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Assessment of Nutrient Contents in River Waters Introduced to Beni Haroun Dam, North East Algeria

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Abstract: The main objective of this study was to assess the hydrochemical water quality of the rivers that flowed into the Beni Haroun dam by integrating the use of biogeochemical and multivariate statistical investigation methods. Water samples were collected from the four principal rivers (Oued Rhumel, Oued Radjas, Oued Kebir and Oued El-Kotone rivers) flowing into the Beni Haroun dam in February 2020. Essential physical parameters (pH, Electric Conductivity (EC), Total Dissolved Solids (TDS) and Dissolved Oxygen (O_2)) and nutrient contents (dissolved inorganic nitrogen (DIN: NH_4, NO_3 and NO_2), phosphate (PO_4) and silicates (SiO_4) were analysed. The results of our study showed important variations in physical parameters according to the characteristics of each river; additionally, SiO_2, NO_3 and NO_2 were found to be highly abundant in Oued Rhumel, Oued Radjas and Oued El-Kotone rivers. This abundance could be explained by the fact that these three rivers were more exposed to anthropogenic pollution principally due to agricultural activities compared to the Oued Kebir river. In contrast, NH_4, as well as phosphate (PO_4), was present at high concentrations in both Oued Rhumel and Oued Radjas rivers. These biogeochemical conditions would have severe impacts on the functioning and productivity of aquatic systems.

Key words: Beni-Haroun dam, nutrient, river, anthropogenic pollution.

Introduction

The continental water cycle plays a decisive role in the climate, ecology and biogeochemistry of the earth. However, this cycle is modified by anthropogenic activities such as agriculture and industry. Vital needs for water are increasing in many regions of the globe causing various types of pollution in both underground and surface water (Bagalwa, 2006; Malmqvist et al., 2002). Water resources are limited and the pressure on rivers becomes particularly important under the effect of dams construction and agricultural lands irrigation (Margat et al., 2004). The inputs of effluents into the aquatic environment can profoundly modify the chemistry of surface water, the flow of nutrients to the coastline and the functioning of coastal ecosystems (Howarth et al., 1996; Liu et al., 2008; Meybeck, 2003; Nixon, 2003; Turner, 2003). The hydrogeochemical characteristics including lithology of watersheds and reservoirs, climate, atmospheric inputs and human activities could have many impacts on the quality and nature of surface water (Lalaoui et al., 2020). These biogeochemical modifications are responsible for numerous negative impacts such as loss of habitat,

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biodiversity and nutrients imbalance, inducing an important proliferation of harmful phytoplankton species, eutrophication and hypoxia (Billen et al., 2007; Cloern, 2001). The data available on water quality shows that most of the Algerian water resources are contaminated by untreated domestic and industrial discharges. Moreover, urban and industrial wastewater outsourced from everywhere is discharged into the natural environment and causes increasingly dangerous pollution for water resources and public health (Fekrache and Boudeffa, 2019).

The objective of this work is to identify the impact of anthropogenic activities that are responsible for surface water quality and consequently their origins in the Beni Haroun dam.

Materials and Methods

Study Area

The hydrographic basin 'Kebir-Rhumel' has an area of 8,110 km^2 that extends from the northern boundaries of Constantine highlands to the South, to the Mediterranean Sea in the North, to the Seybouse basin in the East and the basin of the Soummam in the West (Cahiers de l'agence, 2004). The Kebir-Rhumel basin results from the junction of two rivers. Oued Rhumel and Oued Kebir rivers drain, respectively, an area of 5,315 km^2 and 2,160 km^2 and whose confluence gives birth to Oued Kebir-Rhumel river. The Kebir-Rhumel (KR) catchment is arranged by the Beni Haroun dam (nearly one billion m^3 of water) and the Oued Rhumel (Rh), Oued Kebir (Ke), Oued Radjas (Ra) and Oued El-Kotone (Ko) rivers are considered as the main rivers which flow into this dam (Figure 1). In addition, the area is highly populated by more than 2 million people and consequently, the surface waters are daily submitted to domestic and agricultural untreated wastes. The catchment receives an annual precipitation yield of about 400-800 mm inducing large fluctuation in river flow. In the summer period, most rivers decrease in flow, become almost dry, inducing a low water supply to the dam. However, downstream of the dam, water continues to flow in a constant small quantity. Being irrigated from dams and near-river mouths, the northern

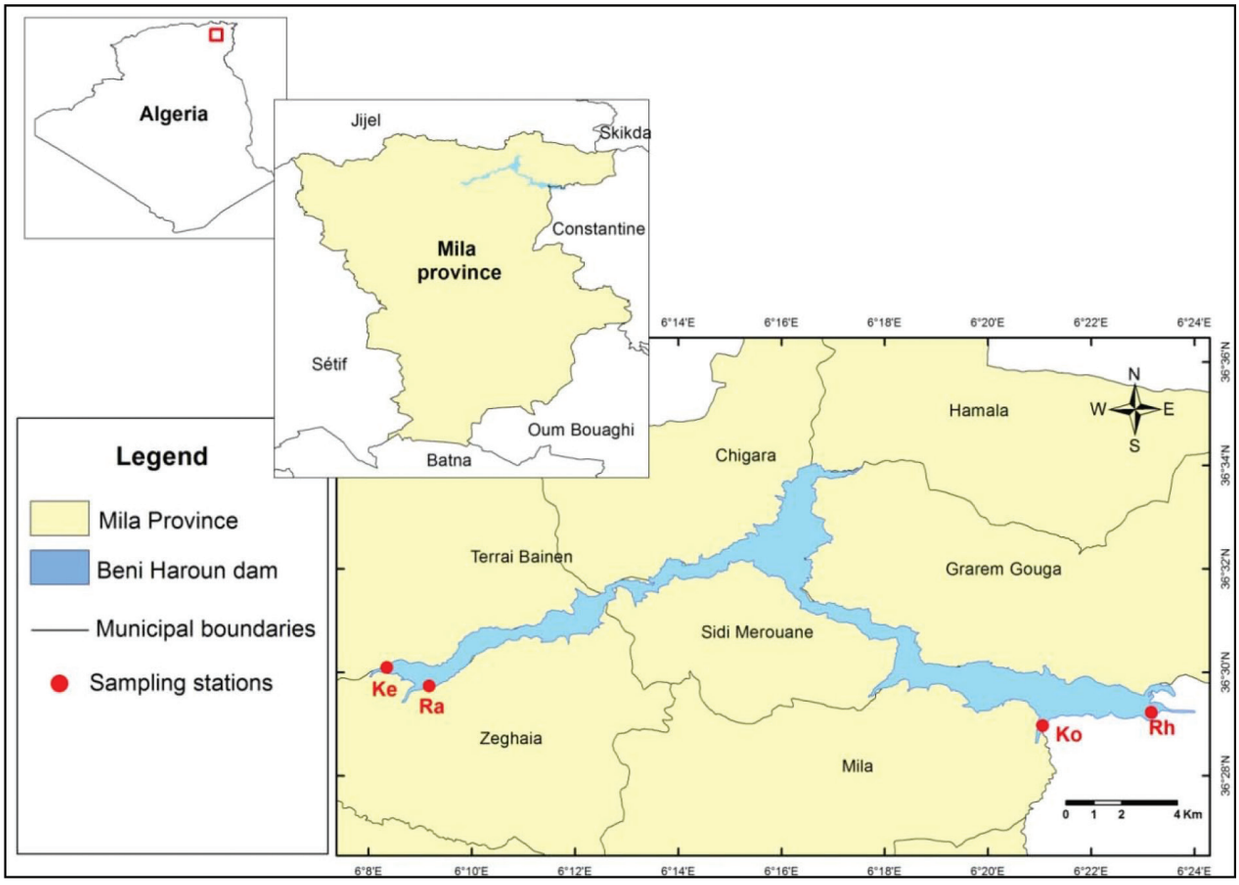

Figure 1: Study area showing the sampling sites (Ke: Oued Kebir; Ra: Oued Radjas; Ko: Oued El-Kotone and Rh: Oued Rhumel rivers).

areas sustain large intensive agricultural activities and the land use becomes mainly dominated by intensive agricultural practices.

Water Sampling and Analytical Methods

Waters surface sampling was performed in February 2020. Measurements of parameters like electrical conductivity (EC), total dissolved solids (TDS), pH and temperature (T) were carried out in situ with the multiparameter probe WTW 197i (Table 1). About 2 L of water from the middle of the river were collected for nutrient analysis. Water samples for nutrient analyses were frozen in polyethylene bottles and processed within two days after collection.

Water samples collected for nutrient analyses were filtered through Whatman GF/C 0.5 µm glass filters. Dissolved inorganic nitrogen DIN (ammonia: NH_4; nitrate: NO_3; nitrite: NO_2), phosphate (PO_4) and silicate $Si(OH)_4$ were determined using the standard colorimetric methods (Preston et al., 1989).

Statistical Analysis

The multivariate method of Principal Component Analysis (PCA) was used to determine the possible correlations between the physicochemical parameters from waters upstream of the four rivers. The PCA has several advantages over other multivariate methods and is more appropriate for the data collected. The statistical software SPSS 22, was used to perform PCA. The contingency table analysed with PCA is a matrix of 11 physicochemical parameters (variables) observed at the 4 sites representing the upstream side of the Beni Haroun dam.

Results and Discussion

Physicochemical Characteristics of Water in the Four Rivers

Physicochemical parameters of water surface samples from the four sites are summarised in Tables 2 and 3. The pH of a water system is an important indicator for determining the quality and purity of water and the degree of its pollution, especially in catchment areas, where the pH of natural water ranges between 6.0 and 8.5 (WHO, 2008). Our results showed that the pH of the four rivers that flow into the Bani Harun dam ranges between 7.3 and 8.3, where the highest pH was recorded in Oued Rhumel river waters at the entrance to the dam (Table 2). Total dissolved solids (TDS) in water resources play an important role in determining the suitability of water for different uses. In our study, the obtained results showed that the water of the Oued Kebir and Oued El-Kotone rivers seems to be purer than Oued Radjas and Oued Rhumel rivers, which exceeded the normal value of TDS. Similarly, the electrical conductivity was lowest in Oued Kebir and Oued El-Kotone rivers than in Oued Radjas and Oued Rhumel rivers. The electrical conductivity of the two remaining rivers exceeded the normal value of fresh water which ranges from 10 to 1000 µs/cm **(**Lalaoui et al., 2020). Moreover, the results obtained from our work showed that the dissolved oxygen (O_2) contents

Table 1: Physicochemical parameters and their respective analytical methods

Variable	*Abbreviation*	*Analytical method*	*Unit*
pH	pH	Potentiometry pH probe	
Electric Conductivity	EC	Conductometry	µS/cm
Total Dissolved Solids	TDS	Drying at 180°C/weighing	$mg.l^{-1}$
Dissolved oxygen	O_2	Oximeters	$mg.l^{-1}$
Temperature	T	Multiparameter WTW Cond 1970i	^oC
Ammonium	NH_4	Spectrophotometry	$\mu mol.l^{-1}$
Nitrite	NO_2	Spectrophotometry	$\mu mol.l^{-1}$
Nitrate	NO_3	Spectrophotometry	$\mu mol.l^{-1}$
Dissolved inorganic nitrogen	NID	$NID = NH_4 + NO_2 + NO_3$	$\mu mol.l^{-1}$
Phosphate	PO_4	Spectrophotometry	$\mu mol.l^{-1}$
Silicates	SiO_4	Spectrophotometry	$\mu mol.l^{-1}$

Table 2: Physical parameters of water samples from the four sites

Site	*pH*	*EC*	*TDS*	*DO*	*T*
Oued Kebir River	7.3	735	329	42	4.9
Oued Radjas River	7.8	1367	590	39	6.8
Oued Rhumel River	8.3	1812	729	37	8.6
Oued El-Kotone River	7.6	899	490	36	8

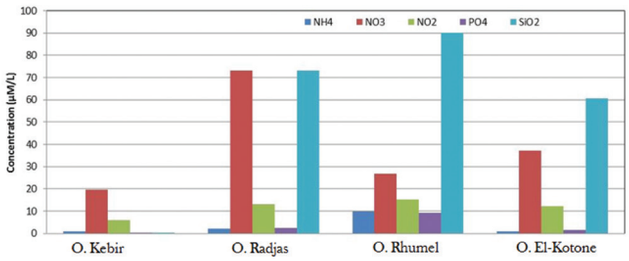

Figure 2: Graph plots of nutrient concentrations in different sites.

was fluctuating between 36 and 42 mg/L in the four sites with a temperature variation between 4.9 and 8.6 (Table 2). Dissolved oxygen is one of the most important indicators of water quality. It is also considered to be a necessary component for aquatic organisms and the aqueous medium in general. When the dissolved oxygen becomes too low, it causes an imbalance in the aqueous medium for all aquatic organisms.

Concerning chemical parameters, as shown in Figure 2 and Table 3, the highest levels of dissolved inorganic nitrogen (DIN) the upstream of Beni-Haroun dam were observed in the Oued Radjas river with a concentration of 88.63 µM, where the values of DIN increased nearly twice as much compared to the value of Oued Rhumel and Oued El-Kotone rivers (51.76 µM and 50.42 Mm, respectively). In contrast, the Oued Kebir river showed the lowest value with a concentration of 26,40 µM. The high level of dissolved inorganic nitrogen in Oued Radjas River may be explained by the introduction of large masses of nitrogen from domestic waste discharged directly into the river in addition to agricultural activities with significant use of fertilizers in this area, as it is confirmed in other studies (e.g., Margat et al., 2004). In contrast, the low level of DIN marked in the Oued Kebir River may be explained by the geographical specificity of this area which is dominated by mountainous parcels and a limited population.

For ammoniac nitrogen (NH_4), the highest concentration was observed in the Oued Rhumel river with a value of near 10 µM, which may be explained mainly by high levels of domestic, agricultural and industrial discharges, these results are similar to those of Fekrache and Boudeffa, 2019. For nitrite (NO_2), our results showed that the levels varied from 5.84 µM to 15.15 µM. The lowest and highest values were registered at Oued Kebir and Oued Rhumel rivers respectively. Nitrite is often having the lowest levels in normal waters (Margat et al., 2004). The NO_3 showed a maximum value of 73.18 µM at the Oued Radjas river, while the lowest value (19.68 µM) was observed in the Oued Kebir river (Table 3).

During the sampling campaign, concentrations of Orthophosphates (PO_4) in all four sites varied from 0.34 µM (in Oued Kebir river) to 9.29 µM (Oued Rhumel river). The high concentration of PO_4 in the Oued Rhumel river could be explained by the release of large masses of phosphorus from agricultural, industrial and domestic wastes. Many other Algerian adjacent coastal catchments suffered from the same problem (Ounissi and Bouchareb, 2013). Similarly, high levels of orthosilicates (SiO_4) (without exceeding the world threshold value (Tréguer et al., 1995), were observed in the Oued Rhumel river at a concentration of 90 µM where the Oued Radjas and Oued El-Kotone rivers showed less important concentrations (73 µM and 60 µM respectively). In contrast, the Oued Kebir river showed a very low concentration of Orthosilicates (0.20 µM) (Table 3). This low concentration may be explained by the geographical specificity of this area which has naturally low amount of orthosilicate. Consequently, waters flowing into Beni Haroun dam seem to be

Table 3: Chemical parameters of water samples from the four sites

Site	*NH_4*	*NO_3*	*NO_2*	*DIN*	*PO_4*	*SiO_4*	*N/P*	*Si/N*	*Si/P*
Oued Kebir River	0.88	19.68	5.84	26.40	0.34	0.19	77.64	0.007	0.55
Oued Radjas River	2.26	73.18	13.18	88.63	2.29	73.08	38.70	0.82	31.91
Oued Rhumel River	9.98	26.63	15.15	51.76	9.28	89.99	5.57	1.73	9.69
Oued El-Kotone River	1.00	37.28	12.13	50.42	1.61	60.61	31.31	1.20	37.64

• N/P : DIN/PO_4 Si/N : SiO_4/DIN and Si/P : SiO_4/PO_4

Table 4: Correlation matrix of the physicochemical parameters of water samples

	pH	*EC*	*TDS*	*O_2*	*T*	*NH_4*	*NO_3*	*NO_2*	*DIN*	*PO_4*	*SiO_4*
pH	1										
EC	.978*	1									
TDS	.984*	.966*	1								
O_2	-.599	-.443	-.652	1							
T	.809	.681	.833	-.954*	1						
NH_4	.923	.904	.839	-.384	.640	1					
NO_3	.129	.220	.294	-.147	.104	-.218	1				
NO_2	.896	.844	.953*	-.815	.914	.664	.420	1			
DIN	.416	.489	.564	-.329	.348	.071	.955*	.658	1		
PO_4	.953*	.918	.882	-.490	.726	.993**	-.169	.739	.127	1	
SiO_4	.892	.846	.953*	-.804	.903	.655	.442	1.000**	.677	.729	1

* P value (significant correlation) at the 0.05 level
** P value at the 0.01 level

strongly disturbed because the molar ratio Si/N/P deviated from the Redfield molar ratios whose SiO_4/DIN ratio varied from 0.007 to 1.73, Si/P from 0.55 to 37.64 and DIN/PO_4 from 5.57 to 77.64 or the four sites (Table 3). However, the mean value of SiO_4/DIN ratio of waters flowing into Beni Haroun dam exceeded 1 (Si:N > 1), implying that Silica was delivered in excess over nitrogen, these resluts suggest that this environment is favourable for diatoms development (Redfield et al., 1963). Indeed, our results are in contrast to major global rivers which experience a significant decrease in the Si/N, which may significantly affect the function of the aquatic ecosystem (Bernard et al., 2010; Humborg et al., 2008; Ragueneau et al., 2006).

Statistical Results

For PCA analysis we included 11 physicochemical variables which are pH, CE, TDS, soluble O_2, T, NH_4, NO_3, NO_2, DIN, PO_4 and SiO_4. Correlation analysis applied to these variables showed that most of them were strongly correlated with high statistical significance (Table 4).

Indeed, PCA applied to these parameters generated two ordered factors, explaining 83.95% of the variance. Factor 1 (F1) alone was responsible for 58.52% of this variance (Table 5). Parameters with the highest factorial charges were EC (0.944), NH_4 (0.934), PO_4 (0.909), pH (0.889) and TDS (0.830). Factor 2 (F2) was responsible for 25.43% of the total variance and also included parameters with high factorial charges, such as O_2 (-0.868) (Table 5), although the remaining ones also presented a strong relationship, given the high values of factorial charges.

Table 5: Factorial charges and variance explained in the factorial analysis of the variables assessed, after rotation using the varimax method

	Factor 1	*Factor 2*
pH	**.889**	.423
EC	**.944**	.329
TDS	**.830**	.554
O_2	-.170	**-.868**
T	.457	**.767**
NH_4	**.934**	.073
NO_3	.019	**.597**
NO_2	.623	**.779**
DIN	.273	**.687**
PO_4	**.909**	.187
SiO_4	.624	**.780**

As shown in Figure 3, the factorial plan projection F1 × F2 of the correspondence analysis indicates two segregated areas: Oued Radjas and Oued Rhumel rivers with levels of high pH, TDS, EC, NH_4 and PO_4 resulting from the different anthropogenic activities in watersheds, in contrast to Oued Kebir and Oued El-Kotone rivers characterised by high levels in NO_2, NO_3 and SiO_4 which are the characteristics of pristine rivers.

The major characteristics of the studied rivers are the high values of NH_4 and PO_4, especially Oued Radjas and Oued Rhumel rivers, contrary to SiO_4 levels that were remarkably low. These biogeochemical conditions would have severe impacts on the river systems and on the functioning and the productivity of the receiving Ben Haroune dam waters.

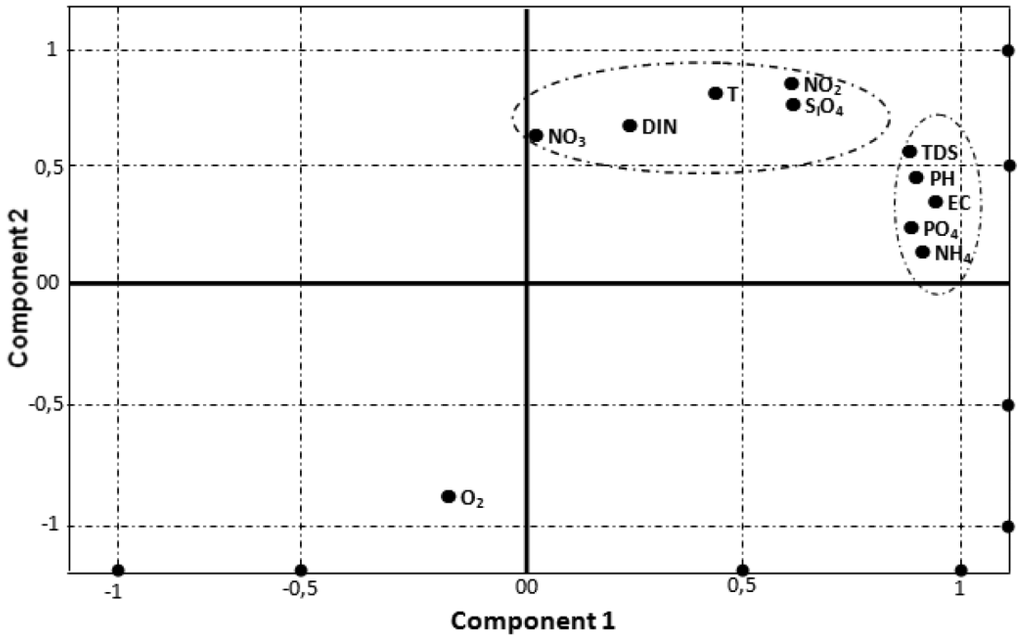

Figure 3: Factorial plan projection 1 × 2 of principal component analysis of 11 variables (NH_4; NO_2; NO_3; DIN; PO_4; SiO_4; pH; TDS; EC; T; O_2) from the 4 sites: Ke: Oued Kebir river; Ra: Oued Radjas river; KO: Oued Kotone river and Rh: Oued Rhumel river.

Conclusion

In conclusion, we can affirm that the major parameters of waters introduced to the Beni Haroun dam were analysed in the present study and marked by conditions of high enrichment, in particular in NH_4 and PO_4, unlike SiO_4 (compared to threshold values). Overall, the transfer of nutrients to the Beni Haroun dam may be summarised as follows: 1) the high level of nutrients could be explained by the human activity in the Kebir-Rhumel basin. 2) Oued Rhumel and Oued Radjas rivers were characterized by high values of ammonia (NH_4) and phosphate (PO_4) which reveal the dominance of agricultural and domestic pollution. 3) Oued Kebir and Oued El-Kotone rivers were less exposed to human activities compared to Oued Rhumel and Oued Radjas rivers.

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