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Impact of Anthropogenic Pressures on the Physicochemical Characteristics and Sediment Composition of Oubeira Lake (El Kala National Park)

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ABSTRACT

Oubeira Lake is a shallow freshwater body covering approximately 21.73km² of wetlands in northeastern Algeria. Listed as a Ramsar site since 1983, it lies within the El Kala National Park. This endorheic aquatic system receives wastewater from small surrounding settlements and is subject to overexploitation for agricultural purposes, especially under drought conditions. These anthropogenic pressures significantly impact the lake's physicochemical characteristics, leading to water level decline, increased turbidity, and altered biodiversity. Local fishers report annual changes in fish stock availability, strongly linked to water level fluctuations affecting biomass reproduction. To assess the presence of exchangeable trace metals (ETMs) in the lake's sediments, 24 sampling stations were surveyed along six transects, with three additional stations representing major tributaries. The study focused on both exchangeable bases and specific ETMs, including aluminum (Al), iron (Fe), manganese (Mn), calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K). Analytical results were statistically treated using Principal Components Analysis (PCA), a robust method that enables the identification of key variables relevant for environmental modeling.

INTRODUCTION

Lakes of the Mediterranean basin, and especially those of North Africa, endure a qualitative and quantitative degradation resulting from natural constraints such as precipitation flooding and pond development, as well as anthropic actions (pumping-out and/or discharging-in). Consequences of this degradation have been registered regarding the economic development of the region **(Alayat, 2013; Bensafia *et al.*, 2020; Smida *et al.*, 2024)**.

Oubeira Lake, which has persisted for four decades, had completely dried up by the end of summer 1990 due to over-pumping for human drinking consumption during

sequential years of drought. The hydric potential is therefore not inexhaustible, even if it seems sufficient **(Alayat, 1991)**. In addition to seasonal fluctuations in humidity and climate changes, human activities and pond expansion are the main factors leading to ecological disturbances and alterations in ecosystem structure and biofunctioning. Beyond its Ramsar designation, Oubeira Lake is a critical biodiversity hotspot and essential habitat for migratory and endemic species, playing a central role in maintaining the ecological balance of the El Kala region.

Studies achieved on the Lake have shown bathymetric decreasing related to the mud sedimentation progress, which affects the water quality. Bathymetry is demonstrated to act on the biodiversity, which is the case with fish reproduction, as the ecosystem's valuable capacity reduces through time. Hard materials discharge (sediments and nutrients) is the source of a severe ecosystem decline. Baiting sediments is suggested to resolve the studied biome **(Östbom, 2017)**.

Measurements realized on sediments are taken in order to study exchanges occurring throughout the water column with the underlying sedimentation phase. From a scientific viewpoint, environmental control campaigns generate big data, complicated to be inferred **(Kowaliski *et al*., 2006; Félipe-Sotelo *et al*., 2007)**. In this context, the use of several statistical multivariate methods (Principal Components Analysis, classification methods) in order to infer such data seems to be highly efficient for a better conception regarding water quality and environmental states of the studied areas **(Simenov *et al*., 2003; Franco *et al*., 2021; Ustaoğlu *et al*., 2021; Panjgotra *et al*., 2022)**.

Hence, the aim of the current project consists in a diagnosis of the oubeira Lake sediments throughout the physicochemical parameters measured *in situ* as well as *in vitro* to better interpret its biofunctioning. Based on the PCA program, we could identify potentially interesting statistical tools, furnished for monitoring and modelization applications.

MATERIALS AND METHODS

1. Area of the study

Our studied area extends over 21.73km^2 water plan surface, geographically sited at 36°51'N, 8°23'E North eastern Algeria, by 23m altitude above sea level (Fig. 1). Mainly rain-fed, this lake is connected to Demenet Er Rehan, Degrah and Bouhchicha wadis, as the most important tributaries; its hydrological regime is then, tightly related to climate conditions.

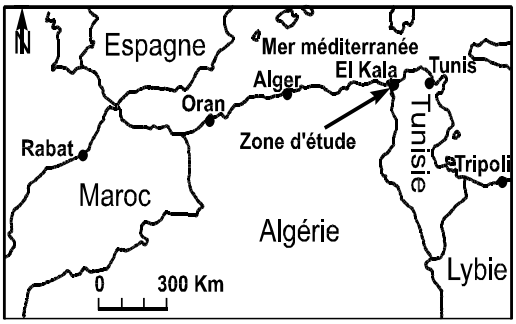

Fig. 1. The area of study location

To ensure a better biomonitoring follow-up of this lake, in order to limit the anthropogenic effects, we mentioned twenty-four observational stations, along six transects as shown in Fig. (2); accordingly, to each of these stations, physico-chemical analyses were respectively undertaken *in-situ* and/or in the laboratory.

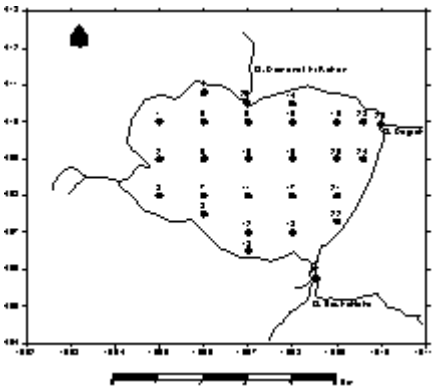

Fig. 2. Observational stations location

Both water and sediments were sampled in parallel, to determine physico-chemical measurements; water and sediment samples were picked, preserved and transported to the laboratory following **Rodier *et al.* (2009)**.

2. Samples processing

During our current study, we performed the following operations:
- Stations location was fixed using a GPS from Garmin 72;
- Sediments were sampled from the bottom of the lake, using a tipper from Ekman, at each station vertical, in order to quantify concentrations;
- Exchangeable bases and MTE were determined by inductively-coupled argon plasma atomic emission spectrometry (ICP-AES);
-XLSTAT 2014 statistical software was used for data processing.

RESULTS AND DISCUSSION

1. Bathymetry

The bathymetry of the lake enabled the establishment of a topographical map of its bottom, allowing the identification of potential irregularities and, consequently, the deduction of its geomorphology. Measurements indicate an increasing accumulation of sediment (vase) from the banks toward the center of the basin (Fig. 3). The lakebed tends to be flat and regular. The maximum depth, observed in April, reaches 2 meters at the center of the lake.

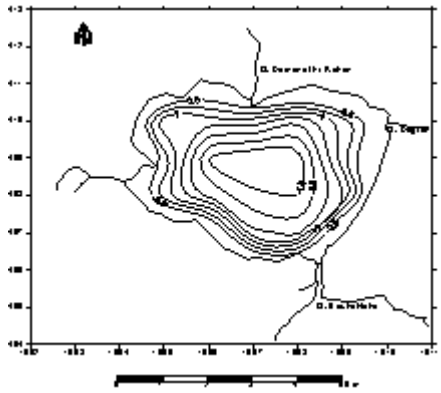

Fig. 3. Isobath plan of the Oubeira Lake

2. Descriptive analysis

Exchangeable bases and MTEs of the studied sediments, originate from grit and clay formations of the watershed. While altered, these formations release minerals, in particular, those presented in Table (1). The experimental values result from the accumulation of these elements during floods.

Table 1. Exchangeable bases concentrations and sediment MTEs of the Oubeira Lake (g/kg)

Minerals	Minimum	Maximum	Average	Standard deviation
Al	0.23	2.78	1.17	0.69
Fe	1.32	12.51	4.96	2.86
Mn	0.25	1.98	0.96	0.42
Ca	29.98	66.12	51.87	8.80
Mg	21.25	27.23	24.54	1.54
Na	98.23	160.23	124.38	19.00
K	13.56	21.52	17.62	2.20

Consequently, the sediments of the Lake remain a substantial reservoir of the MTEs, down the water column (**Zhang *et al.*, 2019; Wijesiri *et al.*, 2019; Li *et al.*, 2020;**

Wu *et al.*, 2022). They mainly develop from the geochemical background of the region and, on a secondary basis, from the anthropization of the lake under study. Descriptive analysis of the results did not reveal any outliers that would distort the dispersion.

3. Statistics

Principal component analysis (PCA) is a multivariate analysis method allowing the simultaneous study of big data variables whose total information cannot be visualized because of a space of more than three dimensions. This method would make it possible to specify the relationships between the variables and their related phenomena. The purpose is to obtain full information based on a minimum of axis **(Ayadi *et al.*, 2008)**. This method is the most adequate one to interpret hydrochemical data **(Abrid, 2015; Toumi *et al.*, 2016)**.

PCA is therefore, a tool that offers the possibility of simplifying of aquatic ecosystems study and reducing its costs by reducing the number of variables to be taken into account **(N'diayea *et al.*, 2014; Chen *et al.*, 2016)**. The statistical analysis of the analytical results of the sediments was carried out on a data matrix consisting of seven variables and 27 samples distributed along six transects across Oubeira Lake; the XLSTAT 2014 statistical software was used for data processing.

Correlation matrix updates existing associations between the different variables such as iron and aluminum, iron and manganese, aluminum and manganese. These parameters are relatively well correlated with each other (Table 2).

Table 2. Correlation matrix

Variable	**[Al]**	**[Fe]**	**[Mn]**	**Ca**	**Mg**	**Na**	**K**
[Al]	**1**	**0,9357**	**0,8387**	0,1780	-0,1436	-0,1343	-0,0870
[Fe]	**0,9357**	**1**	**0,9041**	0,2120	-0,2069	-0,2073	-0,1686
[Mn]	**0,8387**	**0,9041**	**1**	0,1392	-0,1814	-0,3563	-0,1643
Ca	0,1780	0,2120	0,1392	**1**	0,0043	-0,0956	-0,1052
Mg	-0,1436	-0,2069	-0,1814	0,0043	**1**	0,1607	0,4071
Na	-0,1343	-0,2073	-0,3563	-0,0956	0,1607	**1**	0,1933
K	-0,0870	-0,1686	-0,1643	-0,1052	0,4071	0,1933	**1**

Eigenvalues of the correlation matrix make it possible to measure the percentage of the variance explained by each factorial (Table 3).

Table 3. Eigen values

	F1	F2	F3	F4	F5	F6	F7
Eigen value	3,0451	1,3557	0,9748	0,8774	0,5727	0,1287	0,0455
Variability (%)	43,5017	19,3674	13,9261	12,5344	8,1813	1,8387	0,6505
Cumulative(%)	43,5017	62,8691	76,7952	89,3296	97,5109	99,3495	100,0000

We paid a major attention to variables with a strong positive or negative contribution to the factorial axis, which would help understand the source of variability explained by the axes. Axis III provides modest information because it is essentially formed by calcium (Table 4).

Table 4. Variables contributions (%)

	F1	**F2**	**F3**
[Al]	0,5197	0,2537	-0,1134
[Fe]	0,5477	0,1727	-0,0801
[Mn]	0,5360	0,1316	-0,1030
Ca	0,1576	0,0158	0,9293
Mg	-0,1919	0,6114	0,2432
Na	-0,2223	0,2981	-0,2057
K	-0,1776	0,6523	-0,0703

On the graphs resulting from the factor analysis, groupings, oppositions and directional trends were noticed. The first factorial plan made up of axes I and II explains 62.87% of the variance, whereas, Axis I expresses 43.50% of the variance and opposes the MTEs to the exchangeable bases.

It reflects the erosion and accumulation of sediments (Fig. 4). Finally, magnesium, potassium and sodium are closely linked and evolve in the same direction; they differ on axis II, which expresses 19.37% of the variance. It defines an axis of mineralization.

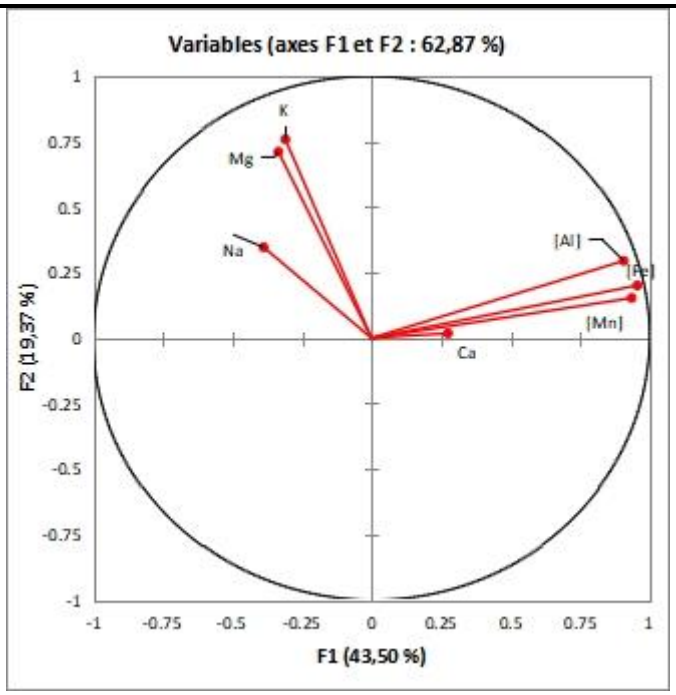

Fig. 4. Variables projection on the first factorial plan

Principal component analysis (PCA) allowed determining the distribution of MTEs and exchangeable bases in our ecosystem sediments. The MTEs are located at the stations close to the outfall of the wadis. They reflect the erosion effect of the watershed and anthropization (Fig. 5).

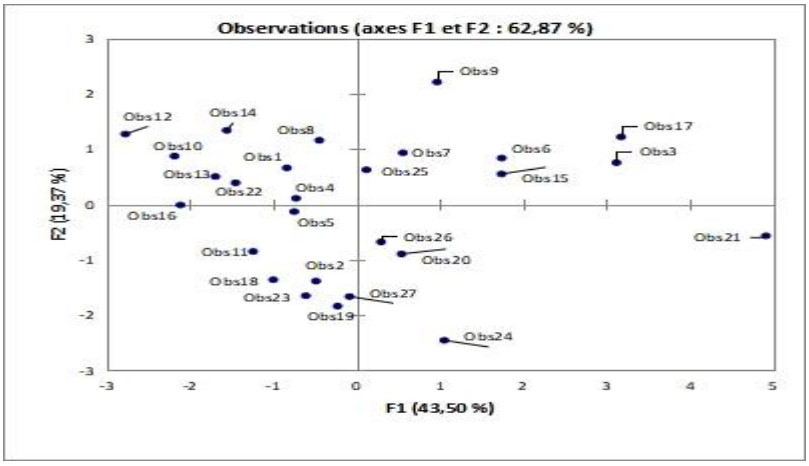

Fig. 5. Invidious projection on the first factorial plan

We mention that the other stations characterize the accumulation of exchangeable bases in the sediments.

CONCLUSION

As part of the preservation of this aquatic ecosystem, a study of the physico-chemical parameters has shown iron, aluminum and manganese present in the sedimental phase. These elements come from the clay and grit alteration from the watershed and incidentally from diffuse discharges. Thus, erosion significantly affects the sediment of lake and constitutes a reservoir of MTEs.

The Histogram of eigenvalues shows that the former factorial plan compound of F1 and F2 axes seems sufficient for mainly explore the at the stations close to the outfalls of the wadis. They reflect the erosion impact of the watershed and anthropization. The other stations characterize the accumulation of exchangeable bases in the sediments.

This study also highlights the importance and usefulness of multivariate analysis techniques to obtain information on sediments quality and thus, avert all kinds of pollution. The PCA allowed us to identify the effect of the geochemical background of the studied region, based on the sediment mineral composition of the Oubeira Lake, and finally to consider five major elements (Iron, Al, Mn, Mg and K) for monitoring and modeling of the ecosystem.

REFERENCES

Abrid, D. (2015). *Physico-chemical, mineralogical, and geochemical characterization of the sediments of the Sidi Chahed dam reservoir and the soils of the Oued Mikkés watershed*. Doctoral thesis, Moulay Ismail University, Morocco, 233 pages.

Alayat, H. (2013). Spatial evolution of the physico-chemical characteristics of Lake Oubeira's waters under severe drought conditions (extreme northeastern Algeria). *European Scientific Journal, 9*, 36.

Alayat, H. (1991). *Surface water and groundwater of the Annaba plain*. Doctoral thesis, University of Nancy II, 382 pages.

Ayadi, I.; Habib, H. and Yasmine, D. (2008). Characterization of siltation in hill lakes of central Tunisia. *International Water Resources Association. XIIIth World Water Congress* (September 1-4, 2008), Montpellier, France.

Bensafia, N.; Djabourabi, A.; Touati, H.; Rachedi, M. and Belhaoues, S. (2020). Evolution of physicochemical parameters and trophic state of three water bodies in El-Kala National Park (Northeast Algeria). *Egyptian Journal of Aquatic Biology & Fisheries, 24*(2), 249-263.

Chen, J.; Li, F.; Fan, Z. and Wang, Y. (2016). Integrated application of multivariate statistical methods to source apportionment of watercourses in the Liao River Basin, northeast China. *International Journal of Environmental Research and Public Health, 13*(10), 1035. https://doi.org/10.3390/ijerph13101035

Félipe-Sotelo, M.; Andrade, J. M.; Carlosena, A. and Tauler, R. (2007). Temporal characterisation of river waters in urban and semi-urban areas using physico-chemical parameters and chemometric methods. *Analytica Chimica Acta, 583*(1), 128-137. https://doi.org/10.1016/j.aca.2006.10.011

Franco, H.; Custodio, M.; Peñaloza, R. and De La Cruz, H. (2021). Application of multivariate statistical methods and water quality index for the evaluation of surface water quality in the Cunas River Basin, Peru. *Asian Journal of Water, Environment and Pollution, 18*, 19-27.

Kowaliski, T.; Zbytniewsky, R.; Szpeina, J. and Buszewsky, B. (2006). Application of chemometrics in river water classification. *Water Research, 40*, 744-752.

Li, Y.; Gao, B.; Xu, D.; Peng, W.; Liu, X.; Qu, X. and Zhang, M. (2020). Hydrodynamic impact on trace metals in sediments in the cascade reservoirs, North China. *Science of the Total Environment, 716*, 136914. https://doi.org/10.1016/j.scitotenv.2020.136914

N'diaye, A.; Salem, K.; El Kory, M.; Ould Kankou, M. and Bauduc, M. (2014). Contribution to the study of the spatio-temporal evolution of the physico-chemical quality of the water on the right bank of the Senegal River. *Journal of Materials and Environmental Science, 5*(1), 320-329.

Östbom, V. G. (2017). *Sedimentation in a small lake, more complex than previously assumed - Bathymetrical and geochemical sediment analyses in Kassjön (63°55'N, 20°01'E)*. Master's Thesis, Environmental Science, Geology, University of Umeå, Sweden.

Panjgotra, S.; Rishi, M. and Awasthi, A. (2022). Water quality assessment of River Tawi, Jammu using water quality index and multivariate statistical techniques. *Water Resources, 49*, 1059-1069.

Rodier, J.; Legube, B.; Merlet, N. et al. (Eds.) (2009). *Water Analysis* (9th ed.). Dunod, Paris.

Simenov, V.; Stratis, J. A.; Samara, C.; Zahariadis, G.; Vousta, D.; Anthemedis, A.; Sofoniou, M. and Koumtzis, T. (2003). Assessment of the surface water quality in Northern Greece. *Water Research, 37*, 4119-4124. https://doi.org/10.1016/S0043-1354(03)00398-1

Smida, B.; Djabourabi, A.; Gouasmia, G.; Aouadi, A.; Benmatouk, H. and Boualleg, C. (2024). Zooplankton diversity in Lake Oubeira, a wetland in the El Kala National Park (NPEK, Northeast Algeria). *Egyptian Journal of Aquatic Biology & Fisheries, 28*(4), 1863-1882.

Toumi, A.; Reggam, A.; Alayat, H. and Houhamdi, M. (2016). Physico-chemical characterization of the waters of a lake ecosystem: Case of Lac des Oiseaux (Extreme NE-Algeria). *Journal of Materials and Environmental Science, 7*(1), 139-147.

Ustaoğlu, F.; Taş, B.; Tepe, Y. and Topaldemir, H. (2021). Comprehensive assessment of water quality and associated health risk by using physicochemical quality indices and multivariate analysis in Terme River, Turkey. *Environmental Science and Pollution Research, 28*, 62736-62754. https://doi.org/10.1007/s11356-021-15135-3

Wijesiri, B.; Liu, A.; Deilami, K.; He, B.; Hong, N.; Yang, B.; Zhao, X.; Ayoko, G. and Goonetilleke, A. (2019). Nutrients and metals interactions between water and sediment phases: An urban river case study. *Environmental Pollution, 251*, 354-362. https://doi.org/10.1016/j.envpol.2019.05.018

Wu, D.; Liu, H.; Wu, J. and Gao, X. (2022). Spatial distribution, ecological risk assessment and source analysis of heavy metals pollution in urban lake sediments of Huaihe River Basin. *International Journal of Environmental Research and Public Health, 19*(22), 14653. https://doi.org/10.3390/ijerph192214653

Zhang, J.; Guo, X.; Zeng, Y. and Deng, J. (2019). Spatial distribution and pollution assessment of heavy metals in river sediments from Lake Taihu Basin. *Environmental Science, 40*, 2202-2210. https://doi.org/10.13227/j.hjkx.201809168