EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2024, 25(8), 27–36
https://doi.org/10.12912/27197050/188714
ISSN 2299–8993, License CC-BY 4.0

Received: 2024.05.03
Accepted: 2024.06.17
Published: 2024.07.01

Statistical Study of Groundwater Salinity at Lake Dayet Erroumi, Morocco

Mohamed El Qryefy[1*], Abdelhadi Hichar[2], Mouhcine El Qryefy[3], Tarik El Hammoumi[1], Khadija El Kharrim[1]

[1] Natural Resources and Sustainable Development Laboratory, Faculty of Sciences, Ibn Tofail University, BP133, 14000 Kenitra, Morocco

[2] Production Laboratory, Faculty of Sciences, Ibn Tofail University, BP133, 14000 Kenitra, Morocco

[3] Laboratory of Electronic Systems, Information Processing, Mechanics and Energetics, Faculty of Sciences, Ibn Tofail University, BP133, 14000 Kenitra, Morocco

* Corresponding author's e-mail: elqryefy@gmail.com

ABSTRACT

In the present study, descriptive and multivariate statistical techniques (principal component analysis) were used to investigate groundwater salinity in the area adjacent to Lake Dayet Erroumi. Nine groundwater samples were collected during September 2019 and analyzed for the following physicochemical variables: pH, EC, DO, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^-, Cl^-, SO_4^{2-} and NO_3^-. On the basis of on concentration averages, cation abundance is $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ and anion abundance is $Cl^- > HCO_3^- > SO_4^{2-} > NO_3^-$. Two principal components were selected on the basis of eigenvalue, which explains 71.39% of the total variance. The first principal component (F1) accounts for 52.37% of total variance and indicates water salinization, which depends on abiotic factors. The second principal component (F2) explains 19.01% of the information and indicates parameters dependent on biotic factors (DO and pH). Projection of the observations revealed two groups of wells: the first group comprises the wells characterized by very high salinity, and the second group comprises the wells with lower salinity. These results show that the wells on the southern shore of the lake are more highly mineralized than other wells. The high mineralization of the groundwater is of natural origin, due to the leaching of Triassic evaporitic rocks.

Keywords: salinity, groundwater, Dayet Erroumi, descriptive statistics, PCA.

INTRODUCTION

Fresh groundwater represents an essential natural resource (Pauw et al., 2012) that plays a crucial role in socio-economic progress and improving living conditions, especially in arid and semi-arid zones (Milnes, 2011). These waters, used for domestic, industrial and agricultural needs (Lotfi et al., 2018), remain a reliable source of drinking water due to their low microbial content and low need for treatment before use (Elemile et al., 2021). Groundwater hydrochemistry is influenced by various natural factors, including chemical and biochemical interactions with soil and sediments, as well as by human activities and exchanges between surface and groundwater (Rao et al., 2010). Increased exploitation of these resources to meet growing needs has led to declining water levels and deteriorating quality (Zhang et al., 2011). The main causes of groundwater quality degradation include human activities, geology, recharge quality, saline intrusion, water-rock interactions and ion exchange (Gharbi et al., 2019).

Salinization represents a widespread threat to fresh groundwater and is one of the main pollution problems facing these resources worldwide (Milnes, 2011). It is characterized by an increase in salt concentration in groundwater or surface water systems (Pauw et al., 2012). This major global groundwater contamination phenomenon can be triggered by various processes, such as seawater intrusion, agrochemical pollution, geogenic contamination and salinization due to irrigation (Milnes, 2011). Groundwater salinization represents one of the main environmental challenges in Morocco, resulting from a combination of factors including the dissolution of evaporitic rocks, seawater intrusion, agricultural pollution, and wastewater discharge. These elements can act separately or synergistically, leading to alterations in the quality of groundwater. Thus, a thorough understanding of salinization mechanisms and their impacts on water resources is crucial to guide sustainable management policies and maintain the availability of water resources, which are essential for the country's socio-economic development. The population living adjacent to Lake Dayet Erroumi uses groundwater for domestic and agricultural purposes. The objective of this research was to study the salinity of groundwater in areas adjacent to Lake Dayet Erroumi using descriptive statistics and principal component analysis.

MATERIALS AND METHODS

Study area description

Lake Dayet Erroumi, located 15 km southwest of Khemisset in Morocco, stands out as the country's only permanent natural lowland lake (Fig. 1). With a surface area of around 90 ha, the lake is characterized by its shallowness, reaching a maximum depth of 14 m. It is an elongated lake in the WSW-ENE direction, measuring 1.6 kilometers long and with a width varying from 400 to 700 m (CEIBM, 2006). The Dayet Erroumi lake has an irregular geometry, linked to the presence of a network of NE-SW to EW-trending normal faults. The outcrops around this lake consist of red clays, sandstones, conglomerates and sandy marls (Elabidi et al., 2015). The lake water is brackish (El Qryefy et al., 2020). Evaporation plays a major role in seasonal variations of the water chemistry (El Qryefy et al., 2021). Lake Dayet Erroumi has an irregular geometry, linked to the presence of a network of NE-SW to EW-trending normal faults that compartmentalize the Triassic and Miocene formations into horsts and grabens (Fig. 2). The outcrops around Lake Dayet Erroumi consist of red clays, sandstones, conglomerates and sandy marls (Elabidi et al., 2015).

Sampling and analysis methods

Groundwater sampling was carried out in November 2019. The sampling points, numbered P1 to P9, were chosen so as to be dispersed and located close to the lake studied (Fig. 3). Water samples were placed in 1-liter polyethylene bottles and transported to the laboratory in a cooler at 4 °C. The pH, dissolved oxygen (DO) concentration and electrical conductivity (EC) were measured in situ using Hanna Instruments HI 98280. Major ion concentrations were determined in the laboratory of the Office Régional de Développement Agricole du Gharb. Sodium (Na^+), potassium (K^+), nitrate

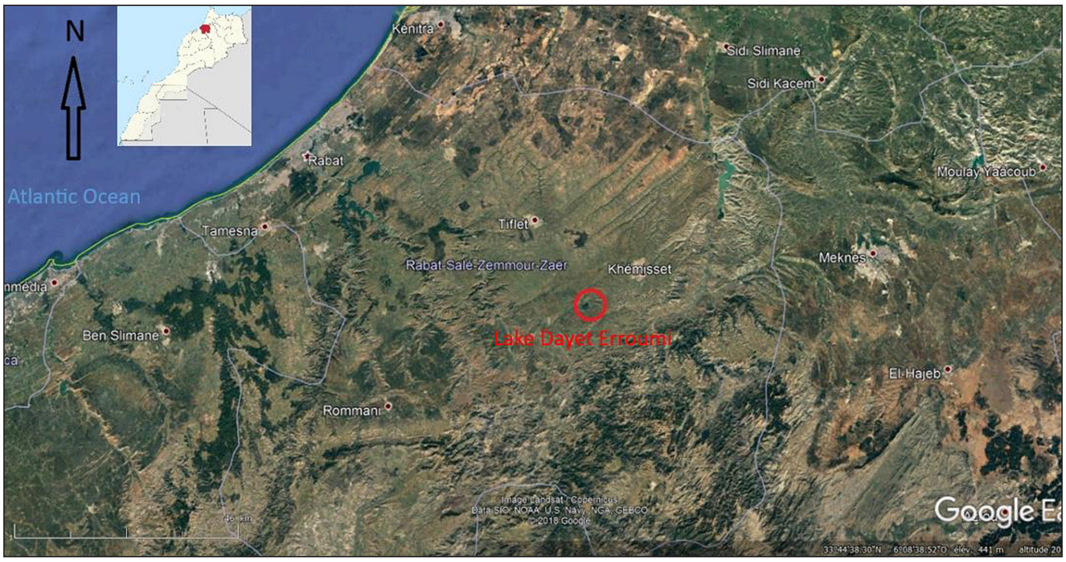

Figure 1. Geographic location of Lake Dayet Erroumi based on Google Earth (2022)

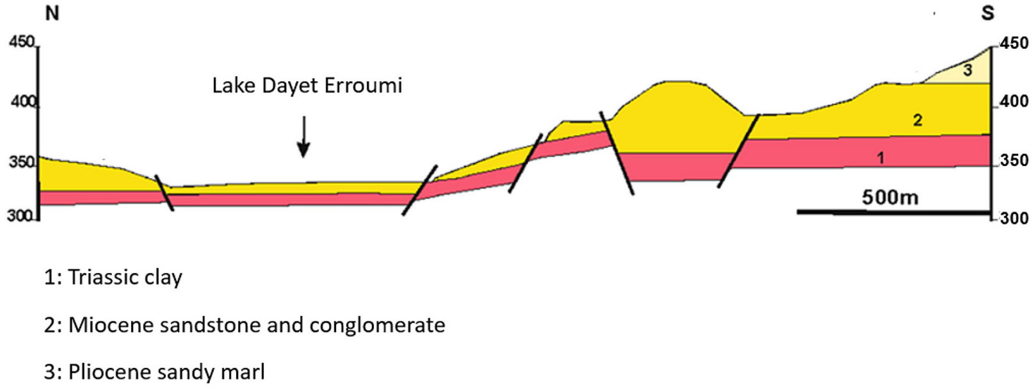

Figure 2. Geological cross-section at Lake Dayet Erroumi (ABHBC, 2015; Elabidi et al., 2015)

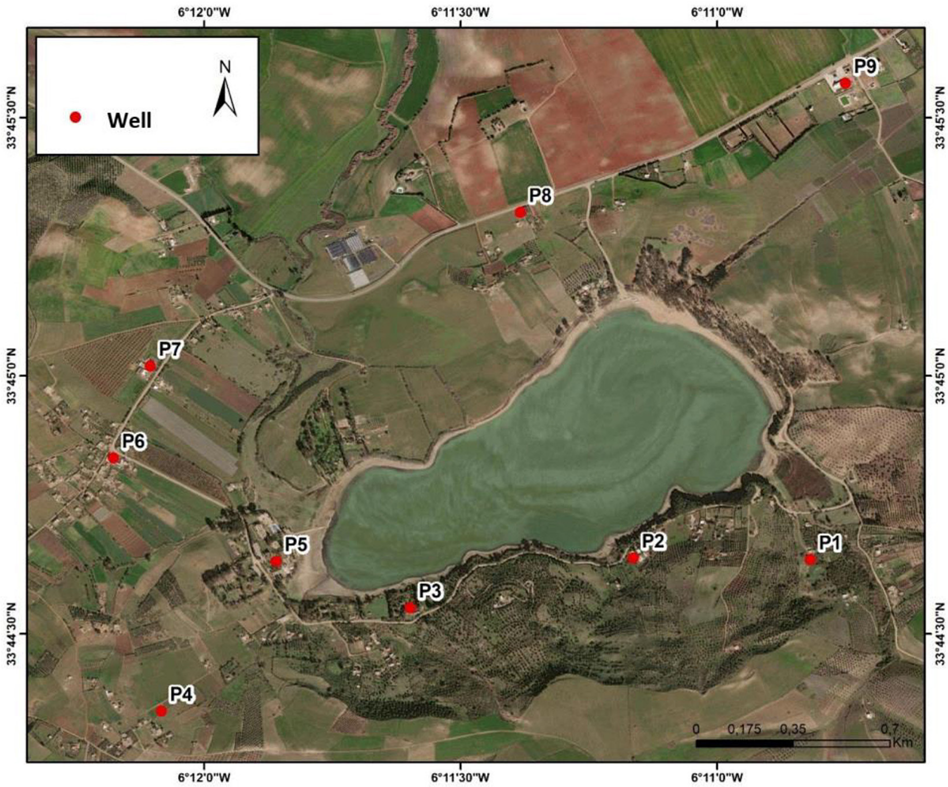

Figure 3. Geographical location of the wells (P1–P9) in the areas adjacent to Lake Dayet Erroumi, based on Google Earth (2021)

(NO_3^-) and sulfate (SO_4^{2-}) were identified using an atomic absorption technique. The calcium (Ca^{2+}), magnesium (Mg^{2+}), bicarbonate (HCO_3^-) and chloride (Cl^-) concentrations were analyzed using the volumetric method. Groundwater physicochemical data were processed using XLSTAT (2023) software to determine descriptive statistics and perform a principal component analysis (PCA). In the case of a large number of samples described by several variables, it is useful to use multivariate statistical analysis methods to characterize the results obtained. PCA is a multivariate analysis technique designed to decompose and reduce any data set into a series of components describing its main properties (Vialle, 2011). PCA is a well-known statistical approach in groundwater research (Ali et al., 2024). It is a method of multivariate data analysis (Gharbi et al., 2019) in which variables from composite datasets are reduced into explanatory principal components (Elemile et al., 2021). Indeed, the various principal components are related to each other, providing certain advantages, such as dimensionality reduction and simplification of the involved problems (Zhang et al., 2011).

Table 1. Descriptive statistics for physicochemical parameters

Variable	Minimum	Maximum	Mean	Std. deviation
Ca^{2+}	112.000	514.400	200.044	125.650
Mg^{2+}	71.930	227.690	129.656	60.002
Na^{+}	138.000	1081.000	579.856	429.993
K^{+}	0.390	1.960	0.937	0.502
Cl^{-}	203.770	2272.000	1041.570	765.188
SO_4^{2-}	31.200	374.880	149.333	125.893
HCO_3^{-}	301.950	1087.020	675.812	235.928
NO_3^{-}	10.540	76.260	42.573	20.649
EC	1640.000	9210.000	4513.333	2778.003
pH	7.250	8.180	7.679	0.250
DO	4.300	12.800	9.500	2.993

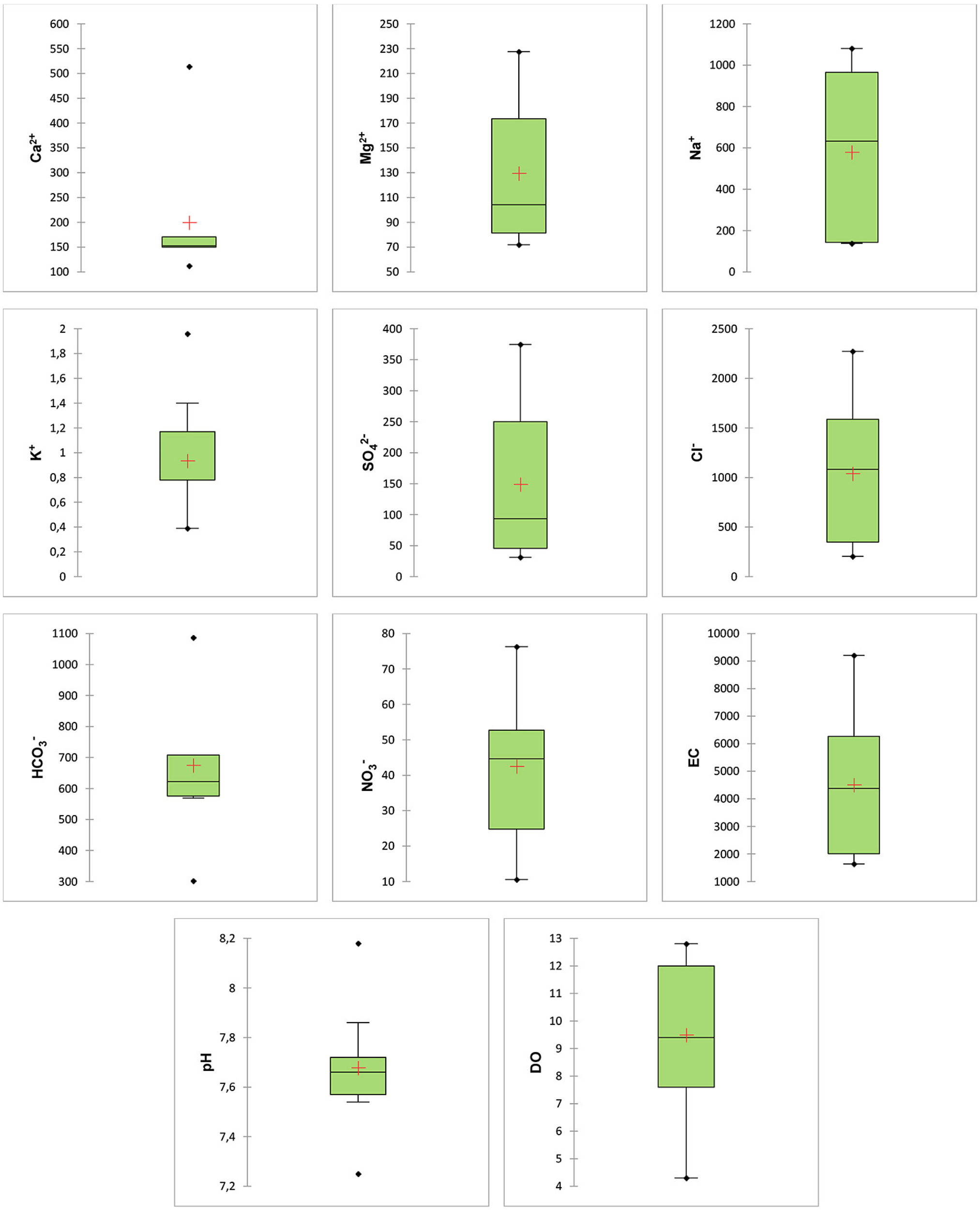

Figure 4. Box plots of the physicochemical parameters

RESULTS AND DISCUSSION

Descriptive statistics

The results of the statistical analysis of groundwater in the study area are presented in Table 1 and Figure 4. The average concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-} and NO_3^{-} in groundwater are 200.04, 129.65, 579.85, 0.93, 1041.57, 149.33, 675.81, and 42.57 mg/L respectively. According to the concentration averages, the abundance of cations is $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$ and that of anions is $Cl^{-} > HCO_3^{-} > SO_4^{2-} > NO_3^{-}$. The dominance of the Na^{+} cation and Cl^{-} anion in groundwater is explained by the leaching of Triassic evaporitic rocks. The pH values range from 7.25 to 8.18, which indicate the presence of slightly basic water. The values of electrical conductivity state a huge variability from 1640 to 9210 µS/cm. Dissolved oxygen concentration in groundwater ranges from a minimum of 4.3 mg/L to a maximum of 12.7 mg/L. These results show that groundwater in the study area is well oxygenated. According to El Qryefy et al. (2023),

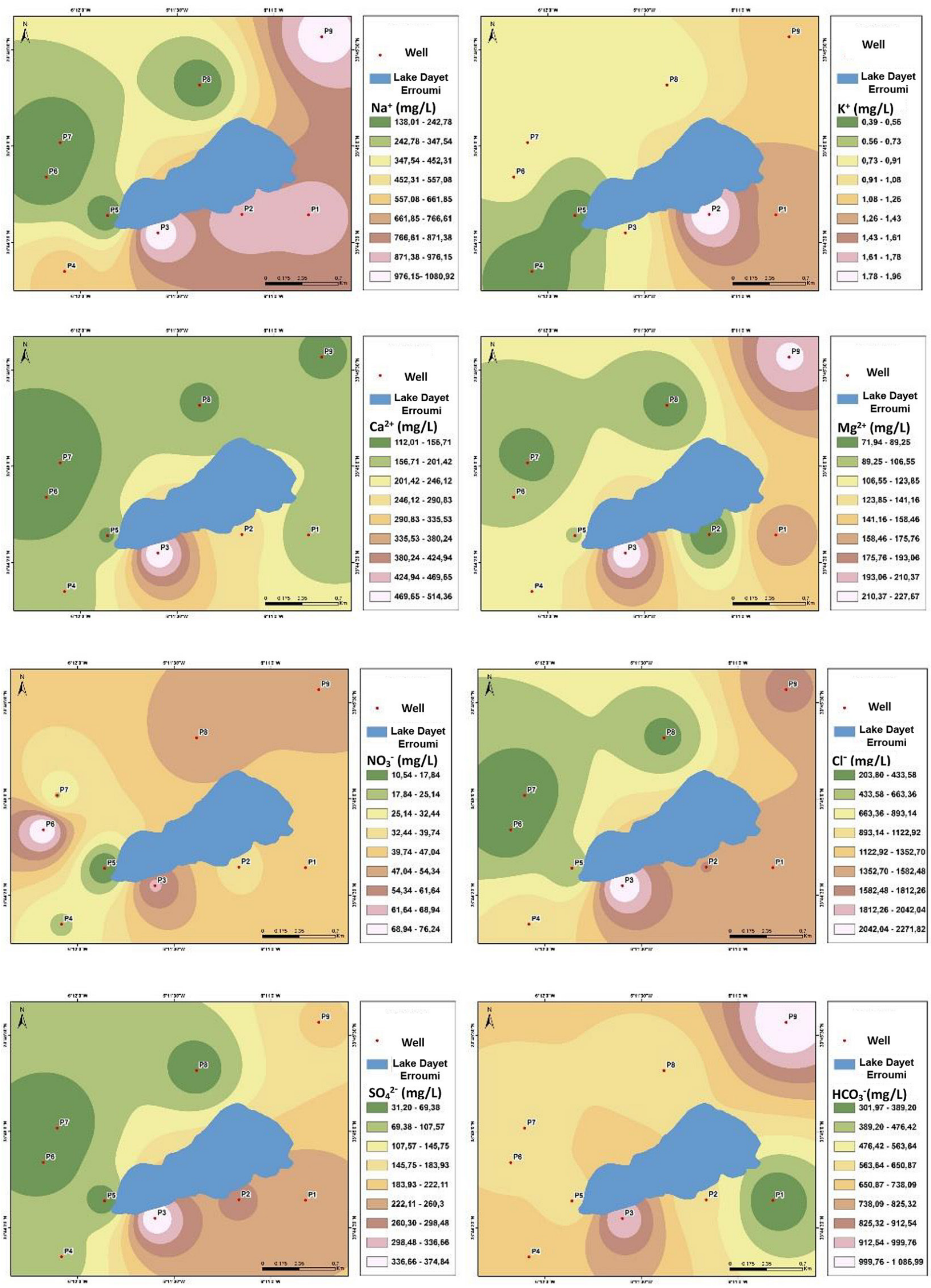

Figure 5. Spatial distribution of major ions

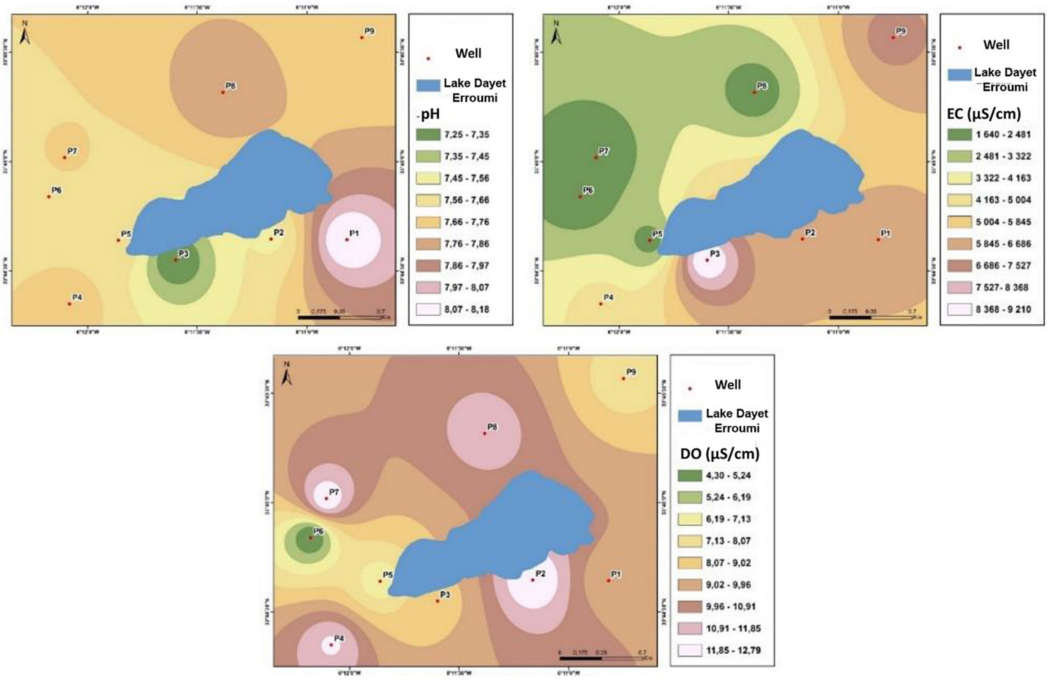

Figure 6. Spatial distribution of pH, DO and electrical conductivity

the high mineralization of water in certain wells (P1, P2, P3, P4 and P9) remains the main factor in the deterioration of water quality for human consumption. In addition, three wells (P3, P6 and P8) recorded nitrate contamination. The spatial distributions of the physicochemical parameters are illustrated in Figures 5 and 6.

Principal component analysis

In the conducted study, PCA was used to establish associations between physico-chemical variables and to note any correlations. The PCA results are presented in Tables 2, 3 and 4. Two main factors (F1 and F2) were identified

Table 2. Distribution of variance along the different PCA factorial axes

Parameter	F1	F2	F3	F4	F5	F6	F7	F8
Eigenvalue	5.761	2.092	1.270	0.892	0.520	0.396	0.057	0.013
Variability (%)	52.377	19.017	11.546	8.105	4.729	3.597	0.514	0.116
Cumulative %	52.377	71.393	82.939	91.044	95.773	99.370	99.884	100.000

Table 3. Correlation matrix (Pearson (n))

Variables	Ca	Mg	Na	K	Cl	SO_4	HCO_3	NO_3	EC	pH	DO
Ca	**1**	0.544	0.615	0.135	**0.755**	**0.828**	0.426	0.273	**0.765**	-0.623	0.072
Mg	0.544	**1**	**0.710**	0.028	**0.761**	**0.668**	0.583	0.370	**0.795**	-0.161	-0.365
Na	0.615	**0.710**	**1**	0.577	**0.976**	**0.913**	0.371	0.201	**0.970**	-0.139	0.142
K	0.135	0.028	0.577	**1**	0.467	0.558	-0.181	0.212	0.452	0.134	0.274
Cl	**0.755**	**0.761**	**0.976**	0.467	**1**	**0.959**	0.401	0.211	**0.996**	-0.237	0.094
SO_4	**0.828**	**0.668**	**0.913**	0.558	**0.959**	**1**	0.273	0.291	**0.957**	-0.279	0.091
HCO_3	0.426	0.583	0.371	-0.181	0.401	0.273	**1**	0.277	0.455	**-0.688**	-0.203
NO_3	0.273	0.370	0.201	0.212	0.211	0.291	0.277	**1**	0.264	-0.209	-0.425
EC	**0.765**	**0.795**	**0.970**	0.452	**0.996**	**0.957**	0.455	0.264	**1**	-0.272	0.056
pH	-0.623	-0.161	-0.139	0.134	-0.237	-0.279	**-0.688**	-0.209	-0.272	**1**	0.165
DO	0.072	-0.365	0.142	0.274	0.094	0.091	-0.203	-0.425	0.056	0.165	**1**

Table 4. Correlation between parameters and PCA factorial axes

Parameter	F1	F2	F3	F4	F5
Ca	0.823	-0.141	0.323	0.165	-0.391
Mg	0.798	-0.280	-0.275	-0.430	0.016
Na	0.928	0.290	-0.051	-0.123	0.143
K	0.424	0.660	-0.256	0.441	0.235
Cl	0.969	0.189	0.015	-0.134	-0.021
SO_4	0.952	0.227	-0.011	0.068	-0.182
HCO_3	0.539	-0.637	0.253	-0.071	0.479
NO_3	0.373	-0.363	-0.587	0.509	0.035
EC	0.984	0.130	-0.005	-0.116	0.006
pH	-0.405	0.608	-0.504	-0.404	0.005
DO	-0.018	0.681	0.599	0.084	0.164

for assessing the salinity and physicochemical composition of the water. These two factors account for 71.39% of the total variance. The first factorial axis F1 accounts for 52.37% of total variance. It shows a strong positive correlation with EC, Na^+, Cl^-, SO_4^{2-} (> 0.90) and a weaker correlation for Ca^{2+} and Mg^{2+} (Table 4 and Fig. 7). This factor indicates the salinization of the water, which depends on abiotic factors (geology of the region). The dominant groundwater ions (Na^+ and Cl^-) are highly positively correlated, confirming that these two chemical elements have the same origin (halite). The second factor explains 19.01% of the information and shows a positive correlation with DO and pH and a negative correlation with HCO_3^- (Table 4 and Fig. 7).

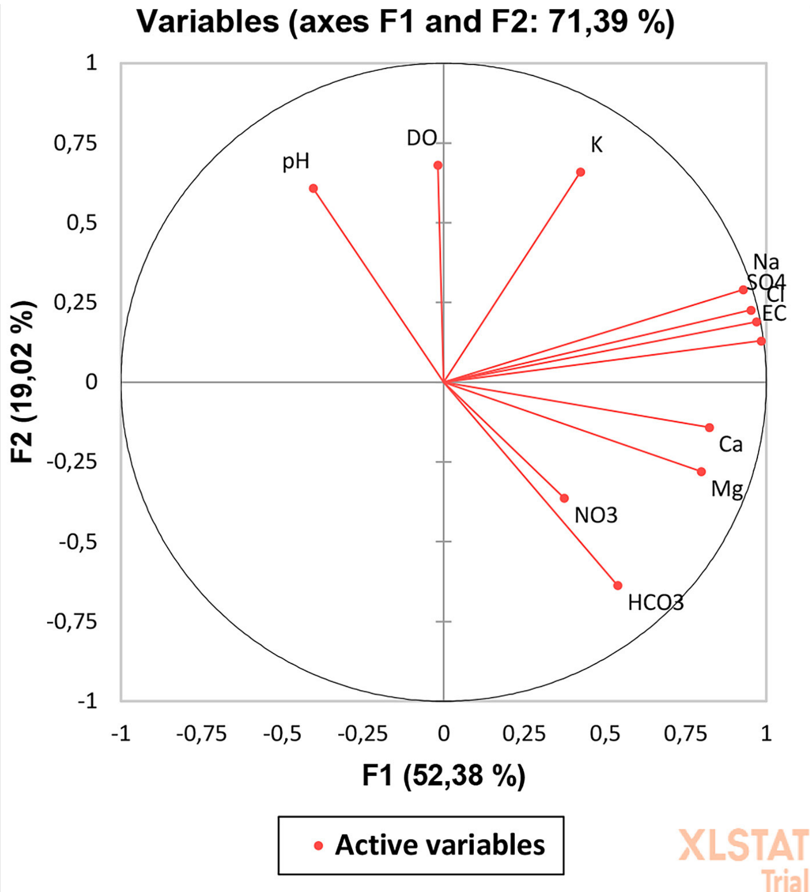

Figure 7. Correlations between variables

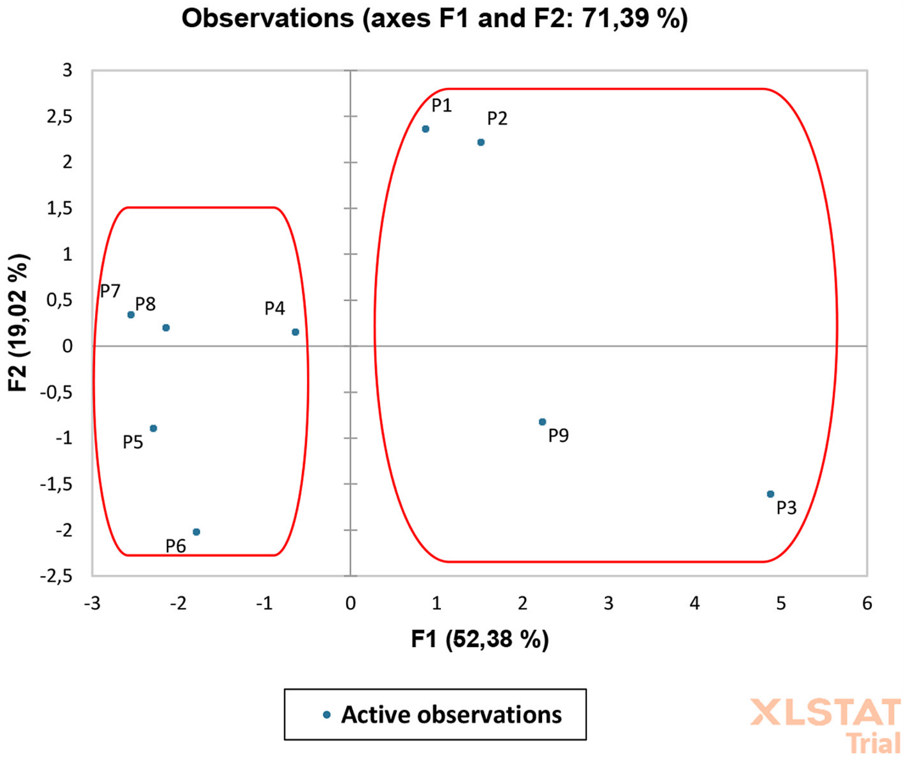

Figure 8. Projection of observations in the first factorial plane

This factor indicates parameters dependent on biotic factors. The projection of observations into factorial planes (Fig. 8) highlighted two groups of wells: the first group (P1, P2, P3, and P9) consists of the wells characterized by very high salinity, and the second group (P4, P5, P6, P7, and P8) comprises the wells with lower salinity. The high mineralization of groundwater is explained by the leaching of Triassic evaporitic rocks. Indeed, the study area is located on the Khemisset plateau, which is characterized by Triassic-age evaporitic formations (Et-Touhami et al., 2000). The study by El Qryefy et al. (2023) shows that the water from the wells located to the north of the lake is suitable for irrigation, while the water from the wells on the opposite shore is unsuitable for irrigation due to its high salinity. Generally, these waters are suitable for irrigating salt-tolerant crops on well-drained soils. In similar research conducted in Morocco, the salinization of groundwater could be attributed to the dissolution of evaporitic rocks (Bahir and Ouhamdouch, 2020; Elgettafi et al., 2012; Ouarani et al., 2023; Rochdane et al., 2022), seawater intrusion (Mountadar et al., 2018; Najib et al., 2016; Ouarani et al., 2023), agricultural pollution (Fakir et al., 2002; Re et al., 2013), or the combined presence of these three factors (El Mandour et al., 2008; Fakir et al., 2002). Wastewater can also infiltrate aquifers, contributing to the salinization of groundwater (Elmeknassi et al., 2022; Jilali et al., 2015).

CONCLUSIONS

This work was based on the geochemistry of groundwater in the areas adjacent to Lake Dayet Erroumi. It aimed to assess water salinity using descriptive and multivariate statistical methods. Averages of major ion concentrations showed that cation abundance is $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ and anion abundance is $Cl^- > HCO_3^- > SO_4^{2-} > NO_3^-$. Principal component analysis revealed a significant positive correlation between electrical conductivity, sodium and chloride and sulfate. These parameters indicate water mineralization and depend on abiotic factors (lithology of local rocks). The F1 factor, which accounts for more than half of the total variance (52.37%), is an axis of water mineralization. The second axis explains 19.01% of the information and shows a positive correlation with parameters (pH, DO) controlled by biotic factors. Analysis of the observations revealed two distinct groups of wells: the first (P1, P2, P3 and P9) includes the wells with extremely high salinity, while the second (P4, P5, P6, P7 and P8) includes those with lower salinity. The salinization of groundwater adjacent to Lake Dayet Erroumi is of natural origin, due to the dissolution of Triassic evaporitic rocks. This high salinity is a key factor in the degradation of groundwater quality for human consumption and irrigation. Generally, these waters are suitable for irrigating salt-tolerant crops on well-drained soils.

REFERENCES

1. ABHBC, 2015. Synthèse géologique de la région de Dayet Erroumi. Agence du Bassin Hydraulique du Bouregeg et de la Chaouia, Ben Slimane, Maroc.
2. Ali, S., Verma, S., Agarwal, M.B., Islam, R., Mehrotra, M., Deolia, R.K., Kumar, J., Singh, S., Mohammadi, A.A., Raj, D., 2024. Groundwater quality assessment using water quality index and principal component analysis in the Achnera block, Agra district, Uttar Pradesh, Northern India. Sci. Rep. 14, 5381.
3. Bahir, M., Ouhamdouch, S., 2020. Groundwater quality in semi-arid environments (Essaouira Basin, Morocco). Carbonates Evaporites 35, 41. https://doi.org/10.1007/s13146-020-00576-7
4. CEIBM, 2006. Centre d'Echange d'Information sur la Biodiversité du Maroc, Convention sur la Diversité Biologique. Biodiversité au Maroc. https://ma.chm cbd.net/manag_cons/esp_prot/sibe_ma/sibe_cont_hum/dayet-er-roumi-h9-./sibe_h9
5. El Mandour, A., El Yaouti, F., Fakir, Y., Zarhloule, Y., Benavente, J., 2008. Evolution of groundwater salinity in the unconfined aquifer of Bou-Areg, Northeastern Mediterranean coast, Morocco. Environ. Geol. 54, 491–503. https://doi.org/10.1007/s00254-007-0842-3
6. El Qryefy, M., El Madhi, Y., Belghyti, D., El Kharrim, K., 2023. Groundwater Suitability for Drinking, Irrigation and Aquaculture: Case of Areas Adjacent to Lake Dayet Erroumi, Khemisset, Morocco. Egypt. J. Aquat. Biol. Fish. 27. https://dx.doi.org/10.21608/ejabf.2023.312442
7. El Qryefy, M., Najy, M., Lachhab, M., Belghyti, D., Ouardi, J., El Kharrim, K., 2020. Evaluation of the Physicochemical Quality of Dayet Erroumi Lake in Low Water Period (Khemisset, Morocco), in: Proceedings of the 4th Edition of International Conference on Geo-IT and Water Resources 2020, Geo-IT and Water Resources 2020, 1–4.
8. El Qryefy, M., Ouardi, J., Najy, M., Belghyti, D., El Kharrim, K., 2021. Hydrochemical characteristics and water quality assessment of Lake Dayet Erroumi–Khemisset, Morocco. J. Water Land Dev. 179–187. http://dx.doi.org/10.24425/jwld.2021.137110
9. Elabidi, K., Amraoui, F., Amar, M., Bensalmia, A., 2015. Apport de la bathymetrie a l'etude hydrogeologique de Dayet Roumi. 5ème édition du congrès international Eaux, Déchets et Environnement Un défit millénaire (EDE5). Faculté des Sciences et Techniques Settat -Université Hassan 1 er Maroc Les 24–26 Novembre 2015.
10. Elemile, O.O., Ibitogbe, E.M., Folorunso, O.P., Ejiboye, P.O., Adewumi, J.R., 2021. Principal component analysis of groundwater sources pollution in Omu-Aran Community, Nigeria. Environ. Earth Sci. 80, 690. https://doi.org/10.1007/s12665-021-09975-y
11. Elgettafi, M., Elmandour, A., Himi, M., Casas i Ponsatí, A., Elhaouadi, B., 2012. Messinian salinity crisis impact on the groundwater quality in Kert aquifer NE Morocco: Hydrochemical and statistical approaches. Int. J. Water Resour. Environ. Eng. 4(11), 339–351. https://doi.org/10.5897/IJWREE12.002
12. Elmeknassi, M., Bouchaou, L., El Mandour, A., Elgettafi, M., Himi, M., Casas, A., 2022. Multiple stable isotopes and geochemical approaches to elucidate groundwater salinity and contamination in the critical coastal zone: a case from the Bou-areg and Gareb aquifers (North-Eastern Morocco). Environ. Pollut. 300, 118942. https://doi.org/10.1016/j.envpol.2022.118942
13. Et-Touhami, M., Bachmann, G., Lerche, I., 2000. Lithostratigraphy and depositional environments of Lower Mesozoic evaporites and associated red beds, Khemisset Basin, northwestern Morocco. Zentralblatt Geol. Palaontologie Teil I 1998, 1193–1216.
14. Fakir, Y., El Mernissi, M., Kreuser, T., Berjami, B., 2002. Natural tracer approach to characterize groundwater in the coastal Sahel of Oualidia (Morocco). Environ. Geol. 43, 197–202. https://doi.org/10.1007/s00254-002-0644-6
15. Gharbi, A., Ali, Z.I., Zairi, M., 2019. Groundwater suitability for drinking and agriculture purposes using irrigation water quality index and multivariate analysis: case of Sidi Bouzid aquifer, central Tunisia. Environ. Earth Sci. 78, 692. https://doi.org/10.1007/s12665-019-8733-y
16. Jilali, A., Abbas, M., Amar, M., Zarhloule, Y., 2015. Groundwater contamination by wastewater in Figuig oasis (eastern high Atlas, Morocco). Nat Env. Pollut Technol 14, 275–282.
17. M'nassri, S., Lotfi, D., Yann, L., Gerhard, S., Mohamed, H., Rajouene, M., 2018. Identifying the origin of groundwater salinisation in the Sidi El Hani basin (central-eastern Tunisia). J. Afr. Earth Sci. 147, 443–449. https://doi.org/10.1016/j.jafrearsci.2018.07.004
18. Milnes, E., 2011. Process-based groundwater

salinisation risk assessment methodology: Application to the Akrotiri aquifer (Southern Cyprus). J. Hydrol. 399, 29–47. https://doi.org/10.1016/j.jhydrol.2010.12.032

19. Mountadar, S., Younsi, A., Hayani, A., Siniti, M., Tahiri, S., 2018. Groundwater salinization process in the coastal aquifer sidi abed-ouled ghanem (province of el Jadida, Morocco). J. Afr. Earth Sci. 147, 169–177. https://doi.org/10.1016/j.jafrearsci.2018.06.025
20. Najib, S., Fadili, A., Mehdi, K., Riss, J., Makan, A., Guessir, H., 2016. Salinization process and coastal groundwater quality in Chaouia, Morocco. J. Afr. Earth Sci. 115, 17–31. https://doi.org/10.1016/j.jafrearsci.2015.12.010
21. Ouarani, M., Brahim, Y.A., Mulla, D., Rafik, A., Azennoud, K., Bouchaou, L., Chehbouni, A., 2023. A comprehensive overview of groundwater salinization and recharge processes in a semi-arid coastal aquifer (Essaouira, Morocco). J. Hydrol. Reg. Stud. 49, 101501. https://doi.org/10.1016/j.ejrh.2023.101501
22. Pauw, P., De Louw, P.G., Essink, G.O., 2012. Groundwater salinisation in the Wadden Sea area of the Netherlands: quantifying the effects of climate change, sea-level rise and anthropogenic interferences. Neth. J. Geosci. 91, 373–383. http://dx.doi.org/10.1017/S0016774600000500
23. Rao, Y.S., Keshari, A.K., Gosain, A.K., 2010. Evaluation of regional groundwater quality using PCA and geostatistics in the urban coastal aquifer, East Coast of India. Int. J. Environ. Waste Manag. 5, 163–180. https://dx.doi.org/10.1504/IJEWM.2010.029700
24. Re, V., Sacchi, E., Martin-Bordes, J.L., Aureli, A., El Hamouti, N., Bouchnan, R., Zuppi, G.M., 2013. Processes affecting groundwater quality in arid zones: the case of the Bou-Areg coastal aquifer (North Morocco). Appl. Geochem. 34, 181–198. https://doi.org/10.1016/j.apgeochem.2013.03.011
25. Rochdane, S., Elgettafi, M., El Mandour, A., Himi, M., Casas, A., Daafi, Y., Karroum, M., Chouikri, I., 2022. Contribution of electrical resistivity tomography in the study of aquifer geometry and groundwater salinization of Eastern Haouz and upstream Tassaout domain, Morocco. Environ. Earth Sci. 81, 122. https://doi.org/10.1007/s12665-022-10246-7
26. Vialle, C., 2011. Etude du comportement hydraulique, physico-chimique et microbiologique d'un système de récupération d'eaux de toiture. Evaluation de l'empreinte environnementale (PhD Thesis).
27. Zhang, X., Wu, J., Song, B., 2011. Application of principal component analysis in groundwater quality assessment, in: 2011 International Symposium on Water Resource and Environmental Protection. IEEE, 2080–2083. http://dx.doi.org/10.1109/ISWREP.2011.5893671