Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 27(4): 773 – 783 (2023)
www.ejabf.journals.ekb.eg

Groundwater Suitability for Drinking, Irrigation and Aquaculture: Case of Areas Adjacent to Lake Dayet Erroumi, Khemisset, Morocco

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ARTICLE INFO
Article History:
Received: April 7, 2023
Accepted: July 11, 2023
Online: Aug. 12, 2023

Keywords:
Groundwater,
Drinking,
Irrigation,
Lake Dayet Erroumi

ABSTRACT

This work was organized to study the hydrochemistry of groundwater in areas adjacent to Lake Dayet Erroumi to assess their suitability for drinking and irrigation. The physicochemical analysis of groundwater shows that pH, potassium, magnesium and sulfate values are within the permissible limits of the Moroccan standards for water drinking. The nitrate content from three wells exceeds the maximum value allowed by the Moroccan drinking water standards. These high nitrate values may be due to agricultural pollution or local contamination of wells. The values of electrical conductivity, sodium and chloride indicate that the wells on the north shore meet the Moroccan drinking water standards. On the other hand, the other wells recorded very high values surpassing the Moroccan standards for water drinking. The results of the Wilcox and Wilcox log diagrams show that the waters of the wells located north of the lake are suitable for irrigation. In contrast, the waters of the wells on the opposite shore are not suitable for irrigation due to their high salinity. Generally, these waters are suitable for the irrigation of salt-tolerant crops on well-drained soils.

INTRODUCTION

Groundwater represents a valuable natural resource for various human activities **(Amadi *et al*., 2010)**. It plays an axial role in the economy. Excessive exploitation of groundwater causes scarcity and degradation of water quality. It was reorted that, the deterioration of groundwater quality is due to socioeconomic development, population growth, modernization of agriculture and industrial evolution **(Nasri *et al*., 2018)**. Groundwater pollution is an evolving process in space and time that is difficult to control **(Abdelbaki & Hacène, 2007)**. Agricultural pollution is mainly due to the intensive and excessive use of fertilizers (chemical and organic) and pesticides (herbicides, insecticides and fungicides) **(Adjagodo *et al*., 2016)**.

In Morocco, agriculture is the biggest consumer of water resources. Indeed, the economic activity of Khemisset is mainly based on agriculture. The neighboring population of Lake Dayet Erroumi uses groundwater for domestic and agricultural purposes. Thus, this work aimed to study the hydrochemistry of groundwater in areas adjacent to Lake Dayet Erroumi to assess their suitability for drinking and irrigation.

MATERIALS AND METHODS

1. Study area

Lake Dayet Erroumi represents the only permanent natural low-lying continental lake in Morocco. It is located 15km southwest of Khémisset (Fig. 1). This site is a shallow lake (maximum 14 m) with an area of almost 90 ha. It represents an elongated lake in the WSW-ENE direction, with a length of 1.6km and a width of 400 to 700m. It corresponds to an elongated lake in the WSW-ENE direction, with a length of 1.6 km and a width of 400 to 700m **(CEIBM, 2019)**. The water of this lake is brackish **(El Qryefy *et al.*, 2020)**. The water mineralization is due to leaching Triassic evaporitic rocks **(CEIBM 2019; El Qryefy *et al.*, 2021)**.

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

2. Sampling and analysis methods

Groundwater samples were taken in November 2019. The sampling points, noted from P1 to P9, are scattered and located near the lake (Fig. 2). Samples of water collected were placed in one liter- sterile polyethylene bottles and transported to the laboratory in a cooler at 4°C.

The pH and electrical conductivity (EC) were measured *in situ* using Hanna Instruments HI 98280. The chemical composition was determined in the laboratory of the Regional Office for Agricultural Development of Gharb (ORMVAG). The concentrations of calcium (Ca^{2+}), magnesium (Mg^{2+}), and chloride (Cl^{-})were identified by the volumetric method. The contents of sodium (Na^{+}), potassium (K^{+}), nitrate (NO_3^{-}) and sulfate (SO_4^{2-})were analyzed by implementing an atomic absorption technique.

Moroccan standards have been adopted to assess the potability of water. Wilcox and Wilcox log diagrams were used to determine the suitability of water for irrigation. In this study, the Wilcox and Wilcox log diagrams were drawn by the "*Diagrammes*" software **(Simler, 2014)**.

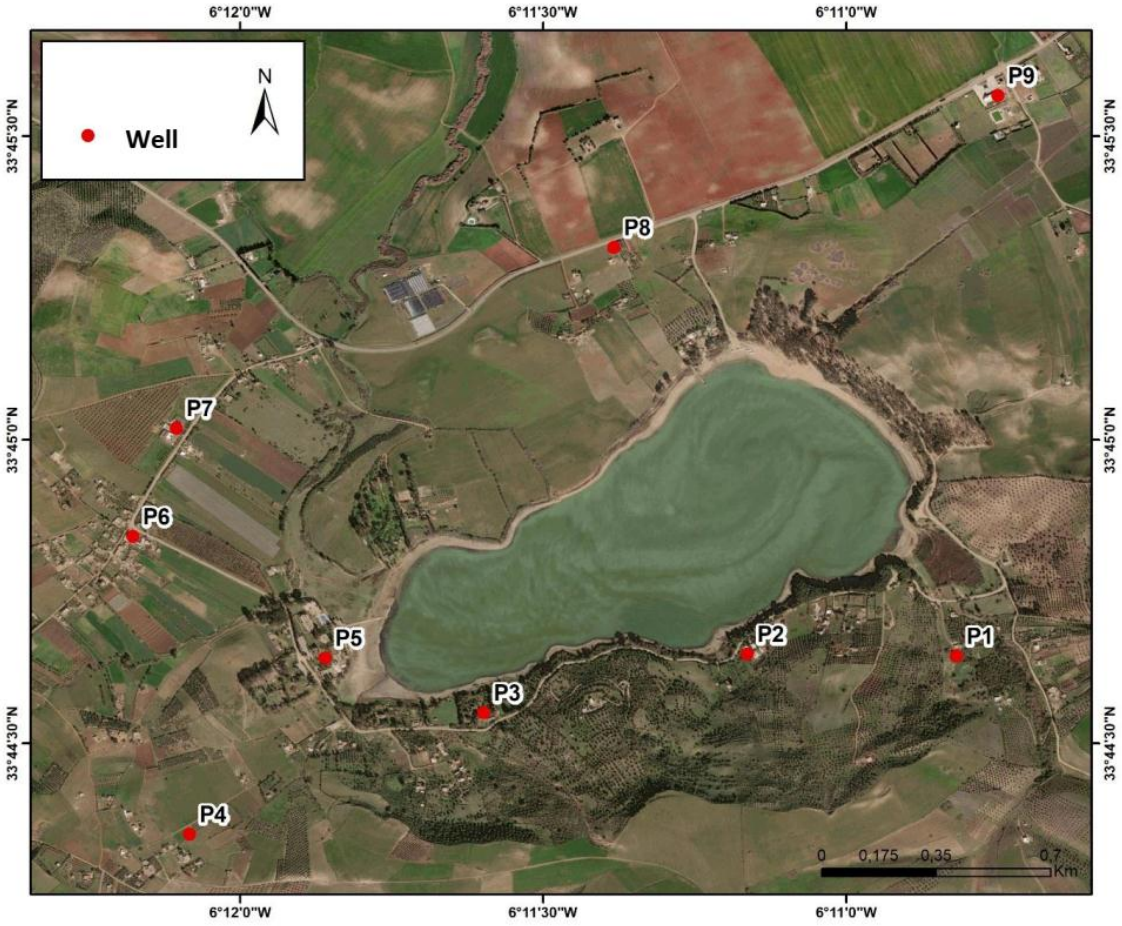

Fig. 2. Geographical location of the wells (P1-P9) in areas adjacent to Lake Dayet Erroumi, based on **Google Earth (2021)**

RESULTS AND DISCUSSION

1. Drinking water quality

The values of the physicochemical parameters of the groundwater are presented in Table (1). The results showed that the groundwater's pH values meet the Moroccan drinking water standards **(NM 03.7.001, 2006)**. The water electrical conductivity values are lower than the Moroccan standard set at 2700 µS/cm in wells P5, P6, P7 and P8. On the other hand, the water of wells (P1, P2, P3, P4 and P9) recorded very high values, which vastly exceed the Moroccan drinking water standards **(NM 03.7.001 2006)**. If the electrical conductivity of water exceeds 2000 µS/cm, it has a laxative effect on consumers **(Chemaou El Fehri, 2016)**.

The waters of wells P1, P2, P3, P4 and P9 recorded very high chloride concentrations, which exceed the Moroccan standard **(NM 03.7.001 2006)** set at 750 mg/L. On the other hand, the waters of wells P5, P6, P7 and P8 recorded chloride contents which meet the Moroccan standard **(NM 03.7.001 2006)**. The sodium concentration is very high in wells P1, P2, P3, P4 and P9 compared to the other wells P5, P6, P7 and P8.

The nitrate content of water from wells P3, P6 and P8 exceeds the 50mg/ L recommended by Moroccan drinking water standards **(NM03.7.001, 2006)**. These high nitrate concentrations may be due to agricultural pollution or local contamination of wells. **Er-Raioui *et al*. (2011)** explained that, a high nitrate concentration in drinking water can be pathological for humans and animals. The sulfate content of all the water from the wells studied is below the limit value (400 mg/L) allowed by the Moroccan standards **(NM 03.7.001, 2006)**.

Table 1. Physico-chemical parameters of groundwater samples from the study area

Parameter	P1	P2	P3	P4	P5	P6	P7	P8	P9	Moroccan standards
pH	8,18	7,54	7,25	7,72	7,65	7,57	7,68	7,86	7,66	6,5-8,5
CE (µs/cm)	6270	6210	9210	4380	2120	1800	1640	2010	6980	2700
Ca^{2+} (mg/L)	170,4	262,8	514,4	170,4	150,4	112	117,6	150	152,4	200
Na^{+} (mg/L)	920	966	1 081	632,5	138	142,6	138	165,6	1 035	-
Cl^{-} (mg/L)	1 579,75	1586,14	2 272	1 082,75	431,68	225,07	203,77	349,32	1 643,65	750
Mg^{2+} (mg/L)	173,5	71,93	227,69	116,88	104,25	103,28	74,36	81,41	213,6	-
K^{+} (mg/L)	1,4	1,96	0,78	0,39	0,39	0,78	0,78	0,78	1,17	-
SO_4^{2-} (mg/L)	250,08	270,72	374,88	93,6	48,48	41,76	31,2	45,6	187,68	400
NO_3^{-} (mg/L)	44,64	37,2	62,62	24,18	10,54	76,26	24,8	52,7	50,22	50

Based on the results of this study, only the waters of two samples (P5 and P7) are suitable for human consumption. The high mineralization of the water in certain wells (P1, P2, P3, P4 and P9) remains the essential factor in the deterioration of the quality of water intended for human consumption. The high salinity of groundwater can be explained by the leaching of evaporitic rocks from the Triassic **(El Qryefy *et al*., 2020, 2021; Et-Touhami, 2000)**. In addition, three wells (P3, P6 and P8) recorded water contamination by nitrates.

2. Groundwater suitability for irrigation

In our study, the Wilcox and Wilcox log diagrams were adopted to assess groundwater suitability for irrigation. The Wilcox diagram **(Wilcox, 1948)** is based on the electrical conductivity on the abscissa axis and the sodium content on the ordinate axis. This diagram defines five classes of water: excellent, good, permissible, doubtful and unsuitable. The sodium content in water is expressed as a percentage according to the following formula **(Madhav *et al*., 2018; Adimalla, 2019; Xu *et al*., 2019)**:

$$Na\% = \frac{\left(Na^{+} + K^{+}\right) \times 100}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}}$$

The Wilcox log diagram is based on the sodium adsorption rate (SAR) in the ordinate axis and the electrical conductivity in the abscissa axis. The SAR represents the content of sodium relative to calcium (Ca_2^{+}) and magnesium (Mg_2^{+}) in water **(Sajil Kumar *et al*., 2014; Belksier, 2017; Bhatti *et al*., 2019)**. The sodium absorption rate (SAR) is used to express the intensity of the alkaline risk **(Rouabhia & Djabri, 2010; Gouaidia *et al*., 2013; Khechana & Derradji, 2014)**. The SAR is defined by the formula below **(Xu *et al*., 2019; Ravi *et al*., 2020; Mao *et al*., 2021)**:

$$SAR = \frac{Na^{+}}{\sqrt{\left(Ca^{2+} + Mg^{2+}\right)/2}}$$

Salinity is the main water quality problem for irrigation since salts can affect both soil structure and crop yield **(Fipps, 2003)**. Eminently, these salts cause on the one hand modifications of the permeability and the aeration of the soil, and on the other hand disturbances of the metabolism and the osmotic process of the plants **(Gouaidia, 2008)**. Na^{+} concentration is an important parameter in water quality classification for irrigation purposes **(He *et al*., 2019)**. Sodium indirectly harms vegetation by degrading the physical properties of the soil **(Rouabhia & Djabri, 2010)**. In this context, **Minhas *et al*. (2019)** reported that, sodization leads to a deterioration of the soil structure and consequently to the manifestation of physical stress. It is remarkable that, excess sodium causes the clogging of soil particles **(He *et al*., 2019)**. Consequently, this clogging reduces permeability, leading to plant asphyxiation **(Rouabhia & Djabri, 2010)**. When the

concentration of Na^+ ions in the soluble state in the soil is high, these ions frequently replace the Ca_2^+ cations in the absorbing complex **(Rouabhia & Djabri, 2010)**.

The results obtained by the Wilcox diagram (Fig. 3) show that the groundwater adjacent to Lake Dayet Erroumi belongs to the following classes: “good” (P6, P7 and P8), “Doubtful “(P5) and “unsuitable” (P1, P2, P3, P4 and P9).

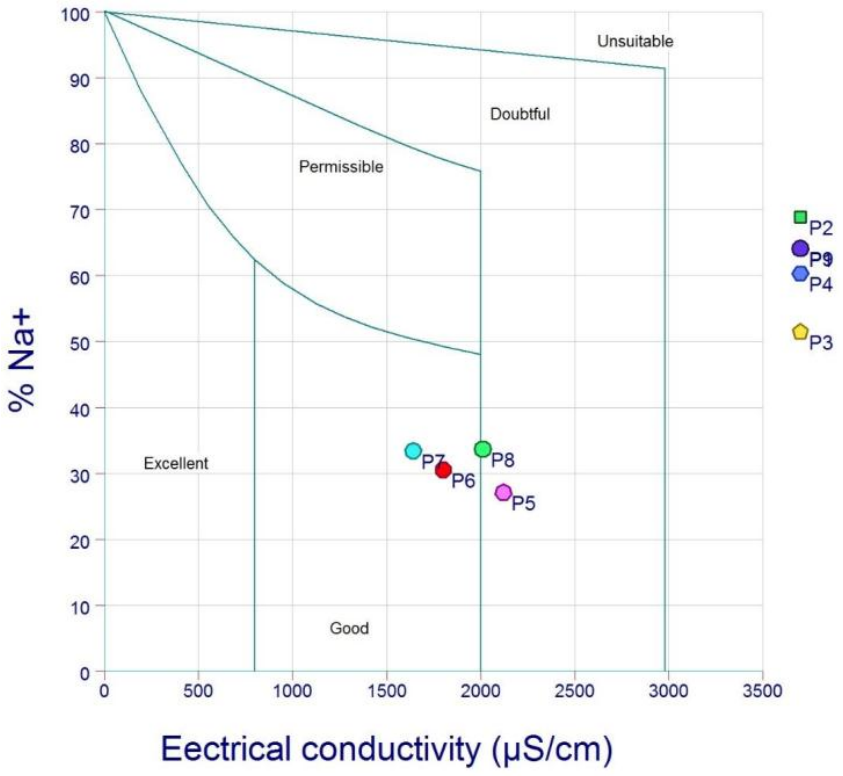

Fig. 3. Classification of groundwater according to the Wilcox diagram

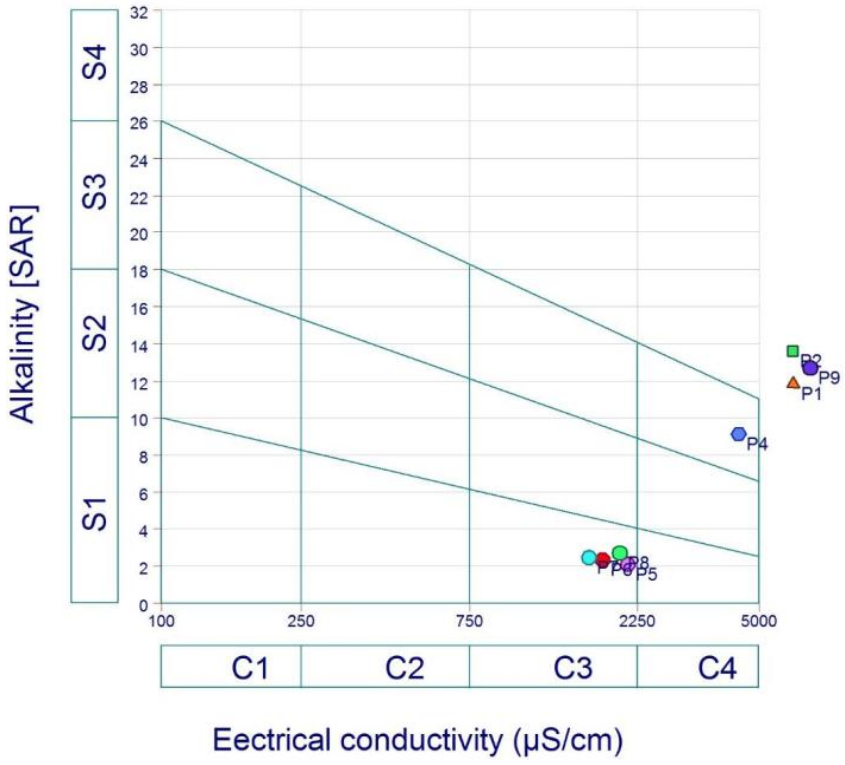

Fig. 4. Classification of groundwater according to the Wilcox log diagram

According to the Wilcox log diagram (Fig. 4), the groundwater studied belongs to the following classes:

- C3-S1 for wells P5, P6, P7 and P8. This class designates moderately mineralized waters, with a low risk of alkalinization.

- C4-S3 for well P4. This class indicates highly mineralized waters, with a high risk of alkalinization.

- C4-S4 for wells P1, P2, P3 and P9. This class designates highly mineralized waters, with a very high risk of alkalinization.

The previous results indicate that, the waters of the wells located north of the lake (P5, P6, P7 and P8) are suitable for irrigation. On the other hand, the waters of wells P1, P2, P3, P4 and P9 are not suitable for irrigation due to their high salinity. Generally, these waters are suitable for the irrigation of salt-tolerant crops on well-drained soils (Table 2).

Table 2. Groundwater quality for irrigation purposes

Quality	Class	Samples	Irrigation use
Excellent	C1-S1		Water safe to use for irrigation of most crops on most soils.
Good	C2-S1 C2-S2		In general, water can be used without special measures to irrigate moderate salt-tolerant crops on soils with good permeability.
Permissible	C3-S1 C3-S2 C2-S3	P5, P6, P7 , P8	In general, water suitable for irrigation of salt-tolerant crops, on well-drained soils. The evolution of salinity must be controlled.
Doubtful	C4-S1 C4-S2 C3-S3		In general, highly mineralized water that may be suitable for irrigation of some salt-tolerant species on well-drained and leached soils.
Unsuitable	C3-S4 C4-S3 C4-S4	P1, P2, P3, P4, P9	Water is not generally suitable for irrigation but can be used under certain conditions: very permeable soils, good leaching, plants very tolerant of salt.

CONCLUSION

Water is an essential element for human life and health. For domestic and agricultural uses, the surrounding population exploits groundwater in areas adjacent to Lake Dayet Erroumi. In this paper, physicochemical analysis was used to assess the suitability of groundwater for human consumption and irrigation in this lake. Nine wells were sampled in September 2019.

The physicochemical study of groundwater revealed that the pH, potassium, magnesium and sulfate values meet the Moroccan water potability standards. While, the nitrate content of the waters of wells P3, P6 and P8 exceeds the maximum value set by the Moroccan drinking water standards. These high values may be due to agricultural pollution or local contamination of wells. The electrical conductivity, sodium and chloride values show that wells P5, P6, P7 and P8 meet the Moroccan drinking water standards. On the other hand, wells P1, P2, P3, P4 and P9 recorded very high values, exceeding the Moroccan water potability standard. All these results show that the high mineralization of water from certain wells remains the essential factor in the deterioration of the quality of water intended for human consumption. The physicochemical data on groundwater revealed that the waters of the wells located north of the lake are suitable for irrigation. In contrast, the waters of the wells on the opposite shore are not suitable for irrigation due to their high salinity. Generally, these waters are permissible to irrigate salt-tolerant crops on well-drained soils.

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