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Impacts of Water Pollution on Ecosystems and Biological Diversity: Case of Oued Soummam (Algeria)

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ABSTRACT

Water is essential for the survival of the human being; it is considered a driving force of all nature in addition to being the main key to sustainable development. In this framework, a qualitative approach was implemented to investigate the surface waters of the Soummam Ouad. The study site lies in the central northeastern side of Algeria in Kabylia, halfway between the Wilaya of Algiers and the Wilaya of Constantine (Algeria). This study was organized to provide a detailed report on the status and the current quality of this Wadi's waters. To accomplish this target, several physicochemical parameters were analyzed to specify the intensity and the violence of the persistent pollution in this Wadi, addressing these effects on the animal and plant biodiversity of this Oued. This study was conducted in December 2022 on the upstream, the center, and the downstream of this watercourse. The water under study was clearly soiled and dirty by several harmful and pernicious pollutants, which can alter and disintegrate the nature and life of the living beings of this aquatic ecosystem. These undesirable results disrupt the functioning of the environment and affect the health of all mankind as well as the biodiversity of both animals and plants. To handle this situation, proper management for all types of pollutants is required before they are discharged into the watercourses causing an imbalance in life.

INTRODUCTION

As the source of all life, water is essential to our health, well-being and dignity, as well as being radical for the functioning of our ecosystems and societies. Access to water is therefore synonymous with development **(Samai *et al*., 2022a)**.

Moreover, water is a symbol of purity, fertility and life. Indispensable to quench our thirst, wash us, recharge our batteries and produce our food; it is just as essential to our societies **(Jones Joneset *et al*., 2021)**.

Since the last world war, this precious resource has been regrettably threatened by the extraordinary economic development, the diversification of consumer goods, the almost generalization of the distribution of drinking water at home and the multiplication of water needs. Though they have largely contributed to the comfort and health of the population, they resulted in the use and pollution of nearly 150 liters of drinking water per day and per capita in our regions **(Zenati *et al.*, 2018)**.

Water pollution is a physical, chemical, biological or bacteriological degradation of its natural qualities, caused by man and his activities. It disturbs the living conditions of aquatic flora and fauna, which compromise the uses of water and the balance of the natural environment **(Belalite *et al.*, 2021)**. Water pollution is caused by the discharge of dirty water from our domestic activities (washing and cleaning, urine and faeces disposal, etc.) in addition to various industrial and agricultural activities that are necessary to provide the food and goods we need **(Grzegórska *et al*., 2020)**. Thus, from our homes, we discharge wastewater, sometimes in minute quantities and sometimes unknowingly: fecal matter and toilet paper, sand and soil, food waste and grease, various detergents, cosmetics, drugs, pathogens, hormones, biocides (bleach, pesticides, herbicides), micro-plastics, tectile fibers, nanomaterials, etc. **(Al-Khatib *et al*., 2017)**.

Wastewater is sometimes referred to as graywater when it is water with low pollutant load, as for example, water of domestic origin resulting from dishwashing or hand washing, bathing or showering. While, it is referred to as black water when it contains various substances that are more polluting water or more difficult to eliminate, such as fecal matter or any type of industrial by-product **(Zeghaba & Laraba, 2018)**.

Rainwater that runs off impervious surfaces is often considered polluted. For example, rainwater runoff from parking lots carries a variety of pollutants such as hydrocarbons or dust from tire or brake system wear. Similarly, herbicides used to quickly and effortlessly weed paved or paved outdoor areas and ending up in run off **(Mihoubi & Mebarki, 2017)**.

Wastewater discharged by hospitals, schools, shops, hotels, restaurants, dentists, laboratories and artisans (bakers, butchers, hairdressers, etc.) are often, for technical or hygiene reasons, loaded with specific professional products.

Agricultural pollution is also a source of pollution of waterways. Improperly used fertilizers and pesticides pollute groundwater by seeping into the soil with rainwater and irrigation water in addition to surface water by runoff and entrainment of these products into waterways (**Belouanas & Menani, 2019)**.

In addtion, industries produce wastewater and discharge a wide range of pollutants. For the product fabrication, water is used during the manufacturing processes, and

subsequently the organic matter, salts, hydrocarbons, metals, biocides, micropollutants and various chemicals are found in these waters (**Wear *et al.*, 2021)**.

Therefore, this research was conducted to provide a well- detailed study on the physico-chemical parameters of the surface waters of Oued Soummam to determine the intensity of the existing pollution in this Oued, with the aim of protecting animal and plant biodiversity and achieving the sustainable development for our country.

MATERIALS AND METHODS

1. The study site

The Soummam wadi valley lies in the central north-eastern Algeria in Kabylia, halfway between Algiers and Constantine (Fig. 1). It draws a narrow SW-NE trench, which is interposed between the mountainous massifs of the Djurdjura in the West and its extension towards the North-East by the Aghbalou-Gouraya range, and the Bibans in the South and their extension towards the East by the Babors. The upstream part represents the beginning of the Soummam wadi from the confluence of the Oued Boussellam and the Oued Sahel, located 2km southwest of the city of Akbou, and the downstream termination is represented by the mouth of the Soummam, located on the eastern outskirts of the city of Bejaia **(Zouggaghe & Moali, 2009)**.

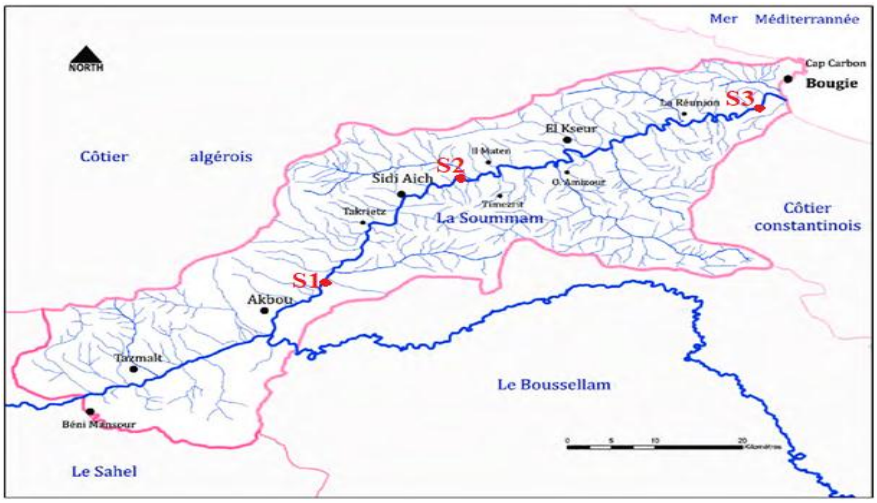

Fig. 1. A map of the study area showing the collection sites

The study area is part of the semi-arid bioclimatic stage with cold winters, characterized by a continental climate that is cold and rainy in winter and hot and dry in summer, with the dry period lasting for 6 months or more. The prevailing northwest and west winds bring irregular and often torrential rains causing floods. The Siroco, dry and hot, blows from the South **(Zouggaghe & Moali, 2009)**.

2. Sample collection

The choice of sampling sites was made according to a plan based on the search for the most polluted sites, and thus this choice is logical, representative and justified. Researchers collected samples from the upstream (S1: Akbou), center (S2: Sidi Aich) and downstream (S3: Reunion); the sampling was carried out in December 2022.

In the laboratory, water samples were analyzed according to the standardized protocols of **AFNOR (1999)**.

3. Water measuring parameters and methods

The measured parameters and their methods of analysis are described in the followings:

- Temperature (T), hydrogen potential (pH), conductivity (EC), were measured *in situ* using a portable multi-parameter according to the respective protocols: NF T 90.008, NF EN 27888 and NF EN ISO 7027.
- Suspended solids (SS) by filtration at 0.45µm of a known volume of water according to the NF EN 872 protocol.
- Nitrates (NO^-_3), nitrites (NO^-_2), ammonium (NH^+_4) were determined by colorimetric determination using a spectrophotometer (UV/visible) according to the respective protocols: NF EN ISO 13395 (NO^-_3 and NO^-_2) and NF T90-015.
- Chlorides (Cl^-) were measured by silver nitrate titration with chromate as indicator (Mohr's method) according to the method NF ISO 9297 **(Barour, 2015)**.

4. Statistical analysis

The statistical analysis of the obtained results was performed using the software Minitab version 10, followed by the analysis of variance to a single criterion of classification and the Tuckey test.

RESULTS

1. The Temperature (T°C)

The spatio-temporal evolution of the temperature of this wadi reaches its maximum downstream where it varies between 12 and 14°C (Fig. 2)

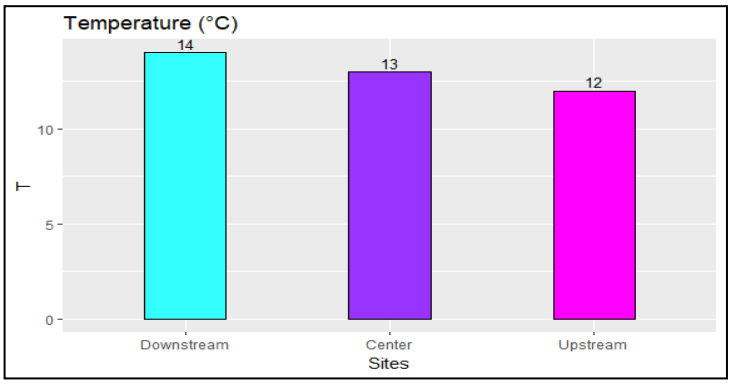

Fig. 2. Spatial variation of temperature

Table 1. Analysis of variance of temperature (T °C)

Source	DL	SomCar adjust	CM adjust	*F*-value	*P*-value
T°C	4	3,000	0,7500	1,00	0,500
Error	4	3,000	0,7500		
Total	8	6,000			

The analysis of variance with a single classification criterion showed that there was no difference between the temperature of the three stations (Upstream, Central and Downstream)

2. The hydrogen potential (pH)

The current results indicate that the waters of Oued Soummam are basic, especially in the upstream, with values ranging between 7.77 and 8.55 (Fig. 3).

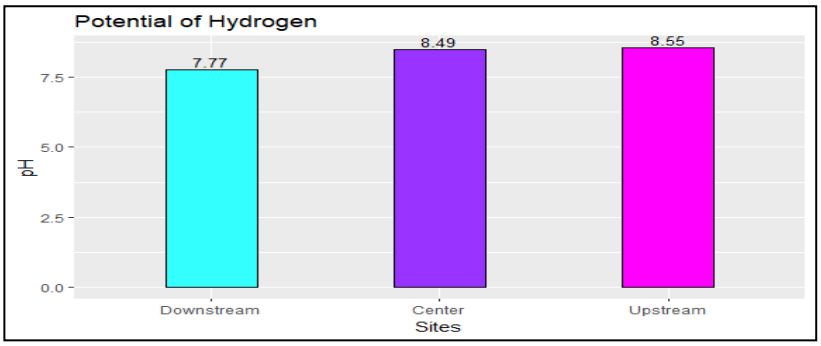

Fig. 3. Spatial variation of the pH

Table 2. Analysis of variance of pH

Source	DL	SomCar adjust	CM adjust	Value F	Value of p
sites	2	1,53310	0,836100	8361,00	0,000
Error	6	0,00070	0,000200		
Total	8	1,53380			

The analysis of variance with a single classification criterion showed that there is a very highly significant difference for the pH parameter among the three sites (upstream, central and downstream)**.**

3. Electrical conductivity (EC µs/cm)

The obtained results of the electrical conductivity for the water samples are displayed in Fig. (4).

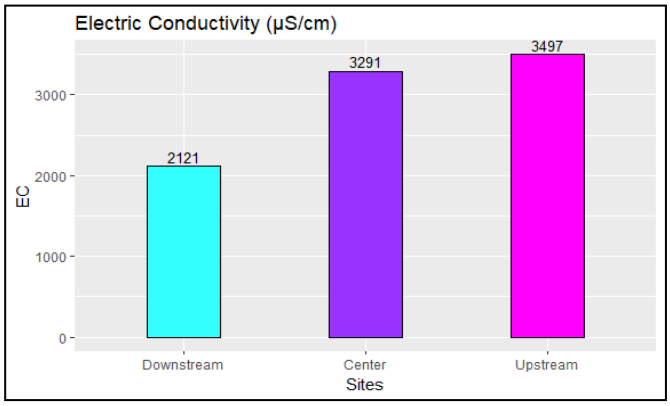

Fig. 4. Spatial variation of EC

Table 3. Analysis of variance of electrical conductivity (EC µS/cm)

Source	DL	SomCar adjust	CM adjust	Value	F	Value of p
sites	2	3732072	1444046	1444046,00		0,000
Error	6	6	1			
Total	8	3732079				

The analysis of variance with a single classification criterion showed that there is an extremely high significant difference for the parameter of electrical conductivity among the three sites (upstream, central and downstream).

4. Suspended solids (SS mg/l)

Fig. (5) presents the values of suspended matter with ranges between 0.51mg/l and 0.53mg/l.

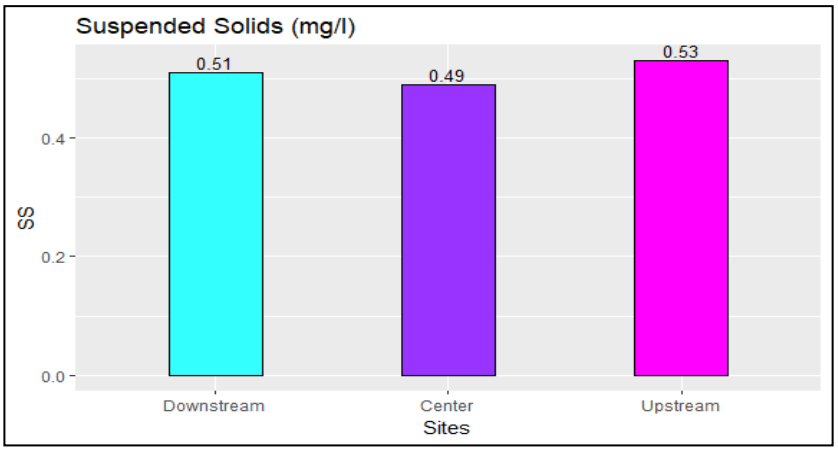

Fig. 5. Values of suspended solids (SS mg/l)

Table 4. Analysis of variance of suspended solids (SS mg/l)

Source	DL	SomCar adjust	CM adjust	*F*- value	*P*-value
SS mg/l	6	3,500	0,5833	0,47	0,802
Error	2	2,500	1,2500		
Total	8	6,000			

For the single-criteria analysis of variance for classification, no difference was detected among the three stations for suspended solids.

5. Nitrates (NO^-_3 mg/l)

A rise in the nitrate level values was recorded ranging from 48.57mg/l to 51.22mg/l (Fig. 6)

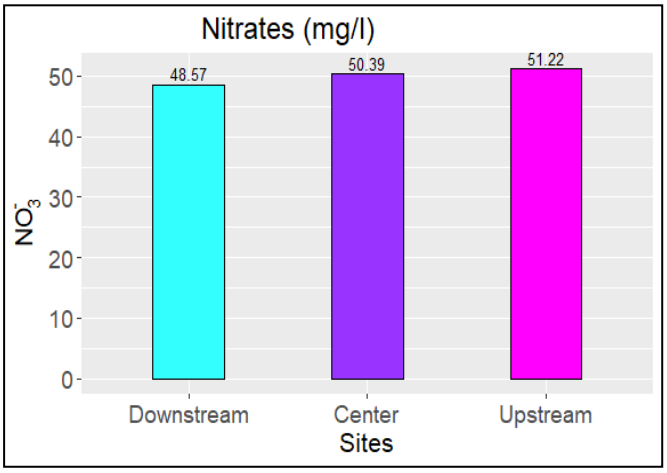

Fig. 6. Spatial variation of NO^-_3

Table 5. Analysis of variance for nitrates (NO^-_3 mg/l)

Source	DL	SomCar adjust	CM adjust	F- value	*P*-value
sites	2	15,4312	8,13419	93307,67	0,000
Error	6	0,0006	0,00009		
Total	8	15,4372			

With a single classification criterion, the analysis of variance recorded an extremely high significant difference for the nitrate parameter among the three sites (upstream, central and downstream).

6. Nitrites (NO^-_2 mg/l)

The values of nitrates in Oued Soummam range from 0.61mg/l to 0.96mg/l (Fig.7).

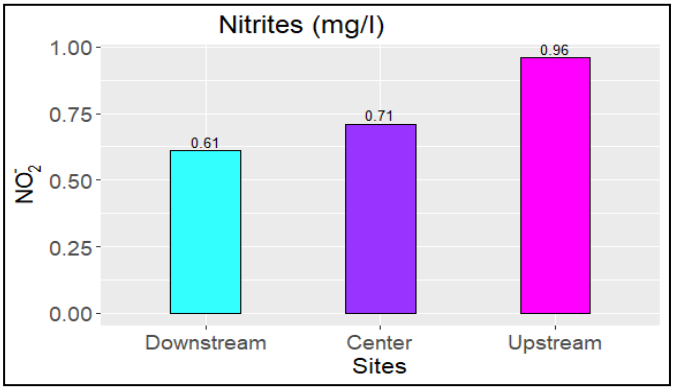

Fig.7. The values of nitrates *(NO^-_2 mg/l)* in Oued Soummam

Table 6. Analysis of variance of nitrites (NO^-_2 mg/l)

Source	DL	SomCar adjust	CM adjust	F value	
Sites	2	0,081200	0,045700	435,00	0,000
Error	6	0,000700	0,000200		
Total	8	0,081900			

The analysis of variance with a single classification criterion showed that there is a very high significant difference for the nitrite parameter among the three sites (upstream, central and downstream).

7. Ammonium (NH^+_4 mg/l)

The concentrations of ammonium ion (NH^+_4 mg/l) are presented in Fig. (8)

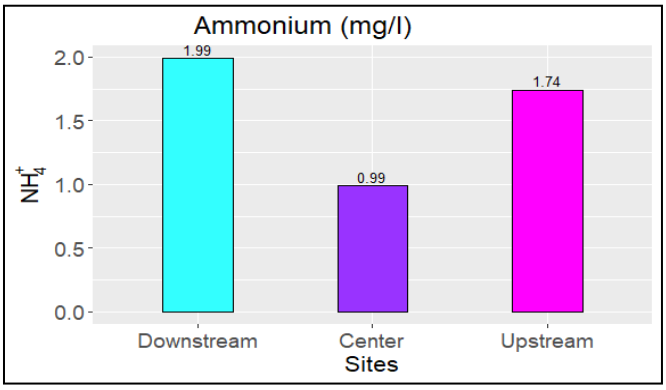

Fig. 8. Spatial variation of NH^+_4

Table7. Analysis of variance of ammonium ion (NH^+_4 mg/l)

Source	DL	SomCar adjust	CM adjust		Value F
sites	2	0,5486	0,32770	4,20	0,209
Error	6	0,4002	0,08850		
Total	8	0,9488			

The single-criteria analysis of variance showed that there was no high significant difference for the ammonium parameter among the three sites under study (upstream, central and downstream).

8. Chlorides (CL^- mg/l)

The results obtained show that the waters of Oued Soummam are loaded with chloride ions, especially the downstream, recording values between 287mg/l and 413mg/l (Fig. 9).

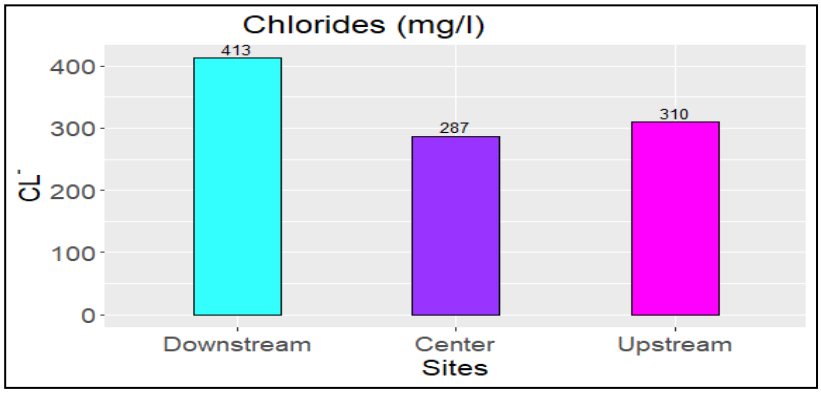

Fig. 9. Spatial variation of Cl^-

Table 8. Analysis of variance of chlorides (Cl^- mg/l)

Source	DL	SomCar adjust	CM adjust		Value F
sites	2	154843	83653,0	83743,00	0,000
Error	6	6	1,0		
Total	8	146789			

The analysis of variance with a single classification criterion showed that there is a very high significant difference for the chloride parameter among the three sites (upstream, central and downstream).

DISCUSSION

The analysis of variance with a single classification criterion showed that there was no difference between the temperatures of the three stations (upstream, central and downstream)

According to **Chapman and Kimstach (1996)**, water temperature is a very important ecological factor that governs virtually all physical, chemical and biological reactions. This temperature acts on the density, viscosity, solubility of gases in water, dissociation of dissolved salts, as well as on chemical and biochemical reactions, development and growth of organisms living in water, particularly microorganisms. The spatio-temporal evolution of the temperature of this wadi reaches its maximum downstream where it varies between 12°C and 14°C (Fig. 2), this is due to the period of sampling which was in the winter (the month of December). The development of temperature can kill certain animal or plant organisms in this watercourse, as for example, mushrooms, algae...

Water pH is a chemical parameter characterizing the acidity or basicity of an environment. It results from the ionic composition of water, and essentially from the presence of carbonates resulting from the exchange of carbon dioxide (CO_2) at the water-air interface, as well as from the dissolution of limestone **(Aminot & Kérouel, 2004)**.
The results obtained show that the waters of Oued Soummam are basic, especially the upstream, recording values ranging between 7.77 and 8.55 (Fig. 3). This increase in hydrogen potential is related to the basic nature of discharges into this stream. The basic nature of the pH of watercourses can influence the biological function of aquatic biodiversity (animal and plant), e.g. mushrooms, algae...

The conductivity of a solution is defined as the conductance of a column of water between two metal electrodes with a surface area of $1cm^2$ and separated from each other by 1cm **(Rodier, 1996)**. Conductivity measures the ability of water to conduct the current between two electrodes. Most of the dissolved matter in water is in the form of electrically charged ions. The conductivity measurement, therefore, makes it possible to assess the quantity of salts dissolved in water and gives an idea of the total mineralization of water **(Samai *et al* .,2022b)** Thus, it was deduced that these waters are strongly mineralized. This mineralization can disturb the fauna of this Oued (It can cause intoxication with the microfauna of this river).

Suspended solids represent all the mineral and organic particles found in water. They are formed resulting from the function of the nature of the land crossed, the season, the rainfall, the water flow regime, and the nature of the discharges **(Rodier *et al*.,1984)**. Therefore, elevated suspended solids levels can be considered a form of pollution. Such an increase can warm water, which will reduce the quality of the habitat for cold water organisms **(Rodier *et al*., 2005; Samai *et al*., 2022)**. The results in Fig. (5) show that the values of suspended matter range between 0.51 and 0.53mg/l. This is related to the

different effluents and discharges that receive this wadi especially upstream, and which are of different sources such as agricultural, urban and industrial. Suspended solids pollution can degrade the aquatic animal and plant of the Oued Soummam.

The nitrates occur naturally in soils, surface, ground water and all plant material. They reach rivers through groundwater and through runoff from agricultural land in winter. Nitrates are used as an indicator of pollution **(Gaujous, 1995; Singh *et al*.,2005)**. Any form of nitrogen (organic nitrogen, ammonia, nitrite, etc.) is likely to be the source of nitrates through an advanced self-purification process. The nitrate values have risen to levels ranging from 48.57mg/l to 51.22mg/l (Fig. 6), and these values exceed the OMS standard (44 mg/l). This increase in nitrates is related to the large volume of wastewater and discharges from certain industries along the Wadi, and especially the upstream. Pollution by nitrites can poison animal and plant species in Oued Soummam.

The nitrites come from either the incomplete oxidation of organic nitrogen or the decline 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 the nitrite content. A high nitrite concentration indicates bacteriological pollution as a result of ammonia oxidation **(Toze, 2006)**.

The values of nitrates in Oued Soummam range from 0.61 to 0.96mg/l (Fig. 7), exceeding the standard set by OMS (0.1mg/ l). Hence, this wadi is highly polluted and loaded with nitrites, especially the upstream, and there is an effect of oxidation of the ammonium form. The high rate of nitrites in watercourses causes harmful effects on animal and plant in Oued Soummam and even leads to the death of the latter.

The ammonium ion (NH^{+}_{4}) is the most toxic form of nitrogen; its presence in water is related either to urban and industrial discharges or the reduction of nitrogenous forms (nitrates and nitrites) in low conditions **(Meinck *et al*., 1997; Kendouci *et al*., 2013)**.

The concentrations observed in all the sampled sites are higher than the OMS standard (0.5 mg/l); ammonium concentrations of Oued Soummam are extremely varying and high, oscillating between 1.74 & 1.99mg/ l (Fig. 8). Ammonium is a good indicator of the watercourses' pollution by urban effluents. This pollution can generate several pathogens to the animal and plant of Oued Soummam.

On the other hand, the chlorides are important inorganic anions found in varying concentrations in natural waters. The origin of this element is butanly related to the dissolution of salt formations and may be in the effluents of chemical plants, wastewater, and the flow of irrigation water **(García *et al*., 2005; Reggam *et al*., 2015)**.

The results obtained show that the waters of Oued Soummam are loaded with chloride ions, particularly the downstream, with values between 287 and 413mg/ l (Fig. 9); these values exceed the standards set by the OMS (250mg/ l). Therefore, it was deduced that, the waters of Oued Soummam are highly polluted by chlorides, which can produce undesirable effects on the balance and functioning of the animal and plant of this Oued.

CONCLUSION

Water is essential to life. For the needs of man and the environment, water must be of good quality. If the quality of water is altered, the whole balance is threatened.

Thus, a hydrological study of the Oued Soummam watershed (Algeria) was conducted to identify and evaluate the intensity of the persistent pollution in this watercourse in order to sensitize the public with the danger of the latter and find solutions for this serious phenomenon.

The results of this research reveal an important pollution rate in this wadi, which is marked by a basic pH, an intense electrical conductivity, with a very considerable mass of suspended matter; in addition, the waters of this wadi are overloaded with chloride ions, ammonium, nitrates and nitrites, which are the best indicators of pollution. Therefore, this study reveals that Oued Soummam is affected by a very intense pollution, negatively affecting and disturbing the existing animal and plant biodiversity.

To put an end to this aggression (pollution) which has degraded this Wadi and these animal and plant populations, it is very imperative to find solutions, such as

- The location of purification stations in each industrial plant.
- Also, in order to avoid the infiltration of chemical substances present in pesticides and fertilizers, farmers are obliged to vegetate the plots of land close to the waterways. This practice allows creating a natural vegetal filter, decreasing the arrival of pollutants in the waterways.

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