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# Degradation of Oued Bousselam (Wilaya of Sétif-Algeria) by pollution

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**ABSTRACT**

Surface waters are increasingly polluted. They contain tons of pollutants from chemical discharges originating from industries, agriculture and daily operations. These pollutants pose a great danger to human health and the environment in general.

Surface water sampling was conducted at 18 sites selected from locations suspected of contaminants. Physico-chemical analyses have been carried out to determine the pollution which caused the degradation of this river.

The results revealed a significant pollution rate from several sources, according to the hated activities near this Oued, whose degradation threatens the Wilaya of Sétif's population and its environment.

It is imperative to control the water quality in this river and prevent the diversification of domestic and industrial wastewater into the water body under investigation, with the installation of treatment plants to treat polluted water.

## INTRODUCTION

Water remains the main constituent of living beings and is indispensable for all life forms. Without water, no organism, whether plant or animal, simple or complex, small or large can live **(Andersson, 2016)**.

Water is particularly important in our lives; it is found in all the activities that punctuate our daily lives **(Karnib, 2016)**. On daily basis, water is used in manufacturing everyday consumer products, food, agriculture and industry **(Brdjanovic, 2015)**. With population growth, urbanization and economic development, water demand is increasing in all urban areas of Algeria. At the same time, climate change and pollution affect water availability for city residents (**Copeland, 2015)**.

Water is a common good essential to all life: a vital element for food, a living environment for many species, and a resource for many economic activities. Globally overexploited and polluted by human activities, water has become a fragile asset over the decades (**Difaf, 2016)**. In a global context of increasing scarcity, the quality and

availability of water resources have become major issues in public health, environment and geopolitical stability in certain regions of the world.

The industry has a close, if not vital, relationship with water. Industrial activities put pressure on the resource in terms of abstraction and pollution. Aware that water is a precious commodity they share, manufacturers have made significant progress in recent years to practice more economical and sustainable resource use (**Keraita, 2015)**. Water is one of the themes best fitting into companies' sustainable development approaches **(Difaf, 2016)**.

The Oued Bousselama is one of the permanent Algerian rivers most affected by pollution. It is the main hydrographic axis of the Sétif region and the main source of the Ain Zada dam, which feeds the old streets of Sétif, El Eulma, Bordj Bou Arrreridj and Bougaâ with water, from which it suffers very severe pollution (**Bentouati, 2011)**.

The objective of this work was to determine, through the results obtained from the analyses of the various physico-chemical parameters, pollution, global mineralization, undesirable elements, as well as the nature and impact of pollution on the quality of surface water in Oued Bousselam (Wilaya of Sétif, Algeria).

## MATERIALS AND METHODS

### 2.1. Description of the study sites

The Oued Bousselam represents the main hydrographic axis of Sétif. It has its source at Ras Ain Bousselam, north of Farmatou and drains to Oued Sommam, with a length of 159km and an annual regularizable volume of nearly 38Hm³. The area of the watershed is 4300km². It is constituted by the meeting of the Oued Gassar, which runs along the foothills south of the Jebel Megress (Altitude: 1737 m), and the Oued Ouricia, which is located in the south part of this djebel. It rises at about 1100m, five kilometers northwest of the town of Sétif (Fig. 1). It extends approximately between longitudes 5° 20' 00" and 5° 25' 00" East and 36° 10' 00" and 36° 15' 00" North **(Sersoub, 2012)**.

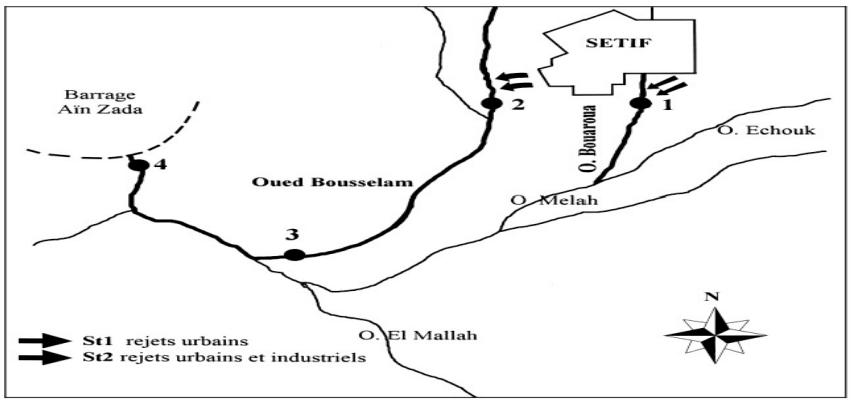


**Fig. 1.** Presentation of the study area

### 2.2. Donor reef and nursery setup

During this research, targeted sampling was conducted, which consists of taking samples from locations where contaminants are suspected **(MDDEPQ, 2008)**. We took 18 samples in October 2022 at a depth of 15 to 20 cm from the following sites:
S1: Oued Guessar.
S2: After the village of Fermatou.
S3: After the discharges of the ERIAD complex (village of Chouf Lekdad, Sétif).
S4: At the exit of the city of Sétif.
S5: After the rejections of the dairy unit (village of Mezloug).
S6: After the discharges of the thermal complex (village of Hammam Ouled Yellès).
S7: After the discharges of the pasta manufacturing complex (In the North part of Sétif).
S8: After the rejections of the pasta manufacturing complex (at South West in Sétif).
S9: After the rejections of the tannery (in the South West of Sétif).
S10: Before the discharge of the Oued Bousselam into the Ain Zada dam.
S11: At the exit of the village of Ain Trik
S12: At the exit of the village of Chouf-Lekeded
S13: At the exit of the village of Raselma.
S14: At the exit of the village of Abid Ali.
S15: At the exit of the village of El Hassi.
S16: At the exit of the village of Gaoua.
S17: At the exit of the village of Ain Arnat.
S18: Oued Ouricia.

In hermetically sealed plastic bottles, water samples were stored at a low temperature (4°C). The water samples were then filtered on filter paper with a 0.45µm pore diameter (**Rodier *et al.*, 2005; Samai *et al.*, 2022a)**. Then, the following physico-chemical analyses were carried out:
The hydrogen potential (pH), and the electrical conductivity y (EC) were determined by direct reading *in situ* using a multi-parameter (Type: WTW pH / Cond 340i / SET), Suspended solids (SS) were assessed by filtration; other physico-chemical parameters such as biological oxygen demand ($BOD_5$), nitrate ($NO^-_3$), nitrite ($NO^-_2$) (**AFNOR, 1986)**, chlorides ($CL^-$), ammonium ($NH^+_4$) were determined following the standards of **AFNOR (1977)** and the protocols of **Rodier *et al.* (2005)**.

### 2.3. Statistical analysis

All results were analyzed using the statistical software XLSTAT, version 7.5.2.

## RESULTS

### 3.1. Hydrogen potential (pH)

pH is an indication of the tendency of water for being acidic or alkaline. PH measures the product ($H^+$) concentration in water (**Devillers *et al.*, 2005; Samai *et al.*, 2022b)**. The result provided an overview of the pH variations at the measured sites. It was noticed that, this variation is almost homogeneous, but it depends on the nature of the water and its origin. In general, all samples have a pH between 8.01< pH < 8.95 (Fig. 2).

### 3.2. Electrical conductivity (EC)

The conductivity of water indicates its more or less saline character. Low-ion waters have a very low conductivity, while seawater, for example, has a very high conductivity. It is expressed in µS/cm **(Audern et *al.*, 2005).**

The electrical conductivity values in the Oued Bousselam vary from 2000 µs/cm to 3500 µs /cm (Fig. 3).

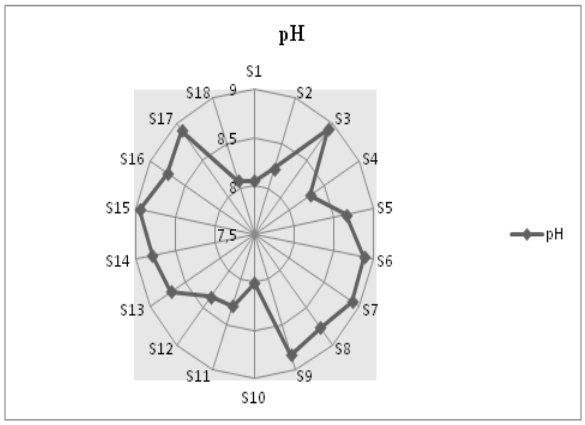


**Fig. 2.** Spatial Variation of pH

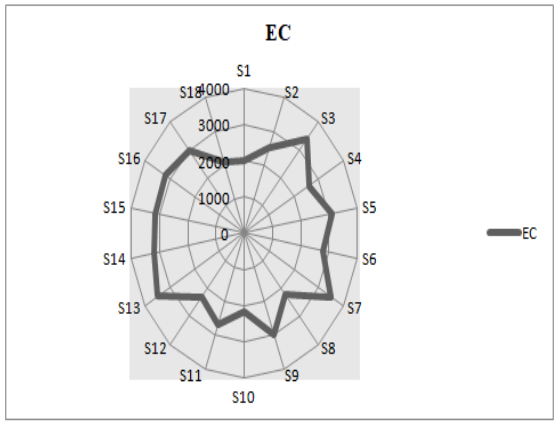


**Fig. 3.** Spatial Variation of EC

### 3.3. Suspended solids (SS)

The composition of suspended solids (SS) is very variable. It depends on the discharges, the terrain crossed by the flowing water, the rainfall, etc... **(Rodier *et al.*, 2000; Samai *et al.*, 2022b)**. The analyses show that the SS levels are very high all along the Oued Bousselam. They are between 0.41 and 0.66mg/ l (Fig. 4).

### 3.4. Biological oxygen demand ($BOD_5$)

$BOD_5$ (Biological Oxygen Demand for Five Days) is the amount of oxygen consumed under the test condition (incubation at 20°C in darkness after five days) **(Boodiers, 1981)**. The results showed a significant increase in $BOD_5$ in the waters of Oued Bousselam. The average values were between 13.50 and 17.60 mg/l (Fig. 5).

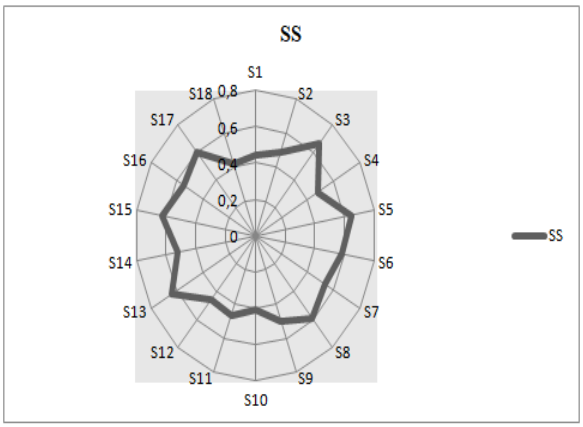


**Fig. 4.** Spatial Variation of SS

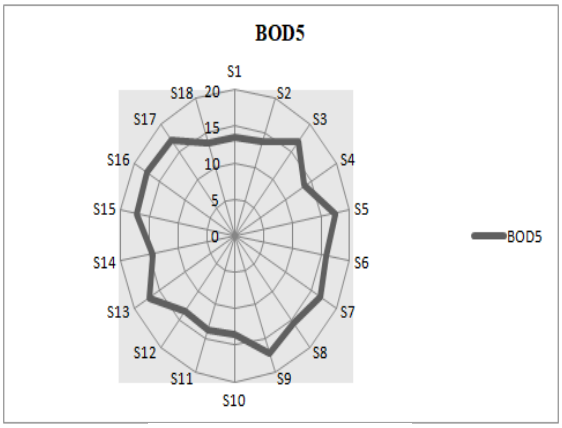


**Fig. 5.** Spatial Variation of $BOD_5$

### 3.5. Nitrates ($NO^-_3$)

Nitrates are formed from the complete oxidation of organic nitrogen. They are present in the soil, surface water and groundwater. They result from the natural decomposition by microorganisms of nitrogenous organic matter, such as vegetable proteins, animal proteins and animal excrement. The ammonium ion formed is oxidized to nitrates. The presence of nitrates in the environment is a natural consequence of the nitrogen cycle (**Demdoum, 2010; Derrahal, 2019)**. The results showed that Oued Bousselam is highly loaded with nitrates, with values between 50.98 and 52.02mg/ l (Fig. 6), and these values exceeded the normal limit (50mg/ l).

### 3.6. Nitrites ($NO^-_2$)

Nitrites come from the incomplete oxidation of organic nitrogen or a reduction in nitrates. The main sources of pollution are the use of fertilizers, the manufacture of explosives, and the chemical and food industries. The nitrate content of water is generally higher than that of nitrites. A high nitrite concentration indicates bacteriological pollution due to ammonia oxidation **(Ayad, 2017)**. Nitrate values ranged between 0.5 and 0.99mg/ l (Fig. 7), all along the Oued Bousselam, which exceeded the standard value (0.1 mg/l).

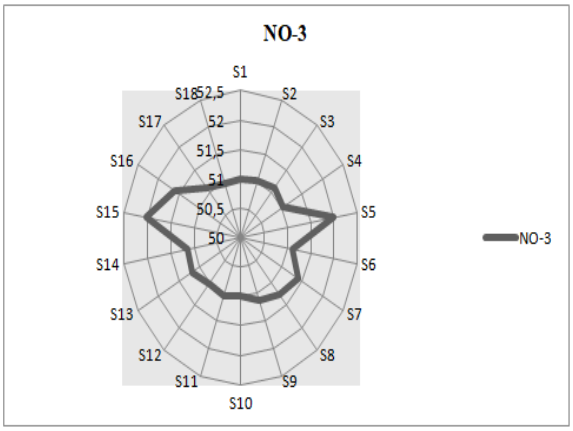


**Fig. 6.** Spatial variation of $NO^-_3$

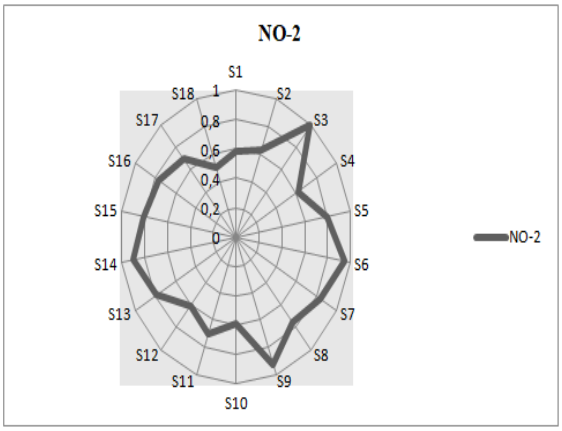


**Fig. 7.** Spatial variation of $NO^-_2$

### 3.7. Chlorides ($CL^-$)

Chlorides are important inorganic anions contained in varying concentrations in natural waters. The origin of this element is mainly related to the dissolution of salt formations and may be chemical plant effluents, wastewater and irrigation runoff **(Kachi, 2015)**. The chloride ion levels recorded in Oued Bousselam are very high, ranging from 75.65 to 88mg/ l (Fig. 8).

### 3.8. Ammonium ($NH^+_4$)

Ammonium ($NH^+_4$) is the most toxic form of nitrogen. Its presence in water is linked to urban and industrial discharges or the reduction of nitrogen forms (nitrates and nitrites) under reduced conditions (**Debieche, 2002)**. The concentrations observed at all sampled sites are above the OMS standard (0.5mg/ l). For Oued Bousselam, the concentrations are high and extremely varied, fluctuating between 0.99 and 1.33mg/ l (Fig. 9).

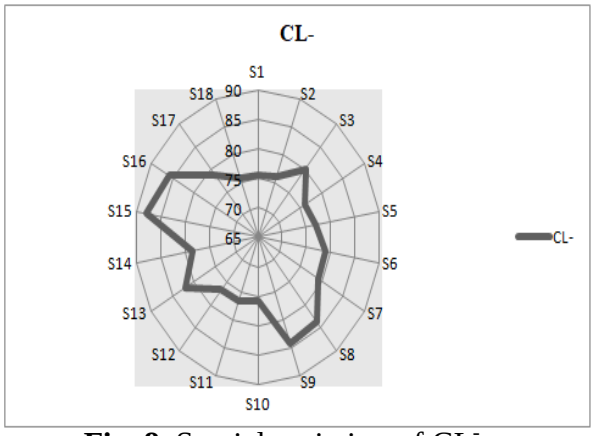


**Fig. 8.** Spatial variation of $CL^-$

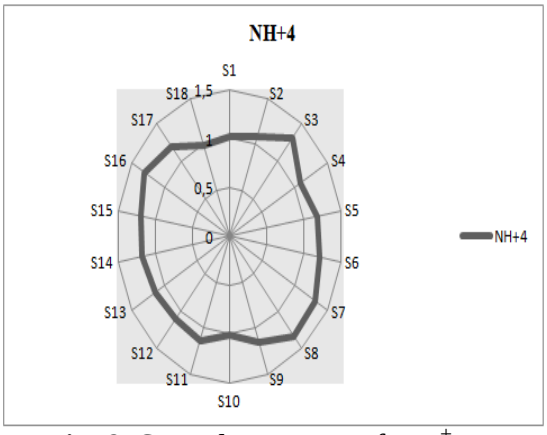


**Fig. 9.** Spatial variation of $NH^+_4$

## DISCUSSION

The pH values recorded indicate that these waters are alkaline, and this is due to domestic and industrial discharges that are basic **(Devillers *et al.*, 2005)**.

The values of electrical conductivity reveal that the waters are highly mineralized. These high conductivity values reflect a continuous supply of mineral salts along the river **(Audern *et al.*, 2005)**. In addition, the measured values of the suspended solids are high. This is due to industrial and domestic discharges that are discharged directly into this river and to the leaching of agricultural lands, which are very large in the Wilaya of Sétif, providing a significant amount of chemical fertilizer **(Rodier *et al.*, 2009)**.

Biological oxygen demand ($BOD_5$) is a good indicator of the biodegradable organic matter content of polluted natural water or wastewater **(Vila**,**1980)**. Hence, the increase in $BOD_5$ is expressed by the fertilizer inputs from agriculture and the domestic and industrial discharges released into the waters of this river.

The results showed that Oued Bousselam is very loaded with nitrates ($NO^-_3$); This pollution is due to the excessive variation of industrial effluents in the Sétif region **(Demdoum, 2010)**.

For ($NO^-_2$); it was deduced that Oued Bousselam (Algeria) is very polluted by nitrites, and there is an effect of oxidation of the ammonium form **(Ayad, 2017)**.

The chloride ion ($Cl^-$) levels recorded in Oued Bousselam are very high; This increase is linked to urban and industrial activities in the Wilaya of Sétif **(Kachi, 2015)**.

For Oued Bousselam, the concentrations of ammonium ($NH^+_4$) are very diverse and high. Ammonium is a good indicator of urban effluent pollution in watercourses **(Debieche, 2002)**.

## 4.1. Statistical treatment of physicochemical data on the waters of Oued Bousselam

### *4.1.1.Method of data processing*

PCA is a data analysis tool that helps explain the structure of correlations using linear combinations of the original data.
The objective of the CPA is to present, in a graphical form, the maximum amount of information contained in a data table based on the principle of double projection on the factorial axes.

The pH, conductivity, suspended solids, $BOD_5$, nitrates, nitrites, chlorides, and ammonium 08 variables are processed by PCA, followed by 18 samples in October 2022.
The Principal Component Analysis (PCA) was performed on a data matrix consisting of 18 rows representing the surveyed sampling stations and 8 columns representing the physico-chemical variables measured.
The goal of the analysis is to obtain a small number of linear combinations of the 18 variables that account for most of the variability of the data.

## 4.2. High water period

### *4.2.1. Correlation matrix*

The correlation matrix gives the significant links between the different variables necessary to study the parameters used. These links are reflected in the correlations between the variables studied.
The application of PCA to the water data in the study area revealed the different correlations in a matrix (Tab. 1). These correlations can be positive or negative.
The calculated correlation values between the physico-chemical parameters studied (pH, electrical conductivity, chlorides, nitrates, nitrites, ammonium, suspended solids, and $BOD_5$) are shown in the following table represents the averages of the values recorded in October 2022.

**Tab. 1.** Correlation matrix of physico-chemical parameters

| | pH | EC | SS | $BOD_5$ | $CL^-$ | $NO^-_3$ | $NO^-_2$ | $NH^+_4$ |
|---|---|---|---|---|---|---|---|---|
| pH | 1 | | | | | | | |
| EC | **0,796** | 1 | | | | | | |
| SS | **0,812** | **0,716** | 1 | | | | | |
| $BOD_5$ | **0,853** | **0,794** | **0,815** | 1 | | | | |
| $CL^-$ | **0,713** | **0,505** | **0,574** | **0,735** | 1 | | | |
| $NO^-_3$ | **0,497** | **0,485** | **0,605** | **0,671** | **0,573** | 1 | | |
| $NO^-_2$ | **0,858** | **0,767** | **0,688** | **0,699** | **0,537** | 0,334 | 1 | |
| $NH^+_4$ | **0,713** | **0,505** | **0,574** | **0,735** | **1,000** | **0,573** | **0,537** | 1 |

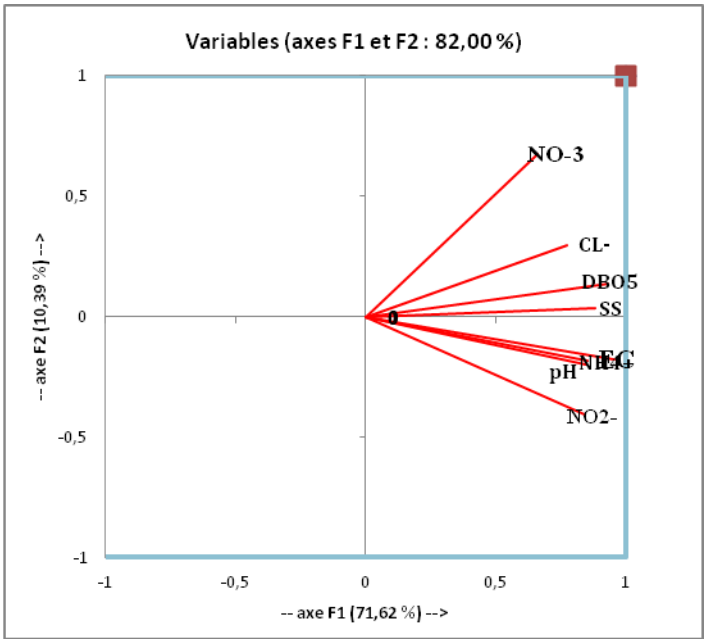


**Fig. 10.** Correlation matrix of physico-chemical parameters

The factorial design (F1, F2) shows an expression of more than 82% (Fig. 10).
The F1 axis illustrates a variance equal to 71.62%, which is expressed towards its positive pole by nitrate ions, chloride ions, BOD5, and suspended solids, which have a highly significant correlation between them, resulting in strong mineralization.
The F2 axis illustrates a variance equal to 10.39%, constituted by a significant correlation between nitrite ions, ammonium ions, pH, and conductivity towards its negative pole, so we can say that the F2 axis indicates organic pollution expressed by the nitrification phenomenon.

The waters of Oued Bousselam are considered more or less oxygenated, which testifies to a disturbed ecological state of the aquatic environment.
So, we see that using different water sources such as boreholes, wells, and especially Oueds without considering the nature of both household and industrial discharges opens up a water deficit. For this, it is necessary to draw up analysis reports as part of the quality control of water intended for irrigation.
Agricultural activities tend to develop preferably near watercourses and where the body of water is easy to reach.

## CONCLUSION

The various results obtained according to our study allowed us to establish a report on the quality of the surface waters of Oued Bousselam (Sétif- Algeria).

The diagnosis revealed the presence of very important pollution at the level of this Oued. This pollution manifests itself, especially by a potential of alkaline hydrogen, a high electrical conductivity, a significant amount of suspended matter, and values of nitrates, nitrites, and chlorides that exceed the standards of Algerian potability.

According to the values of these physico-chemical parameters, it can be seen that the Oued Bousselam is affected by pollution of several origins, such as agricultural, urban, and industrial, which can lead to the degradation and disruption of the biological balance of this water environment and harm the life of flora and fauna of this river.

Therefore, establishing a program of continuous control and monitoring of the various sources of pollution and their effect on the environment is necessary.
Water must therefore be the main arm of water policy.

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