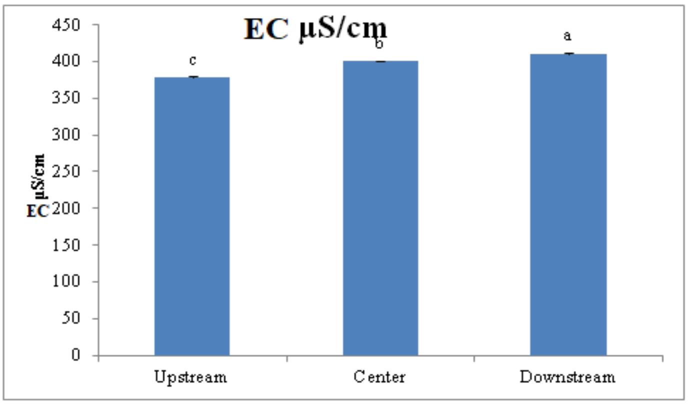

Figure 4. *Spatial variation of CE*

According to the analyses carried out in the laboratory, the TSS contents are well below the accepted standards. The maximum values are recorded at the level of Ben M'Hidi (downstream) (0.29 mg/l) (*Fig. 5*); this is due to industrial and domestic discharges, and to the leaching of agricultural land which brings a significant amount of chemical fertilizer.

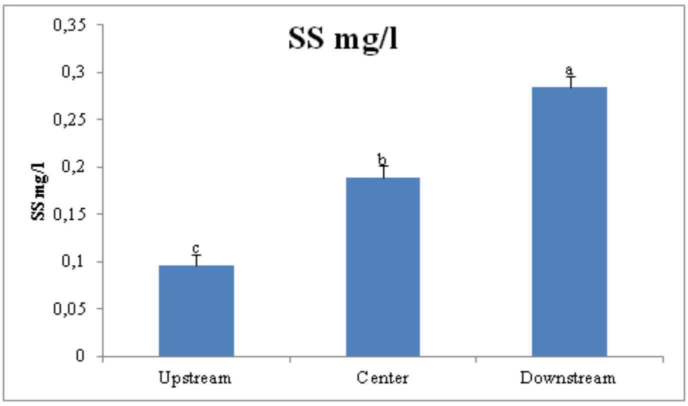

Figure 5. *Spatial variation of SS*

Nitrates (NO^-_3)

Nitrates are the final stage of the oxidation of organic nitrogen in water. Nitrate bacteria (nitrobacter) convert nitrite into nitrate. Nitrates are not toxic, but high nitrate levels cause algal blooms that contribute to eutrophication. Their potential danger remains nevertheless relative to their reduction in nitrates (Rodier, 2009; Lamri and al., 2020). The standard in fresh and natural water is 50 mg/l (Decree 11-125 Water Quality). The results of our analysis show that nitrate levels are between 4.03 mg/l and 20.06 mg/l (*Fig. 6*). The increase in nitrate levels in wadi Bounamoussa waters and its

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presence in surface waters is related to the intensive use of fertilizer products (chemical or organic) (Chapman and Kimstach, 1996; Lgourna and al., 2014).

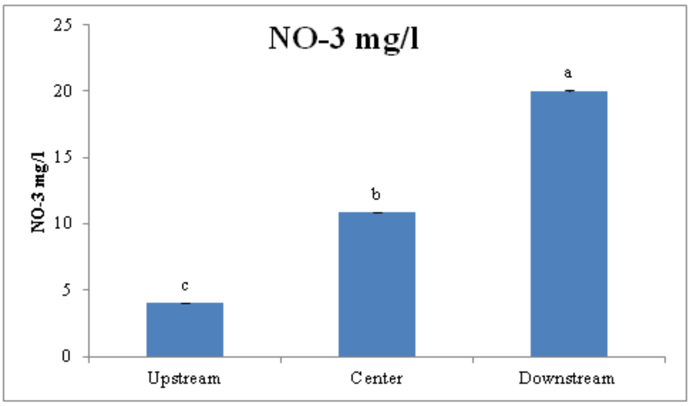

Figure 6. *Spatial variation of* NO^{-}_{3}

Nitrites (NO^{-}_{2})

Nitrites are considered as a very harmful pollutant to human and animal health (Fekhaoui, 1990). At the level of wadi Bounamoussa, nitrite levels recorded in the upstream is 0.11 mg/L, for the center is 0.19 mg/L and 0.22 mg/L for the downstream (*Fig. 7*). They exceed the standard in freshwater and natural which is 0.1 mg/l (Decree 11-125 Water Quality). So, it is constant that the waters of Wadi Bounamoussa are slightly loaded by nitrites especially downstream of the Wadi where agriculture is very responded in this area (Larba, 2014).

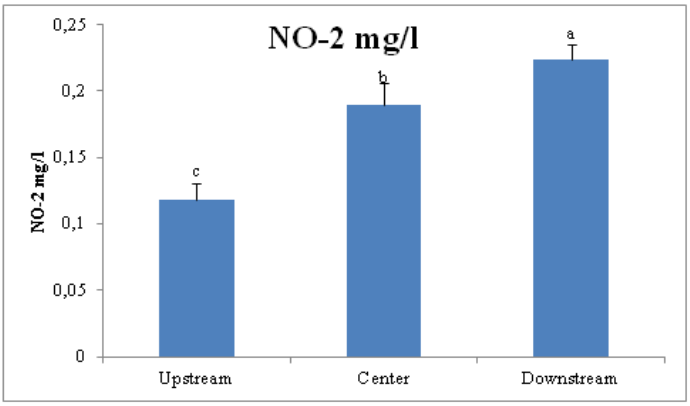

Figure 7. *Spatial variation of* NO^{-}_{2}

Chlorides (Cl^{-})

Water almost always contains chlorides but in highly variable proportions. The chloride content generally increases with the degree of mineralization of water (Tardat-henry and Beaudry, 1984). The presence of chlorides in water is mainly related to the nature of the terrain crossed. Thus, it can be attributed to natural springs, wastewater or saline intrusions (Maiga, 2005). The accepted standard for fresh and natural water is 250 mg/l (Decree 11-125 Water Quality). The concentrations of chloride ions found in

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the waters of wadi Bounamoussa range from 72.10 mg/l to 310.17 mg/l (*Fig. 8*). This evolution is noticed especially downstream, it indicates the contribution of an anthropic contribution that can be of urban or industrial origin.

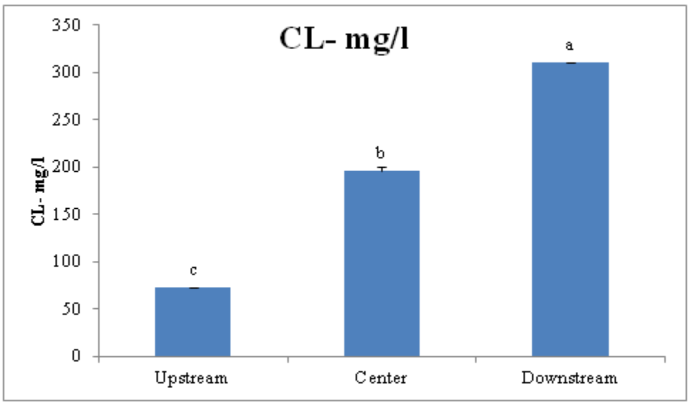

Figure 8. *Spatial variation of Cl^-*

Phosphate (P_2O_5)

Natural phosphates differ by their origin (magmatic, sedimentary or guano), they are present in the composition of soils but with minimal quantities. The high contents of phosphates cause soil pollution (Fekhaoui, 1990). The values of phosphate obtained from our samples exceed the European standards (0.5 mg/l is the threshold of pollution), the reasons can be explained by the cultivation practices of farmers in the region and the addition of chemical fertilizers with intense quantities (*Fig. 9*).

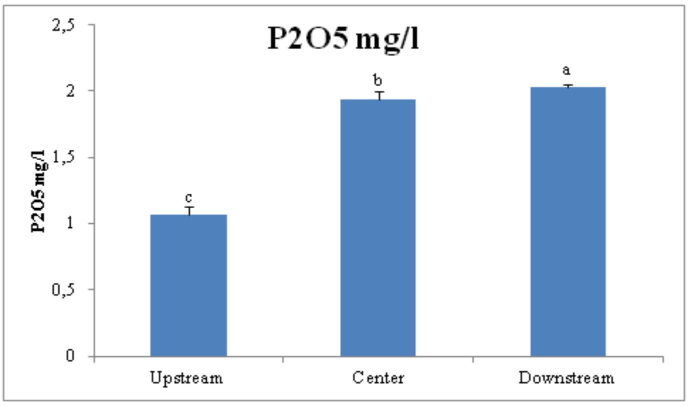

Figure 9. *Spatial variation of P_2O_5*

Analysis of the variance of the physico-chemical parameters of the water of Wadi Bounamoussa (3 stations)

Analysis of the variance of the hydrogen potential (pH)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	135,137	135,137	329,76	0,000
Error	16	6,557	0,410		
Total	17	141,694			

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Analysis of variance of electrical conductivity (EC µS/cm)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	700928	700928	7291,84	0,000
Error	16	1538	96		
Total	17	702466			

Analysis of variance of suspended solids (SS mg/l)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	14,688	14,6882	38,81	0,000
Error	16	6,055	0,3784		
Total	17	20,743			

Analysis of variance of nitrates (NO^-_3 mg/l)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	419,3	419,34	17,02	0,001
Error	16	394,2	24,64		
Total	17	813,5			

Analysis of variance of nitrite (NO^-_2 mg/l)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	15,015	15,0152	39,91	0,000
Error	16	6,020	0,3762		
Total	17	21,035			

Analysis of variance of chlorides (CL^- mg/l)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	163706	163706	30,77	0,000
Error	16	85123	5320		
Total	17	248829			

Analysis of variance of phosphates (P_2O_5 mg/l)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	0,3785	0,3785	0,79	0,386
Error	16	7,6260	0,4766		
Total	17	8,0045			

The analysis of variance with a single criterion of classification of the physico-chemical parameters of the water for the three stations selected at the level of Wadi Bounamoussa showed a highly significant difference for pH, EC, TSS, NO^-_3, NO^-_2, and CL^-, $p = 0.000$. Nevertheless, we did not notice a difference $p = 0.386$ for P_2O^5 between the different stations of this Wadi.

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Soil results

Granulometry

Particle size analysis is used to determine the texture of the soil. According to the textural triangle of the U.S.D.A and using the textural triangle of (Jamagne, 1967), we deduce that the Bounamoussa plain has a sandy clay texture (*Fig. 10*). The particle size of a soil is important because it has a direct effect on porosity. Fine particles (clay) increase water retention, but decrease aeration (Soltner, 1987).

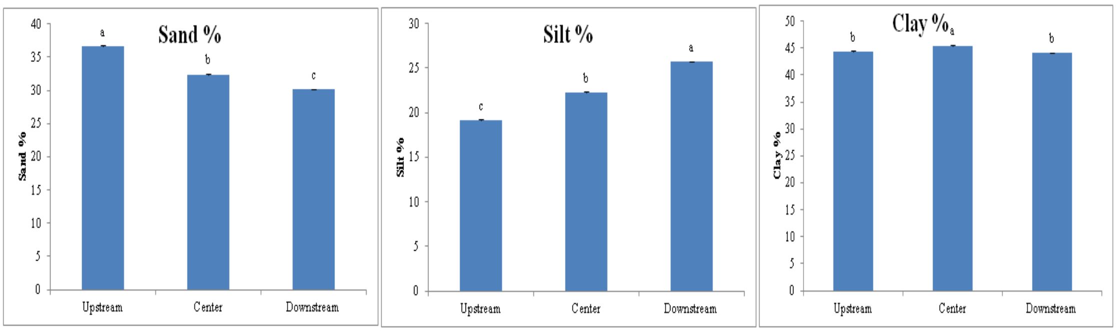

Figure 10. *Content of the granulometry analysis in the Bounamoussa plain*

pH

This is a measure of the acidity of a soil suspension in water, with a standardized soil/water ratio (1/5). It also indicates the concentration of "H^+" ions present in the water (Morel, 1986). The physico-chemical characterization shows that we are in the presence of a weakly basic soil (between 7.49 and 8) (*Fig. 11*). This plain is under the control of several factors which are mainly; the topographic position, the nature of the parent rock and the nature of the vegetation cover.

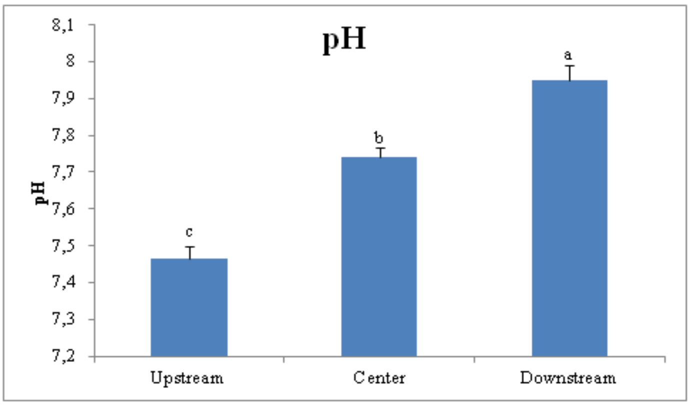

Figure 11. *pH variation in the Bounamoussa plain*

The electrical conductivity (EC)

The electrical conductivity is important to know, because it gives us a general idea about the salinity of a soil. It is directly proportional to the quantity of mineral salts dissolved in water (Durand, 1983). The electrical conductivity in the Bounamoussa

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plain records low values ranging from 30.09 to 130.09 µs/cm (*Fig. 12*). According to Durand (1983), the soils of the Bounamoussa plain are not salty.

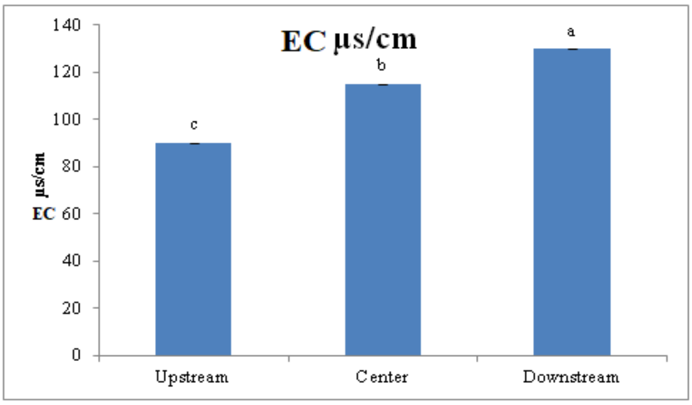

Figure 12. *Spatial variation of CE*

Hygroscopic moisture (H%)

Hygroscopic moisture comes from atmospheric moisture and forms a thin layer around soil particles. It is very energetically retained and cannot be used by the soil fauna or flora (Mbakwiravyo, 2009). The results obtained (*Fig. 13*). Show that the moisture in the study area ranges between 0.041% and 0.075%; these variations seem to be controlled by several factors: climatic conditions (rainfall and evaporation), vegetation and the physical characteristics of the soil which are: permeability, infiltration, water holding capacity and capillary action (Zahi, 2014).

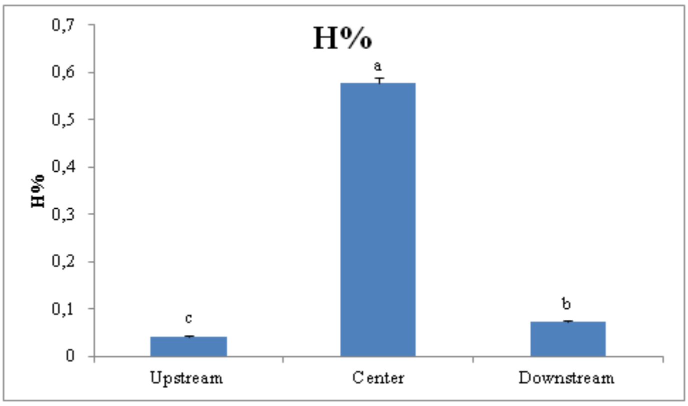

Figure 13. *Variation of hygroscopic humidity in the Bounamoussa plain*

Porosity (Poro%)

The bulk density–actual density relationship defines soil porosity.

Porosity constitutes the void (the pores) existing in a soil. It depends on the granulometric composition and structure of the soil; porosity is between 11 and 14% (*Fig. 14*). From these results obtained it appears that the soils of the Bounamoussa plain are moderately porous, and this is explained by the textural composition which is sandy loam.

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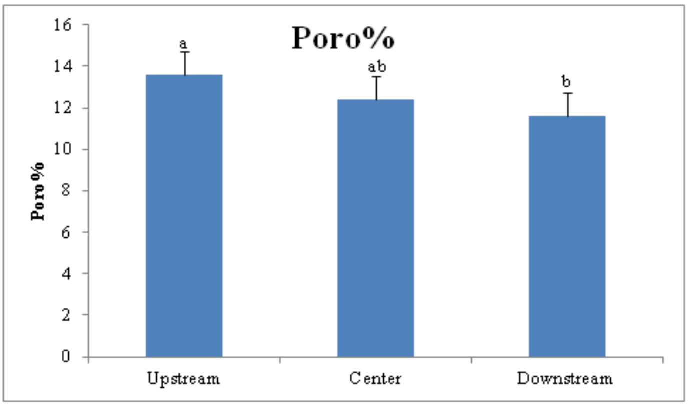

Figure 14. *Variation of porosity in the Bounamoussa plain*

Organic matter (OM%)

Organic matter plays a very important role in the physical, chemical and biological functioning of the soil. It improves the coherence of structural elements, favors the retention of useful water, participates in the reversible storage of nutritional elements, limits the development of certain parasites, and increases soil aeration. It is formed essentially by flows of plants in stages of decomposition, animal excrement and microbial cells (Davet, 1996).

According to Gauchers (1968), the organic matter content of the Bounamoussa plain is moderately high, which is due to cultivation practices and the addition of farmyard manure (*Fig. 15*).

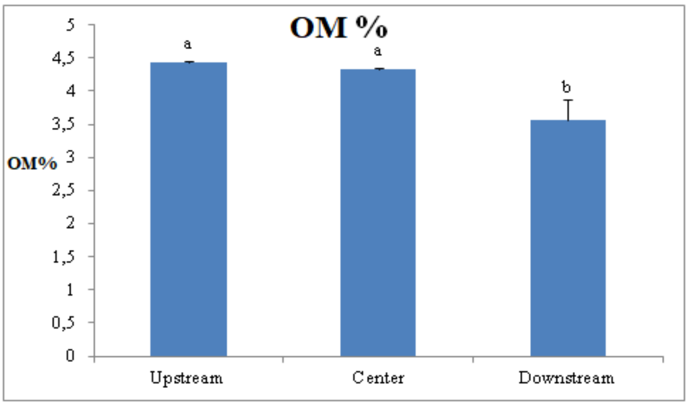

Figure 15. *Variation of organic matter in the Bounamoussa plain*

Analysis of variance of soil physico-chemical parameters at the three stations of the Bounamoussa plain

Analysis of variance of hydrogen potential (pH)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	148,092	148,092	372,51	0,000
Error	16	6,361	0,398		
Total	17	154,453			

Analysis of variance of electrical conductivity (EC µS/cm)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	54180	54179,7	354,00	0,000
Error	16	2449	153,1		
Total	17	56629			

Analysis of variance of hygroscopic humidity (H%)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	14,066	14,0662	34,38	0,000
Error	16	6,547	0,4092		
Total	17	20,613			

Analysis of variance of porosity (Poro%)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	512,00	512,000	315,08	0,000
Error	16	26,00	1,625		
Total	17	538,00			

Analysis of variance of organic matter (OM%)

Source	DL	SomCar Adjust	CM Adjust	Value of F	Value of p
Factor	1	20,352	20,3522	42,57	0,000
Error	16	7,650	0,4781		
Total	17	28,002			

The single-criterion analysis of variance of soil physico-chemical parameters for the three selected stations on the Bounamoussa plain showed a highly significant difference for pH, EC, H, PORO, MO, $p < 0.000$.

Conclusion

In order to irrigate agricultural land, farmers turn to the use of water from wadis and dams whose physico-chemical composition is unknown, not to mention the use of chemical fertilizers with uncontrolled doses and concentrations. All this has harmful effects on agricultural yields, as well as on soil degradation and the environment.

The objective of this work is to highlight the chemical composition of water and soil of the Bounamoussa plain to determine the nature and degree of pollution that affect this plain and degrade the terrestrial and environmental environment.

The results of the physico-chemical analyses of the soil and water reveal the existence of excessive levels of phosphates and chloride, which becomes a risk of salinization of the soil. The presence of high levels of nitrite and nitrate can be a potential risk of pollution of groundwater and the soils of the Bounamoussa plain.

To stop the degradation of the soil and water and to preserve the fertility of this plain, we recommend that farmers monitor the quality of the water and the fertility of the soil by carrying out assessments at least once a year and to control the quantities of fertilizers added to the agricultural land.

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