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ASSESSMENT OF SEASONAL VARIATION IN WATER QUALITY AND ORGANIC POLLUTION: A CASE STUDY OF OULED MELLOUK DAM IN NORTHERN ALGERIA

Abstract: Lentic and lotic ecosystems provide essential services for environmental development but are particularly vulnerable to pollution, mainly caused by anthropogenic activities. This study assesses the water quality of the Ouled Mellouk Dam in northern Algeria over a 15- month period, using physicochemical parameters, and index-based methods to evaluate organic pollution. Key indicators, such as pH, Electrical Conductivity, Suspended Matter, Dissolved Oxygen, BOD5, COD, and various nitrogen and phosphorus compounds were periodically measured to understand pollution levels influenced by human activities. Results for mineralization indicators such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, and SO_4^{2-} indicate that the dam's water generally maintains moderate mineral quality, consistent with standard surface water guidelines. Organic pollution indicators suggest water quality ranging from good to moderate, with average BOD_5 and COD values of 4.16 mg/L and 18.08 mg/L, respectively. However, elevated concentrations of nitrites (NO_2^{-}), exceeding the acceptable threshold (0–0.01 mg/L), signal significant nitrogen pollution. Orthophosphate (PO_4^{3-}) levels indicate low phosphorus-related contamination, with an average of 0.05 mg/L, except during September 2016, when a notable increase in organic load was recorded. The Organic Pollution Index (IPO) indicates that surface water quality generally ranges from low to moderate levels of organic contamination. These results underscore the urgency of implementing effective

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and sustainable management strategies to reduce pollution risks and safeguard the long-term resilience of this vital water resource.

Keywords: surface water, physicochemical quality, organic pollution level, seasonal variation, Oued Mellouk Dam

Introduction

Dams represent a significant water source for various purposes. Efficient management of these resources involves information about their quality, quantity, and variability, particularly in semi-arid countries such as Algeria. Water resources face several challenges due to climate change, resulting in reduced water flow and increased exploitation for various purposes, affecting both quality and quantity. The deterioration of dam water quality can result from natural processes and anthropogenic activities, including the discharge of industrial and domestic wastewater, as well as agricultural drainage into these dams. Protecting water quality from urban or industrial pollutants, including various organic materials and nutrients, mainly nitrates and phosphates, is essential (Mezbour et al., 2018; Belouchrani et al., 2021; Guenfoud et al., 2021). Numerous organic substances are easily biodegradable and can naturally break down in aquatic environments through self-purification. However, excessive amounts can lead to the asphyxiation of aquatic wildlife. Therefore, regular monitoring and evaluation of dam water quality are essential for the integrated management of these water resources (Negm et al., 2020; Xu et al., 2022).

To monitor dam water quality, sampling networks prove to be an excellent source of information, offering a local and temporal understanding of the dam's water conditions. These networks provide insights into temporal conditions, as well as the seasonal and geographical evolution of the ecosystem. To aid in the processing and analysis of the increasing volume of data collected over time, statistical methods and index approaches have proven to be the most appropriate and widely used methods (Jose and Kumar, 2011; Bouderbala, 2018; Bouderbala, 2021; Hennia et al., 2024).

Effective water quality control requires a thorough understanding of pollution sources and their environmental impacts. Anthropogenic activities, in particular, can significantly alter surface water quality, necessitating the use of reliable diagnostic tools. Indices such as the Index of Organic Pollution (IOP), the Water Quality Index (WQI), and the Fecal Pollution Index (FPI) provide valuable insights for sustainable water resource management and the protection of aquatic ecosystems. In this context, the aim of the present study is to carry out a comprehensive diagnostic assessment of the current pollution status and monitor its evolution in the Ouled Mellouk dam ecosystem (Aïn Defla), with a specific focus on evaluating the effects of human activities on water quality.

Materials and Methods

Research Sites

The Ouled Mellouk Dam is located on the Oued Mellouk tributary on the left bank of the Oued Cheliff, approximately 5 km upstream from Rouinacity about 40 km west of the province of Ain Defla, and about 130 km in the south-western of the capital Algiers (Fig. 1) (NADT, 2017). It is a zoned embankment dam, standing at an approximate height of 51 meters above its foundation. It is characterized by a watershed area of 892 km^2 (it is part of the Middle Eastern Cheliff basin).

The watershed within which the dam is built is characterized by a moderately rugged topographic surface, with maximum altitudes to the south (1786m) and minimum altitudes to the north (183m). This altitudinal distinction is also evident through steep slopes exceeding 30% in the northern and northeastern parts of the basin. In contrast, gentler slopes cover over 60% of the basin's area toward the north and near the dam reservoir. The crest length of the structure is 730 m, with a width of 9 m. It was impounded in 2004 with an initial capacity of 127.00 hm^3 (Touahir et al., 2018). This dam is constructed to provide drinking water for five cities: Rouina, Bourached, Zeddine, El Mayenne, and El-Attaf and it serves as a source of irrigation for agricultural areas including El Amra, El Abadia, and Rouina (NADT, 2017). In recent years, this dam has supported the irrigation of approximately 11,000 hectares of agricultural land, with an average annual volume of 20 hm^3. However, the irrigated area has significantly decreased due to reduced rainfall (Madene et al., 2023).

In terms of geological perspective, the watershed is located on the left bank of the depression of the Cheliff plain, exhibits a lithological succession comprising various formations. The current alluvial deposits, consisting of sandy silt from the floods of the Cheliff, coexist with limestone scree on the slopes. Recent alluvial deposits in the Cheliff plain and its lateral valleys include limy deposits with gravel layers in the debris cones. Ancient plateau alluvial deposits consist of reddish gravelly and silty deposits, supporting wooded hills between Chéliff and the Rouina river. Deeper layers reveal sandstone with Clypeaster and Ostrea crassissima, representing the Tortonian sub-stage. Helvetian clays, thick and gray, are associated with deposits in small sandy basins. Helvetian conglomerates are found in the southern part, near outcrops of Liassic limestones and schists. At the level of the Upper Eocene, scattered clay and quartzose sandstone formations are observed. Limestone formations of the Lias from the Doui are compact, crystalline, and occasionally dolomitic. Doui shales, considered Silurian, form a thick layer of clay shales, slate phyllites, and quartz phyllites. In summary, the region exhibits lithological diversity ranging from current alluvial deposits to Lias formations, reflecting the complex geological evolution of the area (Difi, 2020).

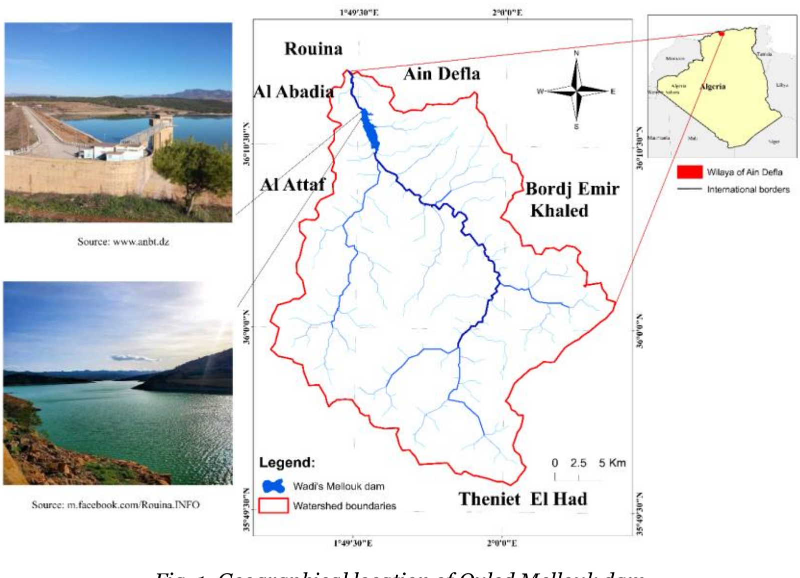

Fig. 1. Geographical location of Ouled Mellouk dam

Monthly water sampling was conducted over a period of one year and three months (January 2016 – March 2017) at a consistent depth in the dam. The recorded results pertain to samples collected from a designated point near the dam wall, commonly used by the Algerian Water Company (AW) and the National Agency for Water Resources (NAWR) for monitoring raw water quality. Generally, standardized techniques were employed for sample collection, utilizing 1-liter polyethylene bottles. The samples were transported in coolers at 4 °C, and subsequent analyses followed methods approved by international norms. In-situ measurements of temperature, pH, electrical conductivity (EC), and dissolved oxygen (O2) were conducted using a WTW340i multi-parameter portable instrument.

Cation and anion concentrations were analyzed at the laboratory of the National Hydraulic Resources Agency following the standard procedures outlined by APHA (2005). The concentrations of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), sulfate (SO_4^{2-}), bicarbonate (HCO_3^{-}), nitrate (NO_3^{-}), nitrite (NO_2^{-}), ammonium (NH_4^{+}), orthophosphate (PO_4^{3-}), and other water quality parameters including Suspended Solids (SS), Biological Oxygen Demand over five days (BOD_5), and Chemical Oxygen Demand (COD) were determined using standardized NF or ISO methods, as well as procedures recommended by Rodier et al. (2009). These analyses employed instrumental, volumetric, and spectrometric techniques. Charge balance errors were maintained within ±5% for all water samples.

For the assessment of organic pollution levels, the Organic Pollution Index (IPO) was calculated using a method that categorizes pollutant concentrations—specifically BOD_5, nitrites, orthophosphates, and ammonium—into five classes. Each parameter's measured value was assigned a class number according to Table 1, with pollution levels ranging from low pollution (Class 5) to high pollution (Class 1) (Bahroun et al., 2011; Guenfoud and Benyahia, 2016; Buhungu et al., 2017; Koudjodé et al., 2023). The IPO was then calculated as the average of these class numbers, following the equation described by Dosso (2021):

$$IPO = \sum_{k\neq 0}^{i} (Ck, \ldots Ci)/n) \quad , \ldots,(\text{eq } 01) \qquad (1)$$

with:

- **C**: the class number of the parameter (Table 1)
- **n**: the number of polluting parameters analyzed (Table 1).

Table 1. Boundaries of the classes of the Organic Pollution Index

Parameters		**BOD_5 mg-O_2/l**	**Ammonium mg-N/l**	**Nitrites µg-N/l**	**Ortho-phosphates µg-P/l**
	Classes				
5		< 2	< 0,1	5	15
4		2- 5	0,1 – 0,9	6 - 10	16 – 75
3		5,1 - 10	1 – 2,4	11 - 50	76 – 250
2		10,1 -15	2,5 - 6	51- 150	251 – 900
1		> 15	> 6	> 150	> 900

OPI values interpretation :

- 5,0 - 4,6 : No organic pollution
- 4,5 - 4,0 : Low organic pollution
- 3,9 - 3,0 : Moderateorganic pollution
- 2,9 - 2,0 : High organic pollution
- 1,9 - 1,0 : Very high organic pollution

Source: Leclercq, 2001

Results and Discussions

Physico-Chemical Quality: Indeed, physicochemical parameters provide indications about water quality, but they are often subject to variations primarily caused by anthropogenic activities that alter water characteristics (Karrouch et al., 2009). The temperature values (Fig.2) related to the raw water of the Ouled Mellouk dam for the first three months of the year 2017 remain slightly lower than the standard (25°C). This could be attributed to the influence of seasonal temperature (winter period). Regarding pH, the results (Fig.2) indicate values fall within the range of the permissible standard for surface water (6.5 to 8.5), with an average value of 8.1. It suggests that the water of this dam is slightly alkaline, but it is within the acceptable range for freshwater environments. This pH range is influenced by factors such as the solubility of minerals, the availability of nutrients, the geology of the area, surrounding vegetation, and human activities. For electrical conductivity (EC), the obtained values (Fig. 2) show that the dam water are characterized by an EC ranging between 1370 and 1900 µS/cm, with an average of 1585.3 µS/cm. The slightly high Electrical Conductivity (EC) values compared to the permissible standard (1500 µS/cm) for surface water may be explained by factors such as high concentrations of dissolved salts, minerals, and other ion-containing substances in the water, such as the presence of certain minerals in high quantities, such as chlorides (more than 150 mg/l) and sulfates with levels exceeding 200 mg/l. Possible contributors may include the geological characteristics of the area, agricultural runoff, and human activities leading to increased ion content in the water. These two elements (Cl^- and SO_4^{2-}) are caused by wastewater discharge and the type of rocks the water flows through before reaching the dam. Chloride ions are commonly associated with wastewater discharge, while sulfate ions may be linked to geological features such as shale formations. Indeed, electrical conductivities provide information about the degree of mineralization of water; high conductivity indicates either abnormal pH or, more often, high salinity (Guenfoud et al., 2021). Between 2005 and 2015, electrical conductivity measurements at the Hammam Debagh Dam in the Guelma region (northeastern Algeria) ranged from 428 to 872 µS/cm. Based on this parameter, the water is generally considered to be of good quality, as most values fall within the recommended range of 400 to 750 µS/cm (Zeghaba and al., 2018). The Total Dissolved Solids (TDS) values observed in the Ouled Mellouk dam ranged from 90 to 380 mg/L, with an average of 260 mg/L, which falls within the recommended limit for various uses. Dissolved oxygen (O_2) values ranged between 5 and 10 mg/L, indicating relatively low oxygenation in the Ouled Mellouk dam, particularly during the spring compared to the summer season. This phenomenon may be attributed to the natural decrease in oxygen solubility as temperatures rise. Cold water typically contains higher levels of O_2, and the presence of pollutants in the streams can further impact solubility (Rodier et al., 2009). The origin of oxygen in natural environments is closely linked to the photosynthetic activity of aquatic plants and atmospheric oxygen dissolution (Gaujous, 1995). Turbidity values fluctuated between 1.50 and 34.30 NTUs. The elevated values can be attributed to various climatic conditions, including rain, storms, and wind, as well as factors such as sediment erosion and streambank erosion. These conditions contribute to an increased presence of suspended matter, such as clays, silts, and microorganisms. Turbidity plays a crucial role in impeding light propagation, thereby restraining vegetation growth. Consequently, addressing turbidity often requires water clarification methods, either through the introduction of a coagulant or by utilizing decantation processes. The recorded values of suspended solids (SS) at 105 °C (Fig. 2) indicate that the raw dam water contains substantial levels ranging from 80 mg/l to 210 mg/l. These values significantly surpass the required standard of 0-30 mg/l, categorizing the waters as poor quality for this parameter. The presence of high levels of suspended matter in aquatic environments can stem from various sources, including rainwater runoff, natural erosion in the watershed, or discharges from urban or industrial effluents. The impact of suspended matter on the physicochemical characteristics of water is notably adverse; it can impede light penetration, diminish dissolved oxygen levels, and consequently restrict the development of aquatic life.

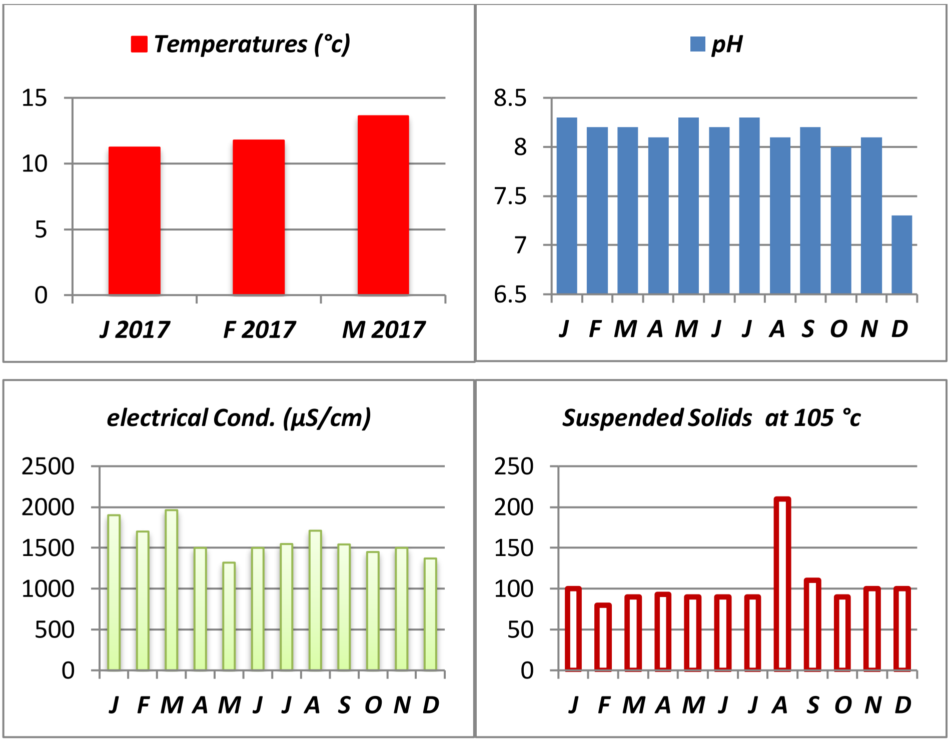

Fig. 2. Values of global parameters of Ouled Mellouk dam water

Mineralization of water quality: Mineralization constitutes the major characteristic of water, defining both the quantity of solubilized elements in the water and the nature of these elements (Bouderbala et al., 2014). For raw dam water of Ouled Mellouk, the obtained results illustrate temporal variations in terms of mineralization elements (Figures 3 and 4).

Calcium concentrations (Fig.3) were ranging between 45 and 114 mg/l. Conversely, lower concentrations are recorded for eight months in the year 2016, with values ranging from 45-97 mg/l. The presence of Ca^{2+} above the recommended threshold for surface water (40-100 mg/l) can be primarily justified by leaching from carbonate (Jurassic limestone) formations during rainfall events. On the other hand, the obtained values for Mg^{2+} exceed the standard established by NAWR (30mg/l) for almost the majority of samples, categorizing the raw dam water as Class II concerning this parameter. The Mg^{2+} concentration ranged from 20 to 100 mg/l (Fig.3). The increase in magnesium levels is primarily attributed to the dissolution of dolomites in the Doui massif and the dissolution of the detritic lower limonite series from the Miocene. Additionally, anthropogenic sources (discharges, agricultural activities) contribute also to this increase (Touahir et al., 2018). Analyses carried out on certain samples taken from the Sidi M'hamad Ben Taiba dam (Ain Defla region) indicate that its waters contain Ca^{2+} (84mg/l for surface water) lower than those of the dam presented in this study (85,58 mg/l in average) (Guetarni et al., 2023). The concentrations of the remaining cations, namely Sodium and Potassium (Fig. 3), were relatively low, ranging between 65 mg/l and 165 mg/l for Sodium and between 2 mg/l and 6 mg/l for Potassium. The high values are primarily due to the dominant agricultural activity in the region, particularly during flood periods, when the leaching of evaporate deposits from the saline formations of the Ouarsenis mountains occurs. In contrast, lower concentrations of Na^{+} are observed during the summer period, attributed to drought conditions. Overall, the dam water exhibit moderate quality to these two parameters.

Concerning anions, specifically chlorides and sulfates, it is evident from the data presented in Figure 4 that the concentrations of these two elements in the water of the Ouled Mellouk dam generally exceed acceptable norms. The concentrations vary between 145-258 mg/l for Cl^{-} ions and 165-358 mg/l for SO_4^{2-} ions. The increase in chloride concentrations may be attributed to wastewater discharge, whereas the higher levels of sulfate ions could be linked to agricultural activities and leaching from evaporate deposits in the gypsum formations of the Ouarsenis mountains ($CaSO_4$), as observed upstream in the basin. Notably, higher chloride levels can impart an unpleasant taste to the water and render it corrosive to pipes. Additionally, chlorides can have detrimental effects on plant life (Bouderbala, 2020). In this context, analyses conducted in 2014 at the Foum El Khanga Dam in the Souk-Ahras region (eastern Algeria) revealed that the reservoir's water, primarily used for agricultural irrigation, contains high concentrations of sulfate ions ($SO4^{2-}$), averaging 325.85 mg/L. These levels are significantly higher than those observed in the dam studied in the present work (Allalgua et al., 2017). Regarding HCO_3 concentrations, they varied from 100 to 350 mg/l, primarily attributable to the geological origin, specifically the leaching and dissolution of Lias limestone formations within the watershed and the basin of the Ouled Mellouk dam.

Indeed, the concentrations of cations and anions have a significant impact on dry residue values, which are commonly used as indicators of water mineralization levels (Rodier, 2009). In this study, the measured dry residue values ranged from 834 to 2295 mg/L, with an average of 1009 mg/L (Fig. 4), indicating that the water in the Ouled Mellouk Dam is moderately mineralized. According to Bouderbala (2021), this places it within the category of medium-quality water.

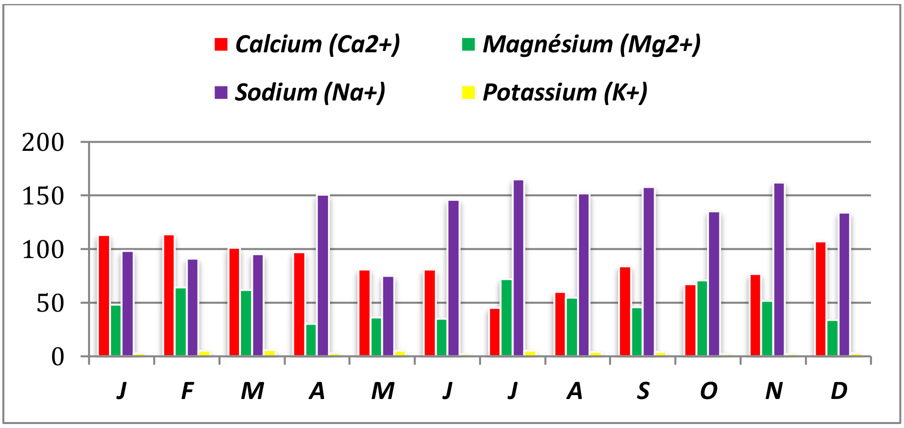

Fig. 3. Raw water cation values (expressed in mg/l) of the Ouled Mellouk dam

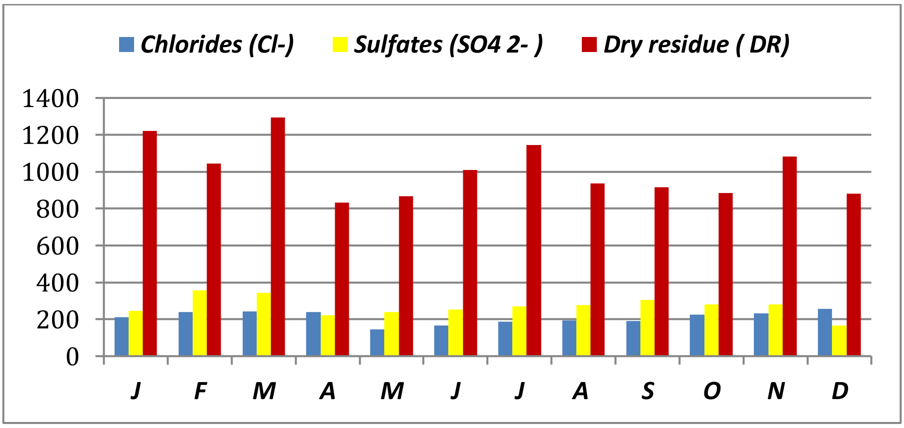

Fig. 4. Raw water anion and dry residue values (expressed in mg/l) of the Ouled Mellouk dam

Organic pollution in the surface water: Several chemical parameters can be determined to assess the organic load present in the surface water of the dam. The BOD_5 is one of these parameters and usually serves as a good indicator of organic pollution in aquatic environments, as well as eutrophication. It denotes the quantity of oxygen utilized by bacteria, either for the partial decomposition or complete oxidation of readily oxidizable biochemical substances present in the water (Guenfoud and al., 2021).

The recorded results of BOD_5 (Figure 5) for the raw water of the Ouled Mellouk dam reveal temporal variations, characterized by low values for the majority of samples taken, ranging between 1-3 mg/l. However, higher values are observed in the remaining samples, reaching a maximum in September (14 mg/l). This increase in BOD_5 may be attributed to the impact of various discharges (urban, agricultural, and industrial) released in the wadi's Zeddine–Rouina. As for COD (Fig. 5), except for certain samples where the recorded values exceed the limitrangeof the Algerian standards (20 mg/l), with a maximum of 61 mg/l in September, other samples exhibit low concentrations ranging between 2 and 17 mg/l. The rise in COD can be explained by the presence of a high pollution load containing non-biodegradable substances since COD values are higher than BOD_5From this perspective, measurements of two key organic pollution indicators conducted by the

NAWR (2016) on the water of the Bouroumi Dam (Aïn Defla region) revealed BOD_5 concentrations ranging from 1 to 7 mg/L and COD values between 7 and 40 mg/L. According to Medjoub (2020), these results classify the water quality of the dam as ranging from good to moderate. Additionally, an evaluation of the same parameters at the Fergoug Dam, located in northwestern Algeria, between 2003 and 2013, showed that BOD_5 and COD levels varied from moderate to high, indicating a more significant degree of organic pollution (Amrani and Ziane, 2017).

About dissolved oxygen (O2 dis.), is a crucial chemical parameter in water as it influences the status of various mineral salts, the degradation of organic matter, and aquatic life (Belghiti, 2013). The levels of dissolved oxygen assessed in the samples collected during the year 2016 (Fig. 5) range between 5.6 mg/l and 11 mg/l, categorizing the water of the Ouled Mellouk dam as having good quality in terms of this parameter. This effective oxygenation can be attributed to exchanges with the atmosphere on one hand and the photosynthetic activity of the environment on the other hand.

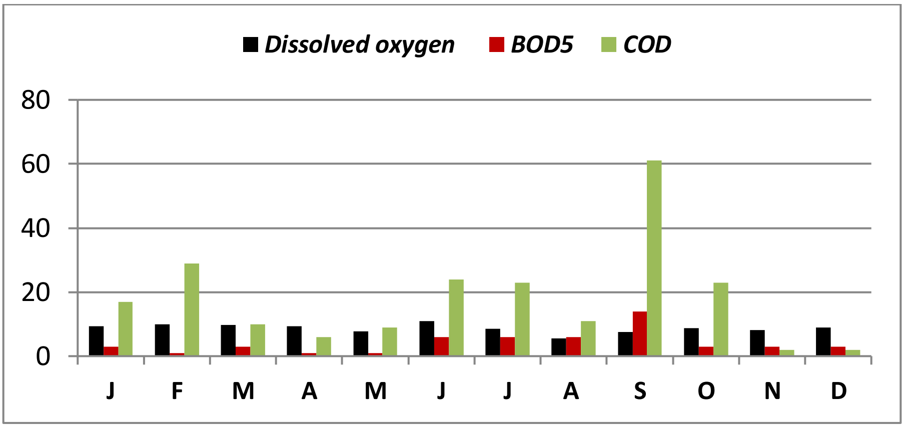

Fig. 5. Values of organic parameters of raw water of the Ouled Mellouk dam (expressed in mg/l)

Nitrogen quality of water: The nitrogen quality of water is often determined by the assessment of various parameters. Nitrates are one of these parameters, constituting the principal component of inorganic or mineral nitrogen present in natural water (Rodier, 2009). Therefore, the results obtained for NO_3^- in the water of the Ouled Mellouk dam (Fig.6) show variations ranging from 0.1 to 9.1 mg/l, with an average of 5.5 mg/l. These values are on the recommended limit for surface water (0-10 mg/l). Nitrate could be related to leaching from the agricultural soil in the dam's watershed. Regarding nitrites, as the second form of nitrogen, the recorded values (Fig.6) oscillate between a minimum of 0.007 and a maximum of 0.103 mg/l. These slightly raised values classify the raw water of this reservoir in Class II, which should be treated before any use. In reality, nitrate ions are transient molecules in the environment and rapidly oxidize into nitrates. Compared to another dam in eastern Algeria (Dalia Dam), a previous study reported that its waters contain nitrite levels ranging from 0.03 to 0.1 mg/L (Allagua et al., 2017). The third parameter, ammonium (NH_4^+), showed slightly elevated values ranging from 0.05 to 0.17 mg/L (Fig. 6). Its presence above recommended levels can reduce chlorine treatment efficiency and promote the growth of microorganisms causing unpleasant tastes and odors. It also disrupts plant nutrition, increasing susceptibility to secondary stress. Overall, nitrogen compounds (NO_3^-, NO_2^-, NH_4^+) mainly originate from agricultural inputs and untreated wastewater due to inadequate infrastructure.

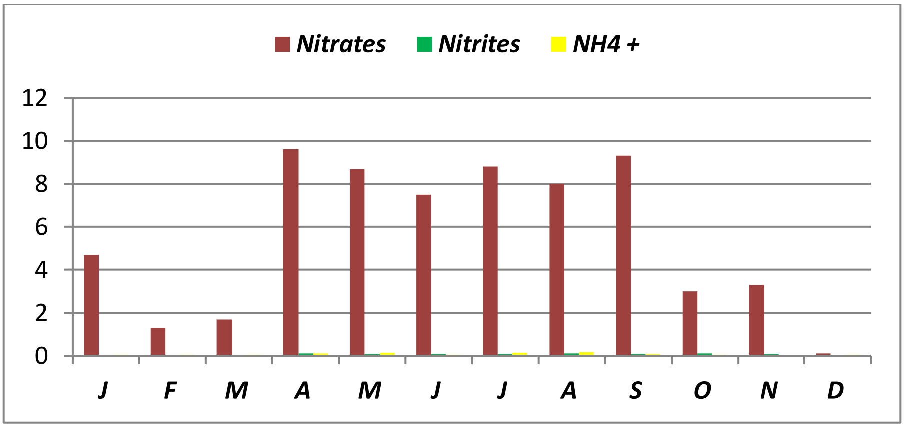

Fig. 6. Values of the organic quality elements for the raw water of the Ouled Mellouk dam (expressed in mg/l)

Phosphates compounds: In its oxidized and dissolved state, phosphate present in natural water results from the leaching of minerals and the decomposition of organic matter. Human activities contribute to an increase in its concentration. Phosphates act as the limiting factor for the growth of plankton and aquatic plants (Grobec, 2017). Analyzing this parameter in its oxidized form (orthophosphates PO_4^{3-}), the simplest and most prevalent phosphate form in water, reveals concentrations in the Ouled Mellouk dam water ranging from 0.01 to 0.245 mg/l (Fig. 7). An exception is noted for November, recording a concentration of 0.01 mg/l. This heightened level of PO_4^{3-}can primarily be attributed to wastewater discharge upstream of the basin and the use of fertilizers, especially those containing phosphorus, in agriculture. Overall, the water of the Ouled Mellouk dam is categorized as of medium to poor quality concerning this parameter. A similar study conducted in 2022 on the Ghrib Dam, also located in the Aïn Defla region, revealed that its raw water generally contains moderate concentrations of orthophosphates, averaging between 0.01 and 0.09 mg/L (Attal et al., 2022). Furthermore, a quality assessment of the Harraza Dam (Aïn Defla region), carried out between 1999 and 2008, showed that its waters are heavily loaded with orthophosphates, placing them in the category of poor-quality water with respect to this parameter (Touhari and al. 2018).

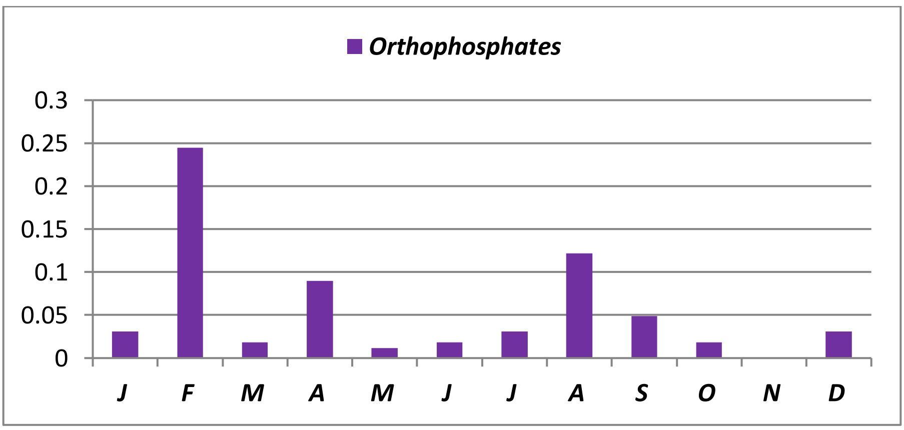

Fig. 7. Values of orthophosphates in the raw water of the Ouled Mellouk dam (expressed in mg/l)

Level of organic pollution: To assess the degree of organic pollution affecting the chemical quality of the raw water of the Ouled Mellouk dam, we employed an index method. The selected index for this study is the Organic Pollution Index (OPI), as proposed for the first time by Leclercq and Maquet (1987). It is also referred to by some scientists as the Organic Load Index. This index provides a simple yet effective tool for accurately classifying water quality and assessing the degree of pollution across both spatial and temporal scales (Leclercq, 2001).

So, the following figure – table illustrates the OPI values calculated from equation 01 for the water of the Ouled Mellouk dam and their corresponding pollution levels It (Table 1) can be observed that the organic pollution of the reservoir ranges from a low level to a moderate level for the majority of months. In contrast, for September, the pollution level was high (Fig. 8). This can be justified by the floods that typically occur during the transition period between the summer and autumn seasons.

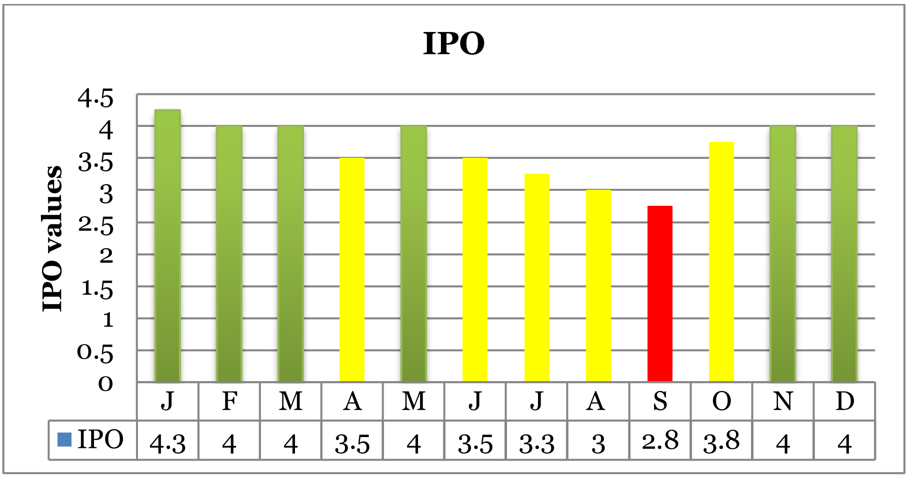

Fig. 8. Organic Pollution Index (OPI) of the water of the Ouled Mellouk dam

Conclusion

Based on this study, we can conclude that the temporal monitoring of the physico-chemical quality of water in the Ouled Mellouk dam reveals signs of pollution, marked by the presence of certain chemical and organic elements in concentrations that often exceed the recommended standards for surface waters. These include nitrogen and phosphate compounds, BOD_5, COD, as well as chloride, magnesium, and sulfate ions.

An exception is observed for dissolved oxygen, with all recorded values falling within a good quality range (5–11 mg/L). This is likely due to atmospheric exchanges, water mixing, and photosynthetic activity in this artificial lentic environment.

Furthermore, the assessment of organic pollution using the Organic Pollution Index (OPI) confirms the presence of pollution ranging from low to moderate levels. This type of contamination often leads to eutrophication.

Therefore, ongoing monitoring and the implementation of pollution control measures are essential to protect aquatic environments and preserve their ecosystem services.

Conflicts of Interest: The authors declare no conflict of interest.

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