**International Journal of Multidisciplinary Research and Development**
**Online ISSN: 2349-4182, Print ISSN: 2349-5979**
**Impact Factor: RJIF 5.72**
**Received: 04-10-2018; Accepted: 05-11-2018**
**www.allsubjectjournal.com**
**Volume 5; Issue 11; November 2018; Page No. 151-159**

# Evaluation of the physico-chemical quality of waters of river Drader (Morocco)

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**Abstract**
The present study deals with the physicochemical characterization of the water quality of the Drader River, Main River of the Drader-Souier basin. This work done on the Drader River is original, since no study of the physico-chemistry of Drader river waters had been done before, it contributes to a better knowledge of the watercourses of the Drader - Souier basins.
This study involved three (3) stations on the Drader riverbed from upstream to downstream, with a frequency of biweekly water withdrawals. We analyzed nineteen (19) physico-chemical parameters (temperature, pH, conductivity, salinity, sodium, potassium, calcium, magnesium, chlorides, sulphates, bicarbonates, orthophosphates, nitrates, nitrites, ammonium, biological oxygen demand, demand chemical oxygen, suspended solids and dissolved oxygen). The results obtained show that the water upstream of the watercourse is an excellent quality against downstream, the water has undergone a slight degradation which can be explained by the intense agricultural activity and possible contamination in the water. Level of station 2 by domestic discharges.

**Keywords:** physicochemical chemical parameters, Drader River - ACP

## Introduction

The coastal basin of Drader-Soueir covers an area of 600 km$^2$. It is located in North-Western Morocco, between the parallels 38 G 90 and 38 G 65 and between the meridians 9 G 70 and 9 G 25.

This small basin, open to the sea, is separated from the basin of Sebou to the south by the hills of Lalla-Zohra (altitude less than 100 m) and South-East by the hills of Lalla-Mimouna (Drâa-Bou-Hafate: 203 m), it is separated from the Loukkos basin to the North-East by the hills of El-Ferjane (197 m), Lalla-Rhano (158 m) and Kurricha (143 m) [1].

The Drader Soueir basin has intense domestic and agricultural activities that generate diversified pollutants that can affect the quality of river and groundwater more or less deeply. In fact, the unsustainable use of fertilizers and pesticides and the lack of awareness of the population towards the protection of the environment, lead to an imbalance of the ecosystem and generate polluting elements that can affect the physico-chemical quality and biological diversity of receiving aquatic environments [2].

The hydrographic network of the basin consists of two main courses: Drader river and Soueir river, emissaries of Merja Zerga and Halloufa respectively.

This work is part of the Drader river. It is still poorly known because the few studies that exist have focused on the hydrogeology of the Drader - Soueir basin [1], and no study prior to ours has been interested in the quality of the waters of the basin.

## Materials and methods

### 1. Presentation of the study area

Drader River drains the Drader- Soueir watershed (Fig. 1). The upper course of this river, north - south direction, is temporary and is in the form of a small stream, while it's middle and lower course, of East - West direction, is permanent and benefits from spills from. The tablecloth of Dhar El Hadechi on its right bank and El Fahis on the left bank. The average flow of the Drader in the vicinity of the Merja Zerga is of the order of 1 m$^3$ / s, whereas during the low water period its flow drops to 600 l/s; 30% of the water supply of Drader river is attributed to the emergence of the water table [1].

The Drader leads in to the Merja Zerga in which it has dug a channel that allows it to reach the sea by the mouth of Moulay-Bou-Selham 150 m wide, 100 m long, 8 to 10 meters deep but which gets clogged sometimes, Merja is a lagoon of brackish water, fed by the Ocean, the Drader and the Nador Canal, which, from the South, carries the drainage water of the Gharb plain, on the right bank of Sebou.

It should also be noted that the latest developments on the Drader river in particular, the installation of a small dyke and numerous water catchment stations, used for agricultural purposes, are leading to a drop in water flow and contributing the reduction of these solid contributions, thus reducing their impact on the lagoon system.

On the other hand, the draining and draining waters of the rice paddies growing in this area increase the inflow of water [3, 4].

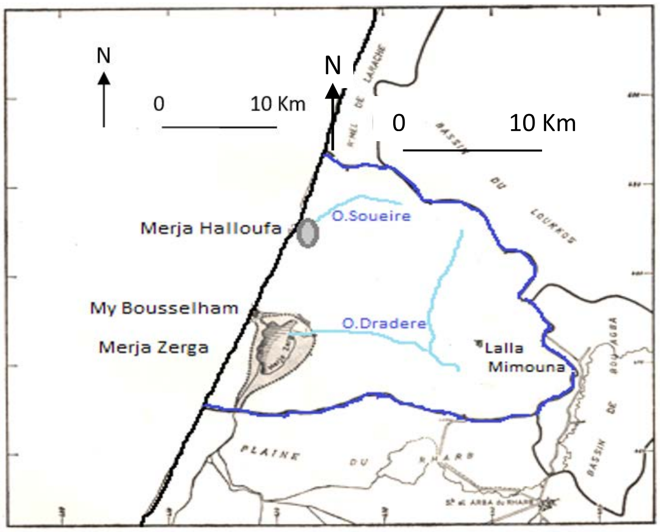


**Fig 1:** Geographical situation of the Drader - Souier basin.

## 2. Sampling and analysis techniques
### 2.1 Withdrawals
Sampling campaigns were mostly conducted at fixed dates throughout the study period over a period of one year (April 2016 to April 217). The measurement frequency is fortnightly in order to obtain a fairly representative image of the quality of the Drader river water and its spatial and temporal evolution.

### 2.2 Physico-chemical variables studied
The general water quality of Drader river has been established on the basis of conventional physicochemical descriptors of water.
The water samples are taken bi-monthly upstream (station S1), at the confluence of the Drader river upper watercourse and its tributaries (station S2) and downstream of Drader river (station S3) (Fig. 2). The water collected was packaged in opaque bottles and kept cold until the arrival at the laboratory [5, 6].

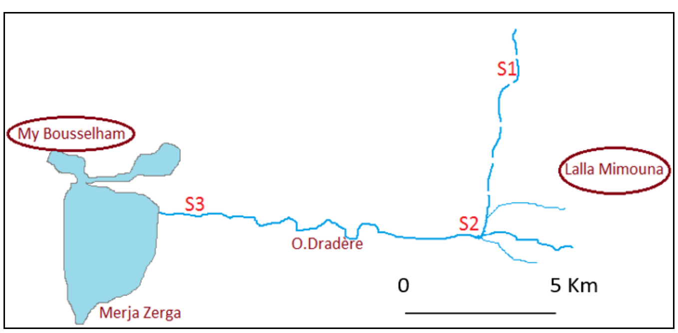


**Fig 2:** Sampling station along Drader River

- **Physical parameters**

Three physical parameters were followed, this is the water temperature, the pH and the conductivity. They are measured in situ with a multi-parameter type HACH, model HQ40d.

- **Chemical parameters**

14 parameters were studied with the same frequency as for the physical parameters.

**Table 1:** Methods of analysis of chemical parameters of water.

| Parameters | Unity | Methods |
|---|---|---|
| DBO5 | mg/l | NF T 90-103 |
| DCO | mg/l | NF T 90-101 |
| MES | mg/l | NF T 90-105 |
| Ammonium | mg/l | NF EN ISO11732 |
| Nitrites | mg/l | NF EN ISO13395 |
| Nitrates | mg/l | NF EN ISO13395 |
| Phosphates | mg/l | NF EN ISO15682 |
| Chlorures | mg/l | NF EN ISO15682 |
| Sulfates | mg/l | NF T 90-040 |
| Sodium | mg/l | NF T 90-020 |
| Potassium | mg/l | NF T 90-020 |
| Calcium | mg/l | NF EN ISO 7980 |
| Magnésium | mg/l | NF EN ISO7980 |
| Bicarbonates | mg/l | MI |

Dissolved oxygen is measured in situ by the multi-parameter type HACH, model HQ40d.

## 3. Data processing
To highlight the overall quality of water and its spatio-temporal evolution in the watercourse studied, it seems interesting to synthesize the results by a statistical treatment the Principal Component Analysis (PCA). It was performed using the ADE-4 software [7] to study spatial distribution. This essentially descriptive statistical method, applied to quantitative variables, aimed to describe the same set of data by new variables in reduced numbers. The PCA analysis allowed us to identify the relationships of the physico-chemical variables studied with each other and also to study the spatial distribution of the study stations [8].

## Results and discussion
### 1. The physical parameters
- **Temperature**

The temperature of the water plays an important role, for example with regard to the solubility of salts and gases including, among others, the oxygen necessary for the equilibrium of aquatic life. In addition, the temperature increases the rates of chemical and biochemical reactions by a factor of 2 to 3 for a temperature increase of 10 degrees Celsius (°C) [9]. The metabolic activity of aquatic organisms is therefore also accelerated as the temperature of the water increases. The value of this parameter is influenced by the ambient temperature but also by possible discharges of hot waste water.
The temperature values recorded in three stations (Fig. 3) show a temporal variation attributed to the influence of the ambient temperature which is high during the summer period and low during the winter period. The minimum and maximum values are recorded in station S1, they oscillate between 16.4 °C recorded in December and 29.4 °C recorded in August.

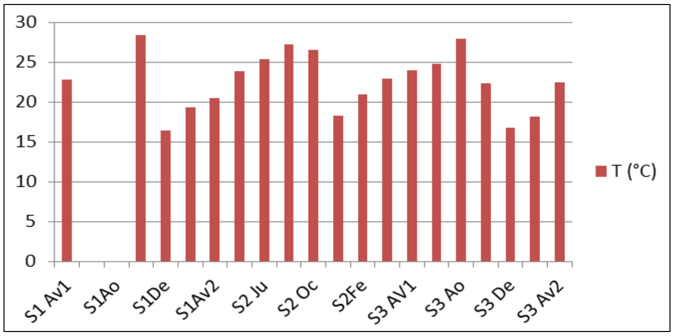


**Fig 3:** Spatio-temporal variation of the water temperature of Drader River.

- **pH**

The pH of the water measures the concentration of $H^+$ protons in the water. It expresses the stability of the equilibrium established between the various forms of carbonic acid and is related to the buffer system developed by carbonates and bicarbonate [10]. The measured values (Figure 4) reveal that the pH is slightly neutral to alkaline in all stations of Drader river, both in rainy weather and in dry periods. Indeed, the pH varies between 7.17 in station S1 (April 2016) and 7.81 in station S2 (October 2016). This can be explained by the presence of carbonates and bicarbonates that can buffer the water. At the Drader-Souier basin, a thick series of Upper Miocene marls (Tortonian), called the "blue marl series", after the establishment of the pre-continental aquifers, covers the pristine formations on almost the entire basin surface. This series is thick several hundred meters as shown by oil drilling carried out in the buttonhole of Lalla-Zohra, south of the basin [1]. The emergence of the water table of the basin gives waters containing carbonates and bicarbonates.

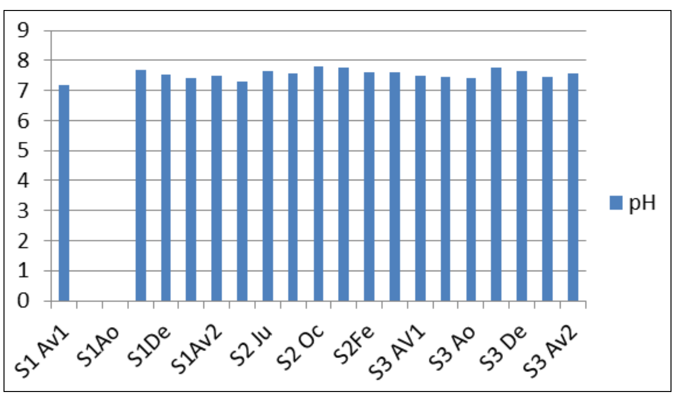


**Fig 4:** Spatio-temporal variation of the pH values of Drader river waters.

- **Electrical conductivity and salinity**

The measurement of the conductivity makes it possible to appreciate the degree of mineralization of water where each ion acts by its concentration and its specific conductivity. The average values recorded (Fig. 5), show significant variations. They fluctuate between 550µs / cm at station S2 (December 2016) and 2730 µs/cm at station S1 (April 2017) slightly exceeding the Moroccan standard for surface water (2700 µs /cm) [11], indicating a excessive mineralization that can be attributed to erosion of the bedrock by water. Overall the conductivity of Drader river waters is high between April and August. This can be explained by the decrease in water flow and the excessive use of chemical fertilizers in agriculture.

The salinity level (Fig.6) reveals values that meet the quality requirements for water intended for irrigation, remaining below the limit value of 2.5g/L [12].

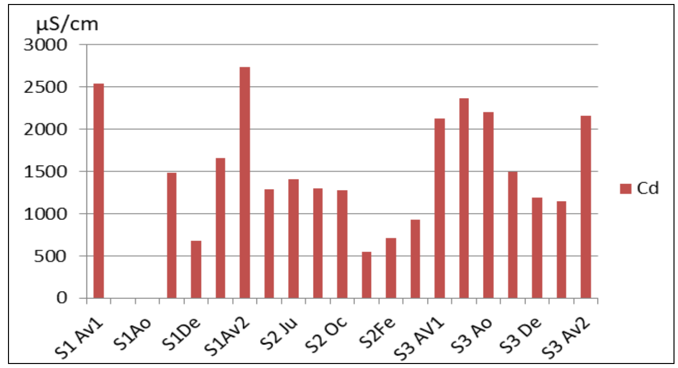


**Fig 5:** Spatiotemporal variation of the values of the conductivity of the Drader river waters.

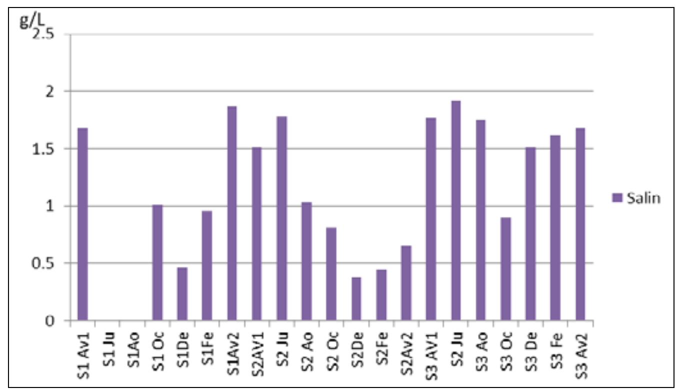


**Fig 6:** Spatio- temporal variation of salinity in Drader river waters.

## 2. Organic pollution parameters

- **Biochemical oxygen demand (BOD5)**

BOD5 (biochemical oxygen demand) refers to the amount of dissolved oxygen consumed by microorganisms in the dark at 20 °C for 5 days. It makes it possible to evaluate the biodegradable organic materials.

The results obtained show that the measured BOD5 values are in the range of 2 to 12 mg/L. All BOD5 values found are below standard (25 mg/L) with the exception of the one found in station 2 of the October sampling of 27 mg/L, highlighting an organic pollution of these samples. waters through the arrival of domestic wastewater in the Lalla Mimouna region. Overall, the lowest BOD5 concentrations are recorded in the first station.

- **Chemical oxygen demand (COD)**

The chemical oxygen demand represents the amount of oxygen consumed by the chemically oxidizable materials in the water. COD is another parameter that allows a more accurate assessment of the amount of biodegradable and non-biodegradable organic material.

The COD values recorded along the watercourse range from 7 mg/L to 19 mg/L, except for the sampling carried out in

October at station 2 which revealed a high value of 61 mg/L, well above the accepted standard (40 mg/L).
The high demand for oxygen could be explained by a contamination of Drader waters by domestic wastewater from the municipality of Lalla Mimouna.

- **Suspended matter (MES)**

The suspended matter represents all the mineral and organic particles contained in the water. It depends on the nature of the lands crossed, the season, the rainfall, the flow regime, the nature of the discharges, etc [6].
The recorded SS values range from 4 mg / L (October) to 29 mg / L (April) for station 1 and between 13 mg / l (December) and 43 mg / L (April) for station 2. Downstream Drader river (S3), the recorded values are 19 mg/L (August) and 31 mg/L (April).
The spatio-temporal evolution of the suspended solids content (MES) (figure 7) in the Drader river shows that the variations of the concentrations in matter in suspension are minimal. These levels of suspended matter in the Drader river are well below the Moroccan norm set at 1000 mg/L. This can be attributed to the low flow and erosion of the watershed which is located upstream of eucalyptus and low discharges of organic waste due to the absence of riparian agglomerations. However, the suspended solids content is greater in station 2, this can be explained by the clay substrate of the stream bed and the likely contamination of water by the wastewater from a small agglomeration installed in hundreds of meters from the left bank of the river.
The figure 7 shows the existence of a correlation between the oxidizable organic matter (COD) and the suspended matter (MES). The concentration of organic matter increases with the increase of the suspended matter and that in almost all the samples of water of the river analyzed, which informs us on the organic character of our suspended matter.

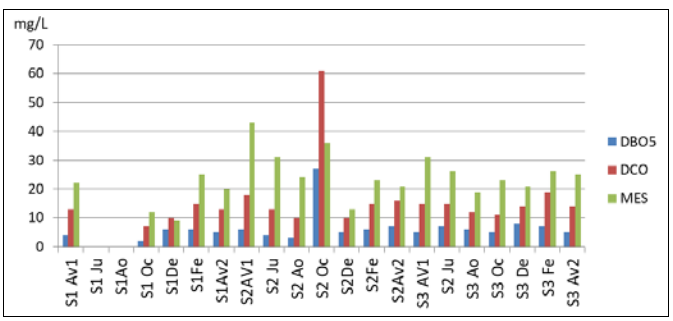


**Fig 7:** Spatiotemporal variation of the values of BOD5, COD and MES in waters Drader river.

- **Dissolved oxygen**

Oxygen is an excellent indicator of water quality. It is one of the most sensitive parameters to pollution. Its value tells us about the degree of pollution and consequently the degree of self-purification of a watercourse.
The evolution of the level of dissolved oxygen in Drader river water shows spatio-temporal variations in dissolved oxygen concentrations. The highest values are recorded in station S1 during the wet period (December, February and April).
Indeed, the levels (Fig. 8) vary between 9.19 mg/L (October) and 11.26 mg/L (December). This can be explained by the decrease in water temperature, since cold water contains a greater amount of dissolved oxygen than hot water [13], and by the high wind speeds that generate a continuous mixing of the body of water and consequently an enrichment of the dissolved oxygen phase during the winter season. These values attest to the excellent quality of the waters of the upper stream of Drader river.
In the middle and lower streams, there is a decrease in dissolved oxygen levels in the water, indicating a slight degradation in water quality. In fact, the values recorded in station S2 vary between 7.83 mg/L (August) and 9.37 mg/L (December) and between 5.78 mg/L (Otober) and 9.03 mg/L (April) in station S3. During the summer, the warming of the water and the decrease of the flow of the river cause a decrease in dissolved oxygen dissolution [14]. Dissolved oxygen is reduced by the activity of bacteria by decomposing the organic matter present [15].
The dissolved oxygen regime in the middle and lower reaches of Drader river remains non-deficient with the exception of the value recorded in October. These results show that the waters of the Drader river are of good to excellent quality.

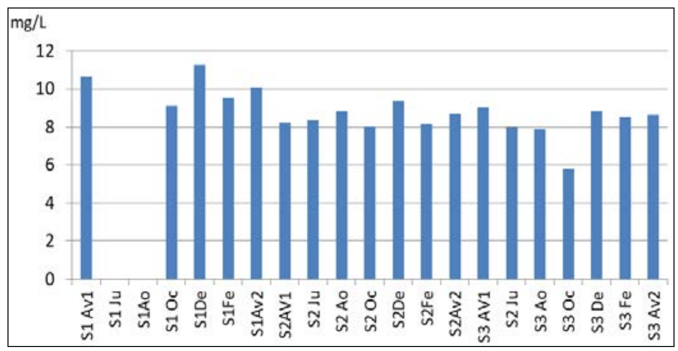


**Fig 8:** Spatiotemporal variation of the values of the dissolved oxygen content in waters Drader river.

### 3. Other chemical parameters

- **Chlorides**

Chlorides are inorganic anions, often used as a pollution index. They influence aquatic fauna and flora and plant growth. The concentrations of chloride ions recorded in the waters of Drader river (Fig. 9) range between 37 mg / L in station 3 (December 2016) and 568 mg/L in station 3 (April 2017). The minimum values are recorded in winter (December and February) in stations 1 and 2 and the maximum values are observed downstream from the Drader River and during the low water period. In waters Drader River, chlorine levels recorded during the study period remain below the Moroccan standards set at 750 mg/L [11]. This makes it possible to classify these waters in the good grid. However, it is necessary to note the spatiotemporal evolution which is marked by an increase of the contents of chloride going from the upstream to the downstream. This evolution can be related to the anthropic contribution and the alternation of wet periods and dry periods which lead respectively to the concentration or the dilution of the salts.

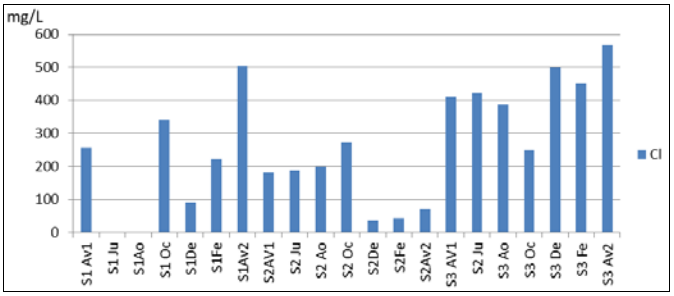


**Fig 9:** Spatiotemporal variation of chloride concentrations in waters Drader River.

- **Nitrogen compounds**

Nitrogen is used as a major indicator of organic pollution. It comes in two forms: organic (proteins, amino acids, vitamins, nucleic acids etc.) and mineral (ammonium, nitrites, nitrates, etc.). The nitrogen forms studied are: ammoniacal nitrogen ($NH_4^+$), nitrites ($NO_2^-$ and nitrates ($NO_3^-$).

- **Ammonia nitrogen**

Ammonia nitrogen is a water-soluble gas. There is a small proportion, less than 0.1 mg/L of ammonia nitrogen in natural waters. It is a good indicator of the pollution of rivers by urban effluents. In surface waters, it comes from nitrogenous organic matter and gaseous exchanges between water and the atmosphere [16]. Ammonium levels recorded vary between values below the limit of detection (< 0.1 mg/L) and 1.49 mg/l measured in station 3 (October 2016). The values recorded in ammonium ions in the waters of the Drader river are generally lower than 0.1 mg/L in the upper and lower watercourses, making it possible to place these waters in the excellent class at good quality according to the quality grid. Moroccan surface waters. Downstream of Drader river, the concentrations of ammonium ions are greater, reflecting an incomplete degradation process of the organic matter and a slight degradation of the water quality.

- **Nitrites**

The nitrite ion ($NO_2^-$) is easily oxidized to nitrate ion and, for this reason, it is rarely present in significant concentrations in natural waters. The main sources of nitrate release are industrial and municipal effluents and the leaching of inorganic nitrogen fertilizers used to fertilize farmland [17]. The results show nitrite contents below 0.1 mg/L.

- **Nitrates**

Nitrate ion ($NO_3^-$) is the main form of combined nitrogen found in natural waters. It constitutes the final stage of the oxidation of nitrogen. Nitrate concentrations in natural waters are between 1 and 10 mg/L. The histogram of nitrate levels in waters Drader river (Fig.10) shows a significant variation. Indeed, in station 1, the nitrate contents oscillate between 7.4 mg/L and 10.9 mg/L. These levels are explained by the weak agricultural activity upstream of the Drader, the upper watercourse crosses a forest sector. In stations 2 and 3, the values recorded are high. The maximum value is reached in December in station 2 (73 mg/L), exceeding the Moroccan and international standards (50 mg/L). The increase in nitrate levels in the middle and lower waters of Drader river can be due to the leaching of fertilizers used in agricultural soils located in the Drader - Souier basin.

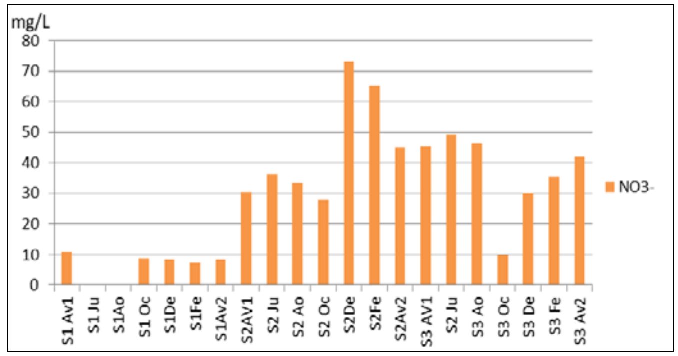


**Fig 10:** Spatiotemporal variation of nitrates concentrations in waters Drader River.

- **Orthophosphates**

Phosphorus, one of the important nutrients, can be found in different oxidized forms. It is included in the composition of phosphoric acid nucleotides, basic units of nucleic acids DNA and RNA. It represents a biogenic element essential for the growth of algae. High levels of this element in surface water can lead to eutrophication. The analysis of the results shows that the concentration of orthophosphates in surface water of Drader river is less than 0.1 mg/l. These results can be explained by the low density of neighboring agglomerations and the low release of phosphorus trapped in sediments [18]. Orthophosphate concentrations are well below the Moroccan standard of 1 mg/L.

- **Calcium, magnesium, bicarbonates and sulphates**

Figure 11 shows that the concentration of calcium in Oued Dradère waters is high, ranging from 68 mg/L to 230 mg/L in Station 1, from 78 mg/L to 168 mg/L in Station 2 and between 125mg/L and 204 mg/L in station 3. Magnesium is present in the water of Oued Dradère but in less quantity by contribution to calcium. Calcium and magnesium essentially depend on the nature of the terrain crossed.

These values show that it is limestone water. These soils are formed from marly mother rock.

For bicarbonates (figure 12), water analysis of Drader river shows a significant variation in the upper, temporary watercourse, which can be attributed to the abrupt change in the flow regime. In the middle and lower streams, bicarbonate contents fluctuate between 191mg/L and 329 mg/L. This richness of water in bicarbonate is explained by nature of the crossed lands which are of marly nature. Bicarbonate develops a buffer system for pH stability [10].

As regards sulphates, the waters of the Drader river are less loaded with sulphates (figure 13), they have contents lower than 250 mg/l, indicating that these waters are not polluted [19].

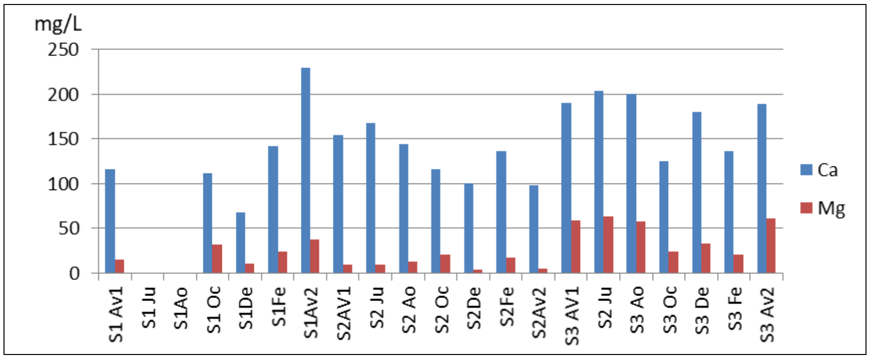


**Fig 11:** Spatiotemporal variation of the calcium and magnesium contents in the waters of Drader river

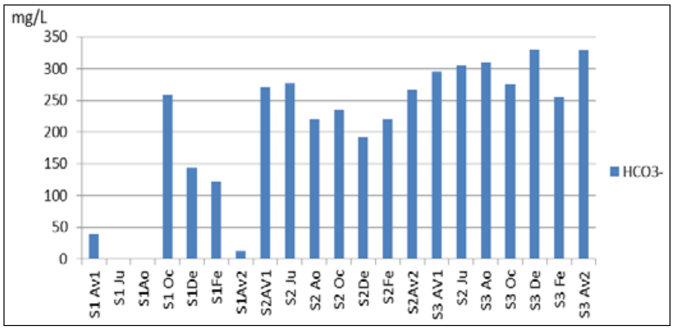


**Fig 12:** Spatiotemporal variation of bicarbonate contents in waters of Drader River.

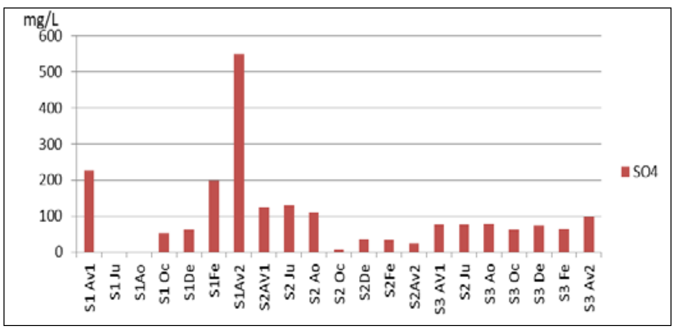


**Fig 13:** Spatiotemporal variation of sulphate contents in waters of Drader river.

- **Sodium and potassium**

Sodium and potassium are nutrients needed by crops. The results of the Drader rivers water analysis, shown in Figure 14, reveal sodium concentrations ranging from 65 mg/L (December 2016) to 300 mg/l (April 2017) in the upper stream. (S1) and 66 mg/l and 128 mg/L in the middle stream. Downstream of the Drader (S3), the values found are between 108 mg/L and 236 mg/L.

Potassium levels in the water of Drader river range between 1.8 mg l and 5.1 mg/L upstream (S1) and between 2 mg/L and 3.7 in station 2, and between 4.8 mg/L and 7.9 mg/L downstream of Drader river (S3). The increase in potassium levels from upstream to downstream of the Drader is explained by the use of chemical fertilizers in crops and by soil leaching.

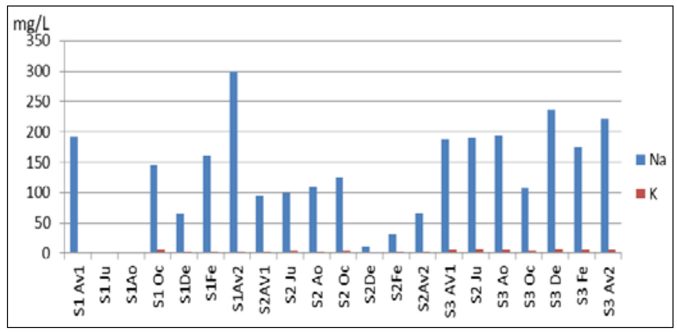


**Fig 14:** Spatiotemporal variation of sodium and potassium concentrations in waters of Drader River

## 4. Spatio-temporal typology of the physicochemical quality of Drader river waters

In order to establish a relationship between the different physicochemical parameters and to better evaluate the effect of anthropogenic activities on the water quality of Drader river, a statistical treatment by the PCA (Principal Components Analysis) was applied to all measured parameters. This method is widely used to interpret hydrochemical data [20, 21].

The analysis of the results shows that most of the information is explained by the first three factorial axes. The eigenvalues of the three components F1, F2 and F3 and their contribution to total inertia are shown in Table 2 and Table 3. Thus, the three axes taken into consideration to describe the correlations between the variables related to spatial structures, hold on their own 72, 23% of total information with respectively 33.28% for axis 1, 22.54% for axis 2 and 16.41 for axis 3.

**Table 2:** Eigenvalues of the axes F1, F2 and F3.

| | **F1** | **F2** | **F3** |
|---|---|---|---|
| Own value | 5.6579 | 3.8317 | 2.7910 |
| Variability (%) | 33.2816 | 22.5395 | 16.4176 |
| Cumulated (%) | 33.2816 | 55.8211 | 72.2387 |

**Table 3:** Correlations between variables and factors

| | F1 | F2 | F3 |
|---|---|---|---|
| pH | -0,436 | -0,534 | 0,019 |
| Cd | 0,867 | 0,272 | 0,189 |
| Salinité | 0,923 | 0,036 | -0,017 |
| Ca | 0,889 | -0,107 | -0,104 |
| Mg | 0,815 | -0,245 | -0,202 |
| Na | 0,914 | 0,167 | 0,140 |
| K | 0,625 | -0,576 | -0,316 |
| Cl | 0,902 | -0,124 | 0,011 |
| SO4 | 0,467 | 0,634 | 0,375 |
| HCO3 | 0,252 | -0,820 | -0,379 |
| NO3 | -0,164 | -0,514 | -0,524 |
| NH4 | -0,168 | -0,428 | 0,637 |
| NO2 | 0,000 | 0,000 | 0,000 |
| H2PO4 | -0,231 | -0,100 | -0,641 |
| DBO5 | -0,130 | -0,555 | 0,670 |
| DCO | -0,082 | -0,530 | 0,745 |
| MES | 0,277 | -0,431 | 0,473 |
| O2 diss | -0,180 | 0,849 | 0,066 |

The analysis of the factorial plane F1 and F2 (Fig.15 and Fig. 16) shows that more than 55.82% are expressed. While the analysis of the factorial plane F1 x F3 (Fig. 17 and Fig. 18) shows that 49.70% are expressed.

The axis 1 is expressed towards its positive pole by the COD, the BOD5, the MES and the sulphate content, showing an increasing gradient of pollution parameters from upstream to downstream.

The axis 2 is defined towards its positive pole by the ions sodium, calcium, magnesium, conductivity and salinity which have good correlations between them and by the orthophosphates in its negative pole. These results reveal a growing gradient of the mineralization of Drader river waters.

Axis 3 is expressed to its negative pole by the pH and by the dissolved oxygen content and towards its positive pole by the ions sodium, calcium, magnesium, conductivity and salinity. This reflects deterioration in the quality of Drader river waters from upstream to downstream.

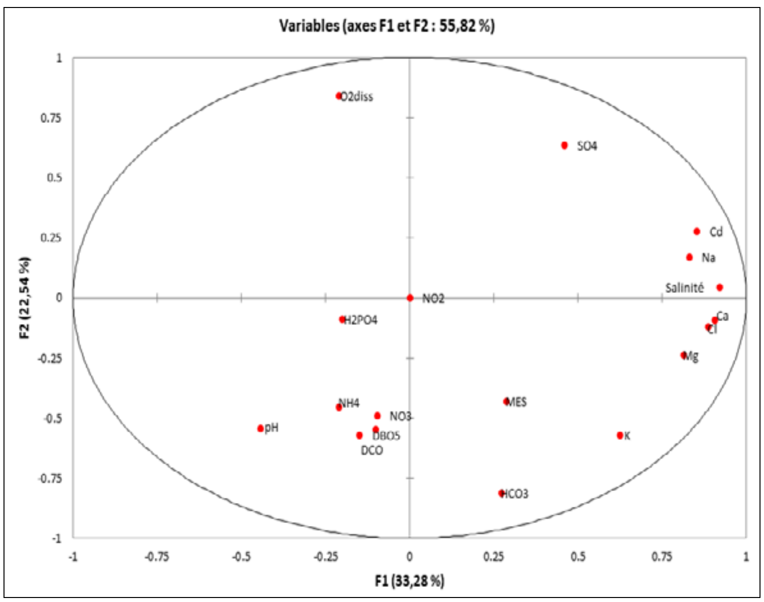


**Fig 15:** Representation of the variables measured in the factorial plane F1 x F2.

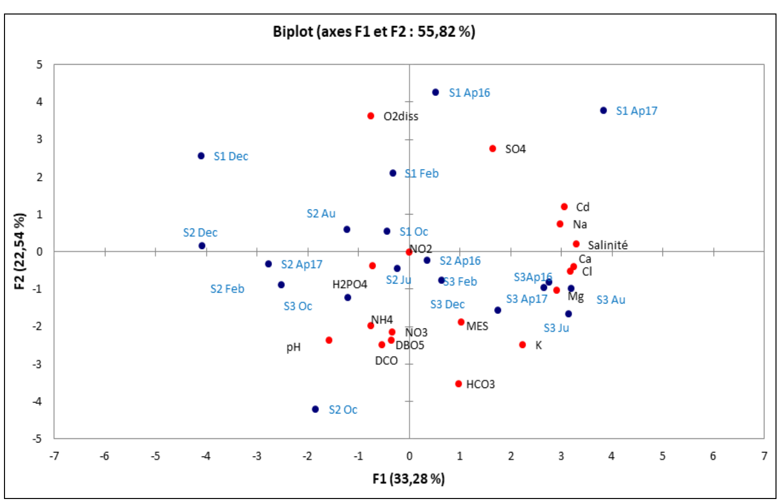


**Fig 16:** Correlation between the variables measured in the factorial plane F1 x F2.

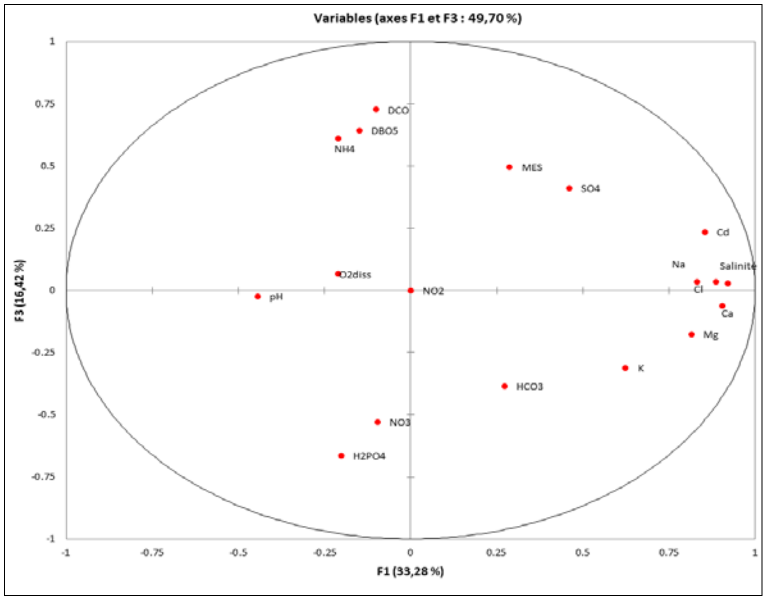


**Fig 17:** Representation of the variables measured in the factorial plane F1 x F3.

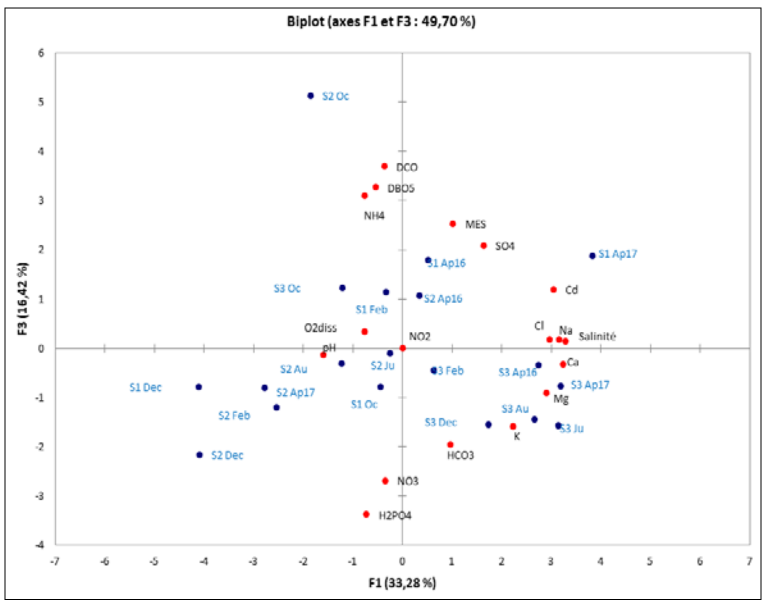


**Fig 18:** Correlation between the variables measured in the factorial plane F1 x F3.

## Conclusion

This study is carried out with the aim of characterizing, for the first time, the quality of the waters of the Drader river. It provides important information on the basis of physicochemical descriptors.

The principal components analysis (PCA) of the 18 variables studied made it possible to obtain a typology of stations / physicochemical variables. The study of the spatial distribution of the values of these variables shows that the station located upstream of Drader river is not affected by any disturbance, attesting to a good ecological state. Stations S2 and S3 show a slight degradation of the water quality of the middle and lower streams, which is manifested by an increase in nitrate concentration and a decrease in oxygen content. These results are attributed to the intense agricultural activity in the lower Drader and the possible contamination of the water by the domestic discharges of the small neighboring agglomerations of the river.

Thus, the preservation of the quality of Drader river water requires permanent monitoring and wastewater treatment at the Lalla Mimouna center to prevent any contamination of the surface or groundwater of the Drader-Souier basin.

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