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Pollution of Superficial Water in the Oued Medjerda Watershed (Algeria)

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ABSTRACT

Water is an essential element for life, not only because it is vital for humans but also because it has massive potential for making energy. It also makes a big difference in other ways for sustainable development.With the growth of human activities in manufacturing, waste treatment, construction sites, transportation (road, air and water), domestic activities (especially heating), agriculture and forestry, these waters will likely become more polluted. Therefore, protecting water is one of the most important things we must do for our growth. Therefore, this research was carried out to diagnose and describe the surface waters of the watershed of Oued Medjerda, Wilaya of Souk Ahras (North-East Algeria), as well as showing the people in this region how polluted this river is and how serious this problem is. The Medjerda is also a crucial waterway for irrigation and thus plays an important role in regional agriculture. The results showed pollutants from urban, agricultural and industrial sources. These results were significant enough to show that the waterway requires rapid purification and that discharges and effluents from any source should not be dumped there.

INTRODUCTION

"Water, a Vital Source" is an exhibition that presents and succinctly illustrates the different facets of this fascinating resource, water. This exhibition allows the youngest to acquire general knowledge about water and measure the importance of preserving this natural resource **(Petrovic *et al.*, 2002).**

The pressure on water resources is growing worldwide; while needs are increasing dramatically, the available water volumes do not change. Therefore, one of the challenges of the 21st century will be to preserve this vital resource and ensure its equitable and development-friendly distribution **(Loperfido, 2014).**

Population growth, urbanization, urban climate change, pollution, changes in land use, and economic growth all directly impact water resources. In 2025, two-thirds of humanity will live in areas subject to water shortages. For development, social equality, economic efficiency, and environmental sustainability must be ensured when allocating water among users **(Jones *et al.*, 2021)**.

Pollution of water resources is one of the leading causes of environmental pollution, and the quality and availability of water resources are undoubtedly one of the major challenges of our century. Its preservation requires better management of pollutants, mainly from human activities. Let us see where the pollution of water resources comes from and what measures exist to control it and reduce the threat it poses to our environment **(Wear *et al.*, 2021)**. Among these negative consequences are deaths linked to physicochemical changes, such as changes in environmental characteristics including salinity, acidity and water temperature. Beyond a certain threshold, these modifications become toxic for the organisms living in the environment **(Loperfido, 2014)**.

Among all the physical-chemistry parameters, oxygen is decisive for fauna and flora. Hypoxia is an amount of dissolved oxygen that is too low to support living things. Anoxia is the ultimate stage, where no more dissolved oxygen is in the water. Episodes of hypoxia can result from too much organic matter. These are degraded by the bacteria in the environment, which consume the oxygen dissolved in the water during this process. However, hypoxia can have other origins, including increased water temperature (oxygen is less soluble in hot water), water stagnation, the release of deoxygenated water and eutrophication **(Almeida *et al.*, 2007)**.

The phenomena of hypoxia and anoxia have heavy impacts on biodiversity, mainly due to the episodes of mortality they cause. Fish are particularly affected, but all animals and plants lack oxygen **(Almeida *et al.*, 2007)**.

Many other physicochemical parameters are decisive; for example, many freshwater organisms, such as fish and amphibians cannot survive at a salinity higher than 3 grams of salt per liter of water **(Davis & McCuen, 2005)**. Moreover, other toxic effects on living beings at a certain dose of polluting substances have a toxic effect on living beings. This means they harm their survival or health when they enter the body (mainly by ingestion, but sometimes by breathing). A distinction is made between acute and chronic toxicity **(Aw & Rose, 2012)**. Acute toxicity is the body's sudden reaction to a large amount of a toxic substance. It can lead to the partial or total mortality of various living beings in a polluted environment. Sometimes, it does not cause mortality but dramatically reduces the ability of organisms to survive another disturbance **(Aw & Rose, 2012)**.

Chronic toxicity is the reaction of an organism exposed over a long period to small quantities of polluting substances. It follows the regular (or even permanent) presence of these substances in low concentrations in the water. It can cause diseases and physiological deficiencies (organ dysfunction, for example), but it can also affect reproduction **(Aw & Rose, 2012)**. In addition, some pollutants are not biodegradable and accumulate throughout the food chain. Even if these substances are found in small quantities in the environment, without consequences for organisms, toxic effects can be observed in predatory species at the top of the food chain **(Davis & McCuen, 2005)**.

To that end, our research is based on the study of the physicochemical characteristics of the superficial waters of the watershed of Oued Medjerda, Wilaya of Souk Ahras (North-East Algeria), which is a watercourse used for irrigation by several farmers, to highlight the severity of the existing pollution in this river and make the public of this region aware of the seriousness of this pollution.

MATERIALS AND METHODS

1. Presentation of the study area

The Medjerda, known as the Bagradas among the Romans, is one of the principal rivers of Tunisia, both in terms of its length (500 km) and the amount of water it provides; the area of its watershed is 23,700km^2, of which 32% is located in Algeria **(Kallel *et al.*, 1974; Abidi *et al.*, 2015)**.

Oued Medjerda flows from the west to the east along the southern slopes of the Medjerda mountains. It starts at the edge of the front of the Tellian aquifers, mostly made up of marl-sandstone sediments from the Miocene. It then flows across the Triassic saliferous diapir of Souk Ahras (Fig. 1).

The waterway goes down several small steps and flows where the Oligocene sandstones meet the limestones. It then flows where the Cretaceous marl and marl-limestone of the huge eroded anticline dome of Berdah change places. Finally, it comes out in the plain of Ghardimaou in Tunisia. In the upper valley of Medjerda is the Ain Dalia dam southwest of Souk Ahras **(Zenati *et al.*, 2018).**

The Medjerda has an area of 22,000 km^2, of which 1,377 km^2 is located within the limit of the Wilaya of Souk-Ahras (Fig. 1). This basin comprises Oued Medjerda and its six branches: Chouk, Zarga, Djedra, Berriche, Ghanem and El Roul **(Zenati *et al.*, 2018)**.

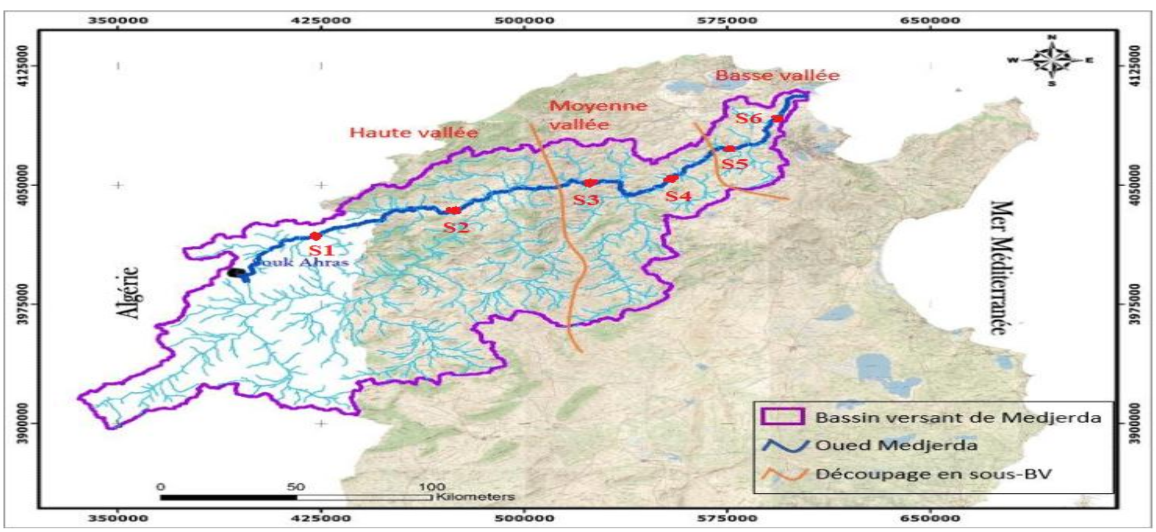


Fig. 1. Location of the study area **(Rhili, 2020)**

2. Sample collection

The sampling sites were chosen based on a plan that looked for the most polluted places. For this choice to be logical, representative and justified, we have opted for the hypothesis of the diversity of sources of pollution in these rivers. It is for this reason that we have chosen six main sites: two upstreams (the site of Tiffech (S1) and the site of Zarouria (S2)), two in the centre (the site of Ouled Dris (S3) and Souk Ahras centre (S4)), two downstreams (the site of Henchir El Kseiba (S5), and the Ouled Moumen site (S6)). Two samples were taken to find out the main physicochemical and surface water features of the Medjerda during the wet and dry seasons of 2022, one in February 2022 and the other in July 2022.

Very clean bottles were used for sampling. They were rinsed three times with water to be analyzed so that they would keep the same characteristics as the water. They were then filled with water (surface water 15 to 20 cm deep) until the overflow to avoid any possible chemical reaction. Finally after capping, each of the bottles was carefully labeled and numbered with the date, the coordinates and the sampling number. Then, they were kept at 4°C during transport to the laboratory and were analyzed within 24 hours.

In the laboratory, the water analysis was carried out according to standard AFNOR protocols **(AFNOR, 1999, 2005)** at the end of each wet and dry season. The products were measured, and their analysis methods are as follows:

- Hydrogen potential (pH), conductivity (EC), turbidity (NTU), and temperature (T) are measured *in situ* using a portable multiparameter according to the respective protocols NF T 90.008, NF EN 27888, and NF EN ISO 7027.

The volumetric method determined the hardness (TH) according to standard NF T 90 003.

- Suspended solids (SS) by filtration at 0.45 µm of a known volume of water according to the NF EN 872 protocol.
- Dissolved oxygen (DO) was measured *in situ* with a field oximeter by NF EN 25814.
- The biological oxygen demand (BOD_5) was measured using a BOD -meter by NF EN 1899.
- The chemical oxygen demand (COD) was determined by a COD meter by Standard NF T90-101.
- Nitrates (NO_3^-), nitrites (NO_2^-) and ammonium (NH_4^+) were determined by colourimetric assay, using a spectrophotometer (UV/visible) according to the respective NF EN ISO protocols 13395 (NO_3^- and NO_2^-) and NF T90-015.
- Chlorides (Cl^-) were measured by titration with silver nitrate, with chromate as an indicator (Mohr's method) according to the NF ISO 9297 method **(Barour, 2015)**.

3. Statistical analysis

Statistical software called Minitab 10 was used to address the results. In addition, the Tuckey test was used to analyze variance with a single classification criterion.

RESULTS AND DISCUSSION

1. Hydrogen potential (pH)

It is a chemical parameter characterizing the acidity or basicity of an environment. It is caused by the way water is made up of ions and mainly by the presence of carbonates, which come from the exchange of carbon dioxide (CO_2) between water, air and the dissolution of limestone **(Aminot & Kérouel, 2004; Samai *et al.*, 2022a)**. The results show that the waters of Oued Medjerda are slightly basic, especially in the dry season (July) (Fig. 2), where the values are between 7.59 and 7.88 during February and between 7.69 and 8.10 in July. This increase in pH is linked to the nature of the waste discharged into this river.

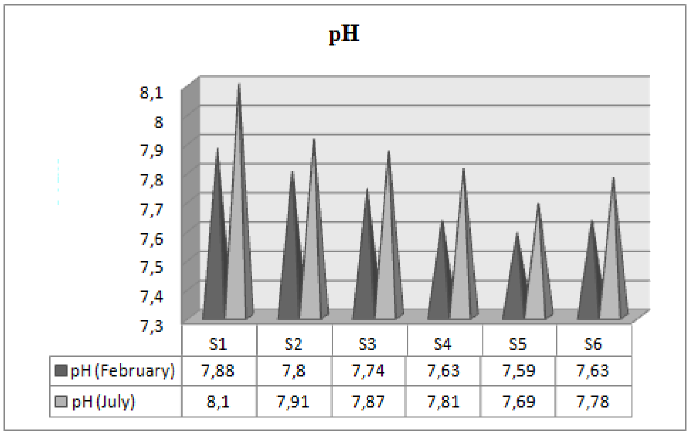


Fig. 2. Variation of pH at the different study sites

2. Electrical conductivity (EC)

Conductivity is the property of water that promotes the passage of an electric current. It is due to the presence in the medium of ions, which are mobile in an electric field. It depends on the nature of these dissolved ions and their concentrations. The electrical conductivity of water is the conductance of a column of water between two metal electrodes of 1cm^2, and the unit of conductivity is the siemens per meter (S/m) **(Mancer, 2010)**. The results in Fig. (3) show that the levels of the electrical conductivity of the Medjerda are excessively high and exceed the *WHO* standard (of 400 µS/cm) for the two companions (February and July), which are of the order of (997 µS/cm and 1196 µS/cm) and (1022 µS/cm and 1309 µS/cm), so it can be deduced that the waters of Oued Medjerda are highly mineralized.

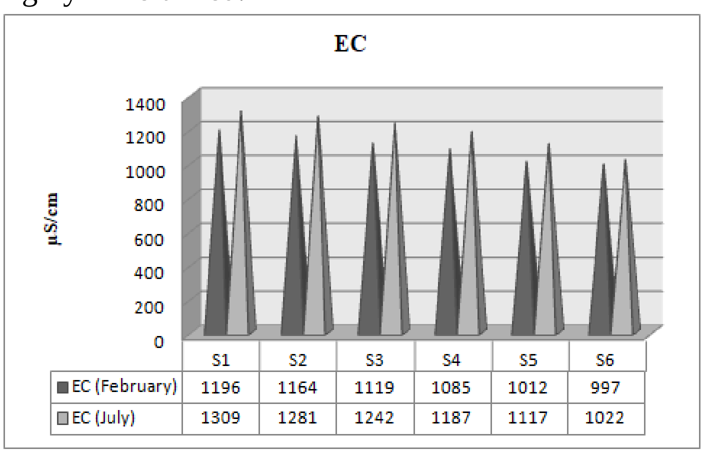
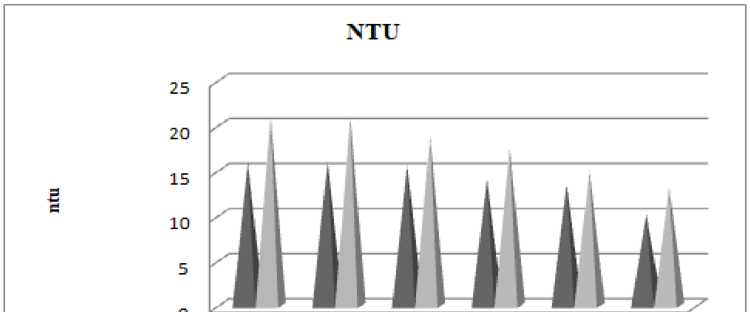


Fig. 3. Variation of EC at the different study sites

3. Turbidity (NTU)

Turbidity is the apparent clue that shows that water contains suspended solids, including organic debris, clays and microscopic organisms **(Zeggai, 2020)**.
Oued Medjerda's turbidity has mostly stayed the same over time and between different sites. However, the values oscillate between 10.18 NTU and 16.02 NTU (for the wet period) and between 13.12 NTU and 21.10 NTU (for the warm period) (Fig. 4), and thus these values show that the appearance of this water is slightly cloudy every day along this Oued and all year round.

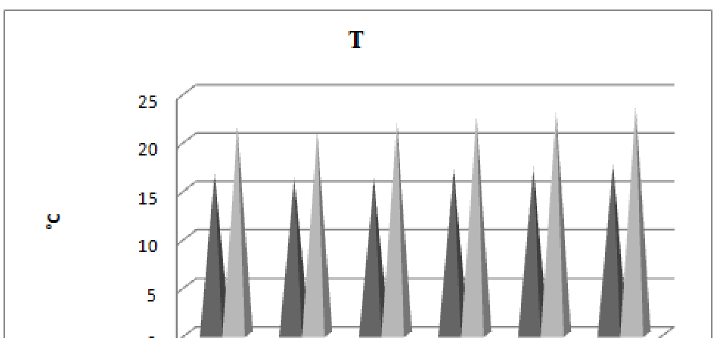


	S1	S2	S3	S4	S5	S6
NTU (February)	15,91	16,02	15,61	14,12	13,33	10,18
NTU (July)	20,87	21,1	18,8	17,54	15,03	13,12

Fig. 4. Variation of turbidity at the different study sites

4. Temperature (T)

Chapman and Kimstach (1996) elucidated that, the temperature of the water is a major ecological factor that controls almost all physical, chemical and biological reactions. This temperature affects the density, viscosity and solubility of gases in water, the dissociation of dissolved salts, chemical and biochemical reactions as well as the development and growth of organisms that live in water, especially microorganisms. The temporal evolution of the temperature of this water shows maximum values in summer and minimum values in winter, as shown in Fig. (5), whose temperature varies between 16.50°C and 17.50°C in February and between 21.5°C and 23.50°C in July.



	S1	S2	S3	S4	S5	S6
T (February)	16,5	16,25	16	17	17,25	17,5
T (July)	21,5	21	22	22,5	23	23,5

Fig. 5. Temperature variation at the different study sites

5. Total hardness (TH)

The hardness of water refers to the total alkaline-earth cations present in water **(Boeglin, 1997)**. Since water often has small amounts of strontium and barium, the total hardness equals the amount of calcium and magnesium ions **(Derwich *et al.*, 2010).**

The spatial evolution of the average total hardness gives the following contents: between 18.97°F and 23.47 °F for the first companion (the month of February) and between 20.02°F and 29.01°F for the second companion (the month of July) (Fig. 6); according to **(Rodier, 1984)**, the waters of Oued Medjerda (Souk Ahras) are moderately hard.

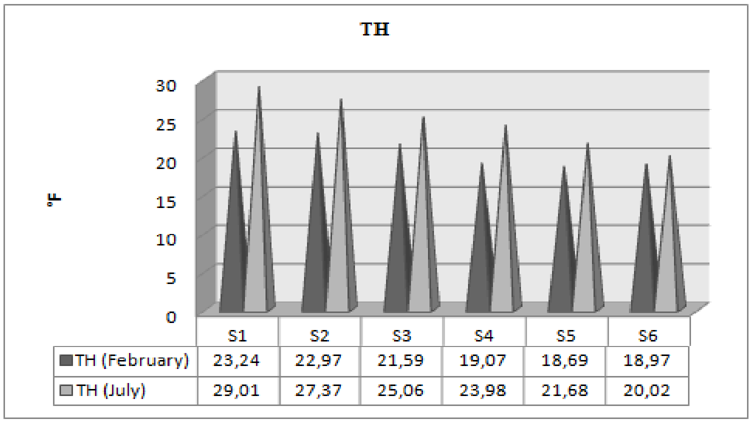


Fig. 6. Variation of total hardness at the different study sites

6. Suspended solids (SS)

Suspended solids represent all the mineral and organic particles contained in the water. They are a 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. Furthermore, such an increase can also lead to a warming of water, which will reduce the habitat quality for cold water organisms **(Légaré & Hébert, 2000; Samai *et al.*, 2022b)**. According to the results obtained (Fig. 7), the values of suspended solids range between 44.95 mg/l and 66.77 mg/l and 56.15 mg/l and 74.98 mg/l, respectively, for the wet and dry seasons. Moreover, this is linked to the different effluents and discharges received in this Oued from different agricultural, domestic and industrial sources.

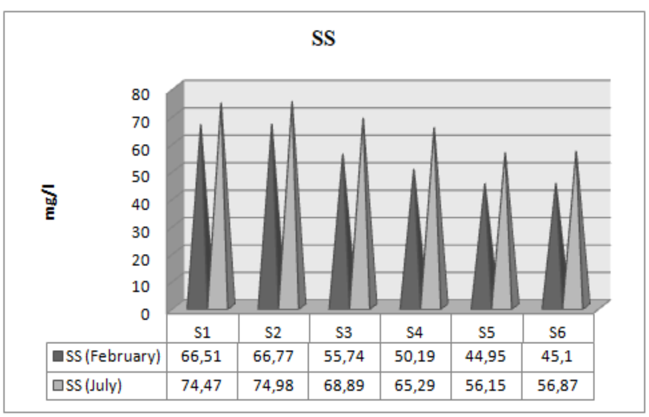
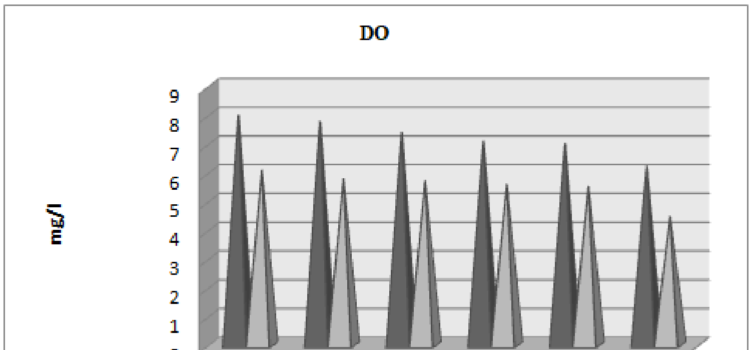


Fig. 7. Variation of suspended solids at the different study sites

7. Dissolved oxygen (DO)

Exchanges between the atmosphere and the water's surface and phytoplankton's photosynthetic activities result in oxygen in the water **(Reggam *et al.*, 2015; Samai *et al.*, 2022c)**. It also makes it possible to assess the concentration of organic or mineral matter, dissolved or suspended in water, through the quantity of oxygen necessary for their total chemical oxidation **(Fathallah *et al.*, 2014)**. The results in Fig. (8) show that the dissolved oxygen concentration is higher in the wet period (February) than in the dry period (July). The recorded values range from 6.23 mg/l to 8.01 mg/l in the first campaign and from 4.48 mg/l to 6.10 mg/l in the second campaign, which would normally result in the death of the fish **(Meinck *et al.*, 1977)**.



	S1	S2	S3	S4	S5	S6
DO (February)	8,01	7,79	7,42	7,1	7,01	6,23
DO (July)	6,1	5,8	5,73	5,61	5,54	4,48

Fig. 8. Variation of dissolved oxygen at the different study sites

8. Biochemical oxygen demand (BOD_5)

The BOD_5 is the quantity of oxygen consumed by the aerobic germs under the test conditions (incubation for five days at 20°C and in the dark) to ensure the degradation of the fermentable organic matter contained in the water **(Ramade, 2002)**.

The BOD_5 measurements reveal that its value varies from season to season. For example, it varies between 41.14 mg/l and 46.19 mg/l in the wet season and between 43.77 mg/l and 48.19 mg/l in the dry season, far exceeding the WHO standard (40 mg/l) (Fig. 9). These values can be attributed to slaughterhouse discharges, urban wastewater and agricultural land manure runoff.

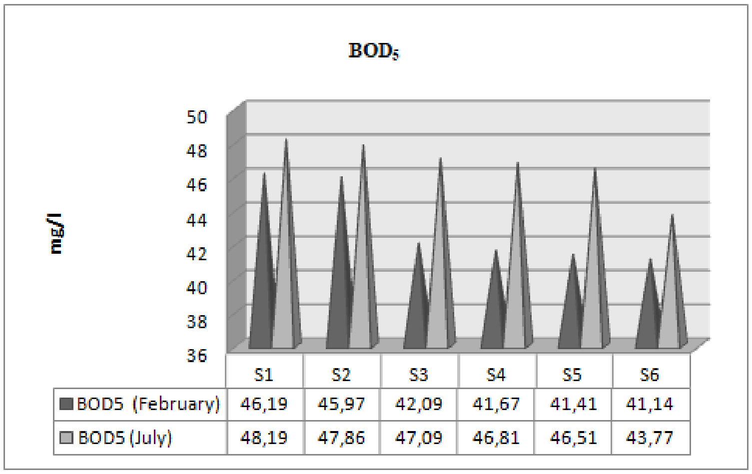


Fig. 9. The Biochemical oxygen demand variation at the different study sites

9. Chemical oxygen demand (COD)

COD measures all or almost all the organic matters in natural or treated wastewater, regardless of whether or not it is biodegradable **(Boukermi & Hamdellou, 2018)**. COD is an important parameter used to characterize the overall pollution of water by organic compounds. The COD indicates the importance of low biodegradability pollutants **(Rodier *et al.*, 2009).**

The COD measurements taken are consistent with the BOD_5, and they are higher in the dry period (33.41 mg/l and 39.35 mg/l) than in the wet period (30.08 mg/l and 33.91 mg/l) (Fig. 9). Therefore, according to the WHOsurface water quality grid (COD 30 mg/l), the waters of Oued Medjerda are not of good quality. Moreover, this is linked to the effect of diffuse organic matter pollution.

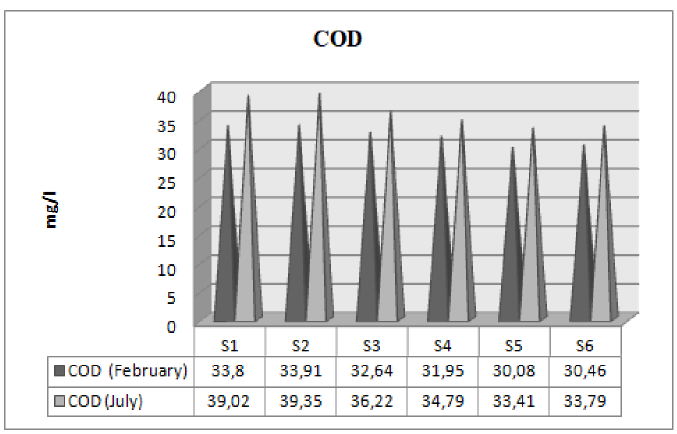


Fig. 10. Variation of the chemical oxygen demand at the different study sites

10. Nitrates (NO_3^-)

Nitrates exist naturally in soils, surface and ground waters and all plant matter. They reach rivers through groundwater and runoff from agricultural land in winter. Nitrates are used as a pollution indicator **(Djermakoye, 2005)**. Through an advanced self-purification process, nitrates are likely made from any form of nitrogen, such as organic nitrogen, ammonia or nitrite. The nitrate values rose to 39.28 mg/l and 44.06 mg/l in the wet period and to 44.84 mg/l and 47.87 mg/l in the dry period (Fig. 10), and these values exceed the WHO standard of 44mg/ l. This rise in nitrates is due to the large amount of wastewater and other wastes thrown into the water by some industries in the Oued, especially in July.

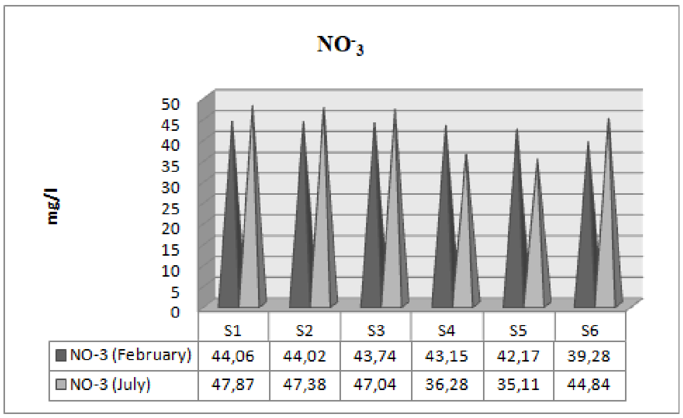


Fig. 11. Variation of nitrates at the different study sites

11. Nitrites (NO_2^-)

Nitrites are dangerous to aquatic organisms, even at low concentrations. Its toxicity increases with temperature. In addition, they cause haemoglobin degradation in the fish's blood, which can no longer carry oxygen. This results in death by asphyxiation **(Sevrin *et al.*, 1995)**. Nitrites come from incomplete oxidation of ammonia, incomplete nitrification or reduced nitrates under a denitrifying action. Therefore, water containing nitrites should be considered suspect because it is often associated with deteriorating microbiological quality **(Rodier *et al.*, 2009)**. The nitrite results show that the waters of Oued Medjerda are heavily loaded with nitrite ions, which exceed the standard set by the WHO (0.1 mg/l), especially during the dry period, when levels vary between 0.41 mg/l and 0.98 mg/l, and during the wet season (0.15 mg/l and 0.39 mg/l) (Fig. 12). All this increase is due to the oxidation of the ammonium form.

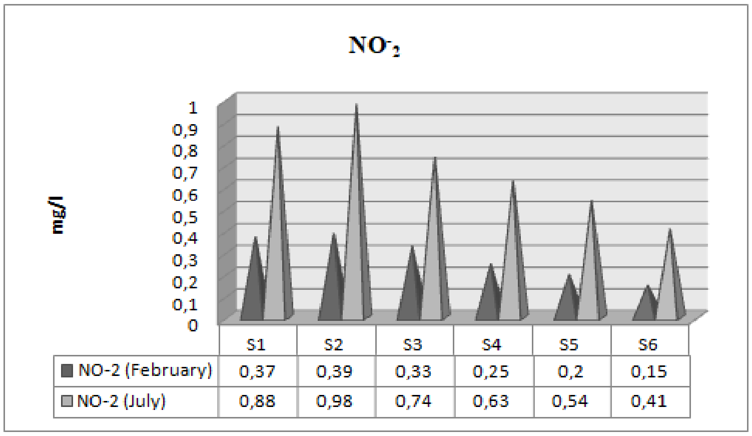


Fig. 12. Variation of nitrites in the different study sites.

3.12. Ammonium (NH_4^+)

In surface waters, ammoniacal nitrogen can come from plant organic matter in watercourses, organic matter from animals or humans, industrial discharges, fertilizers and textiles **(Rodier *et al.*, 2009)**. Thus, ammonium ions in natural waters present an index of pollution caused mainly by urban discharges and the reduction of nitrates. The results obtained from our research show that the concentrations of these elements in Oued Medjerda are very high, especially in the dry period, where we recorded 0.24 mg/l and 0.39 mg/l and 0.21 mg/l and 0.31 mg/l in the wet period (Fig. 13). All these values are higher than the WHO's standard (0.1 mg/l). Therefore, according to these values, these waters are in the wrong class.

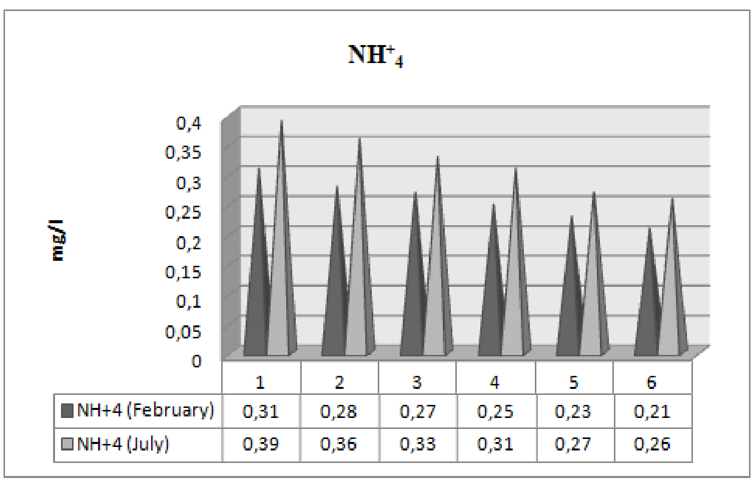
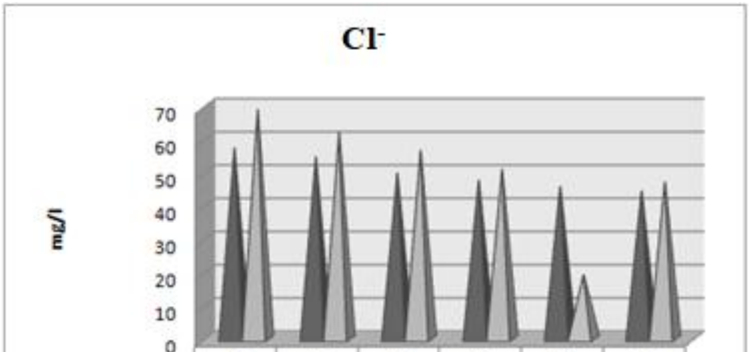


Fig. 13. Variation of ammonium at the different study sites

13. Chlorides (Cl^-)

Chlorides are important inorganic anions contained in varying concentrations in natural waters. The origin of this element is predominantly related to the dissolution of salt formations and may be in the effluents of chemical plants, wastewater or irrigation water **(Samai *et al.*, 2022)**.

The results show that the waters of Oued Medjerda are not charged with chloride ions, particularly those whose values are between 44.74 mg/l and 57.61 mg/l in the wet period and between 47.34 mg/l and 69.07 mg/l in the dry period (Fig. 14). These values do not exceed the standards set by the WHO (250 mg/l), thus we determined that chlorides do not pollute the waters of Oued Medjerda.



	S1	S2	S3	S4	S5	S6
CL-(February)	57,61	54,87	50,18	47,97	46,02	44,74
CL- (July)	69,07	62,17	56,79	51,17	19,37	47,37

Fig. 14. Variation of chlorides at the different study sites

The analysis of variance with a single criterion of classification for the physicochemical parameters of Oued Medjerda (Souk Ahras) showed a highly significant difference for NO_2^-, T, and DO and a significant difference for NH_4^+, COD, BOD_5, and TH, and there was no difference for Cl^-, NO_3^-, SS, NTU, EC, or pH between the two months.

These results show that the pollution rate in Oued Medjrda and for the different physicochemical parameters are significantly increased, compared to the study of **Abidi *et al.* (2015)**, who reported that, the pollution and quality of this Oued was average compared ti our study carried out in 2022.

CONCLUSION

Water is a rare and precious resource, natural and essential to life. However, this water resource raises excellent concerns. The population is exploding, and many uses threaten the quality of this water and the environment. We conducted this study to make a detailed diagnosis and observation of the surface waters of the watershed of Oued Medjerda, Wilaya of Souk Ahras (North-East Algeria).

The results show that the appearance of this water is slightly cloudy, moderately hard, and the temperature is average; however, we are in the presence of slightly basic waters with an excessively high electrical conductivity, as well as the presence of a significant amount of matter in suspension. Additionally, this Oued is loaded with nitrates, nitrites and ammonium, with significant values of the biochemical oxygen demand and dissolved oxygen.

These results show that the waters of this Oued are polluted and contain many toxic pollutants. As a result, it is strongly advised to reduce resource tensions. Therefore, we make it possible to reuse depolluted water, which reduces direct withdrawals from the resource by the same amount while reserving it for human consumption and recycling water through thorough treatments.

REFERENCES

Abidi, S.; Bejaoui, M.; Jemli, M. and Boumaiza, M. (2015). Water quality of the Oued Medjerda, Tunisia and Algeria, and three of its northern tributaries. Hydrological Sciences Journal., (60)9:1607-1619. DOI.org/10.1080/026266667.2014.909597.

AFNOR. (1999). Water quality (6 ed.). Paris, France. 1012pp.

AFNOR. (2005). Water quality (3 ed.). Paris, France. 1152pp.

Almeida, C.A.; Quintar, S.; González, P. and Mallea, M.A. (2007). Influence of urbanization and tourist activities on the water quality of the Potrero de los Funes River (San Luis – Argentina). Environ Monit Assess., (133)1: 459-465. DOI.org/10.1007/s10661-006-9600-3.

Aminot, A. and Kérouel, R. (2004). Hydrology of Marine Ecosystems: parameters and Analyses (2 ed.). Ifremer. France, 505pp.

Aw, T.G. and Rose, J.B. (2012). Detection of pathogens in water: from phylochips to qPCR to pyrosequencing., (23)3: 422-430. DOI: 10.1016/j.copbio.2011.11.016.

Chapman, D. and Kimstach, V. (1996). Selection of water quality variables. Water quality assessments: a guide to the use of biota, sediments and water in environment monitoring (2 ed). E & FN Spon. London, 220pp.

Davis, A.P. and McCuen, R.H. (2005). Water Quality Parameters. Stormwater Management for Smart Growth., (12)1: 12–36. DOI:10.1007/0-387-27593-2.

Derwich, E.; Benaabidate, L.; Zian, A., Sadki, O., and Belghity, D. (2010). Physico-chemical characterization of the waters of the upper Sebou alluvial aquifer downstream from its confluence with Oued Fes. Larhyss Journal., (8)1: 101-112.

Djermakoye, H. (2005). Wastewater from tanneries and dyeworks; Physico-chemical, bacteriological characteristics and impact on surface water and groundwater. PhD thesis. University of BAMAKO.

Fathallah, Z.; Elkharrim, K.; Fathallah, R., Hbaiz, E. M., Hamid, C., Ayyach, A., Elkhadmaoui, A. and Belghyti, D. (2014). Physico-chemical study of wastewater from the paper industrial unit (cdm) a sidi yahia el gharb (Morocco). Larhyss Journal., (20)1: 57-69.

Jones, E. R.; Van Vliet, M. T.; Qadir, M., and Bierkens, M. F. (2021). Country-level and gridded estimates of wastewater production, collection, treatment and reuse. Earth System Science Data., 13(2): 237-254. DOI: org/10.5194/essd-13-237-2021.

Kallel, R.; Bouzaiane, S., and Eoche Duval, J.M. (1974). Monograph of the Medjerda, ORSTOM, Tunis, Tunisia., (261)1: 45-55.

Légaré, S., and Hébert, S. (2000). Monitoring the quality of rivers and small rivers, Québec, State of the Environment Monitoring Directorate, Ministry of the Environment, Enviro. No. ENV-2001-0141, Report No. EQ. pp. 24-124.

Loperfido, J.V. (2014). Surface Water Quality in Streams and Rivers: Scaling and Climate Change, in: Ahuja, S. (Ed.), Comprehensive Water Quality and Purification. Waltham., (12)1: 87-105. DOI: org/10.1016/B978-0-12-382182-9.00064-5.

Mancer, H. (2010). "Analysis of the purifying power of some macrophyte plants in arid regions", Master's thesis, Mohamed Khider Biskra University. Algeria.

Meinck, F.; Stooff, H., and Kohlschutter, H. (1977). Industrial wastewater (2 ed). Masson. Paris, France, 120pp.

Petrovic, M.; Solé, M.; López, De Alda, M. J., and Barceló D. (2002). Endocrine disruptors in sewage treatment plants, receiving river waters, and sediments: Integration of chemical analysis and biological effects on feral carp. Environmental Toxicology and Chemistry., (21)10: 2146-2156. https://pubmed.ncbi.nlm.nih.gov/12371491/.

Ramade, F. (2000). Encyclopaedic dictionary of pollution. International (2 ed). Ediscience. Paris, France, 230pp.

Reggam, A.; Bouchelaghem, H. and Houhamdi, M. (2015). Physico-chemical quality of the Oued Seybouse Waters (North-East Algeria): Characterization and Principal Component Analysis. J. Mater. Environ. Sci., (6)5: 1417-1425.

Rhili, C. (2020). The establishment of a web-GIS of landslides in the Mogods and Hedil region. Master memory. Faculty of Letters, Arts and Humanities Manouba - Specialized Master in Geomatics of Information for Sustainable Development (GEOID). Tunisia.

Rodier, J.; Beuffr, H.; Bournaud, M., Broutin, J.P., Geoffray, Ch., Kovacsik, G,, Laport, J., Pattee, E., Plissier, M., Rodi, L., Vial, J. (1984). Analysis of natural water, wastewater, seawater (7 ed.). Dunod. Paris, France, 310pp.

Rodier, J. (1984). Water analysis. (7 ed.). Dunod. Paris, France, 145pp.

Rodier, J. (1996). Water Analysis: Natural Waters, Wastewater, Seawater (8 ed.). Dunod. Paris, France, 167pp.

Samai, D.; Samai, I.; Meghlaoui, Z., Ramdani, H. (2022). Identification of water pollution in the lower valley of the Mafragh “Extreme North East of Algeria”. Asia Life Sciences., (12)10: 1445- 1456.

Samai, I (a).; Chouba, I.; Nebbache, S., Amri, N., and Ksentini, H. (2022). Study of groundwater chemistry in the Lower Valley of Oued Bounamoussa (El Tarf- Algeria). Eco. Env. & Cons., (28)1. 445-450. DOI: org/10.53550/EEC.2022.v28i01.068.

Samai, I (b).; Amri, N.; Anguel, I., Meghlaoui, Z., Zentar, A. (2022). Impacts of industrial discharges from FERTIAL on the water quality of Oued Seybouse (North East Algeria). Asia Life Sciences., (12) 6: 1255- 1265. URL:

Samai, I (c); Samai, D.; Aounallah, O., Anguel, I., Meghlaoui, Z. (2022). Impacts of the discharges of the oil refinery "SONATRACH" on the surface water of Oued Saf Saf Skikda (Algeria). Asia Life Sciences., (12)9: 1363-1372.

Sevrin-Reyssac, J.; De La, Noüe J., and Proulx, D. (1995). Recycling pig manure by lagooning, (1 ed). Lavoisier. Paris, France. 255pp.

Wear, S-L.; Acuña, V.; McDonald, R., and Font, C. (2021). Sewage pollution, declining ecosystem health, and cross-sector collaboration. Biological Conservation., 255(03): 1-9. DOI.org/10.1016/j.biocon.2021.109010.

Zeggai, F-Z N-E-H, (2020). Heavy metal contamination of water. Master memory. Faculty of Nature and Life Sciences and Earth and Universe Sciences. Biology department. Abou Baker Belkaid University, Tlemcen, Algeria.

Zenati, N.; Belhacene, N.; Rezak, A.. Zeghadnia, L., Messadi, D., and Belkadi, D. (2018). Origin of the water quality degradation of Oued Medjerda downstream. Souk Ahras region. International Journal of Environment and Water., (7)2: 62-72. https://www.researchgate.net/publication/325794470.