Contribution to the study of the hydro-chemical characteristics of the lake ecosystem Dayet Er-Roumi, Morocco

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Abstract. The protection of the Freshwater ecosystem is necessary for the ecosystem equilibrium of the aquatic fauna and a healthy diet for the local community. Lake Dayet Er-Roumi (SIBE) is under the pressure of various pollution forms that are, most of the time, a result of human activities. The purpose of this study is to assess the various forms of pollution as well as pollution's degree and evaluate the quality of the water's lake and its tributaries through spatio-temporal monitoring of diverse physicochemical parameters during two seasons, autumn (low water period) and spring (high water period), of the year 2019. The variations of physicochemical parameters such as pH, EC, and significant anions, namely: NO_3^-, NO_2^-, NH4+, PO43–, SO_4^{2-}, and Cl^- had been studying at seven stations (five stations at lake level and two stations representing the tributaries). The Results revealed wide variations in the concentrations of different physicochemical parameters between the different samples during the two seasons; the data set indicated high concentrations of chlorides in both seasons, with average nitrates and orthophosphates concentrations during the spring season. The results obtained show a very high electrical conductivity with a pH of the water is very basic, which shows that the lake's water is immensely loaded with different minerals. These results greatly exceed the standards of fish water quality and also surface water quality.

1 Introduction

Freshwater is an indispensable resource for life. It deserves special attention, as it is highly altered and threatened by human activities. Indeed, demographic growth accompanied by rapid urbanization causes numerous disturbances for natural environments [1]. Industrialization and the irrational use of fertilizers and pesticides (fungicide, herbicide, and insecticide), and the absence of the citizen's sensitization towards environmental protection [2], give rise to an imbalance in the ecosystem and engender polluting elements that can affect the biological and physical-chemical quality of the receiving aquatic environments [2, 3]. Generally, the assessment of surface water quality is based on the determination of physicochemical parameters and the existence or absence of aquatic organisms and also microorganisms, indicators of water quality.

The study of physicochemical quality and the assessment of surface water's trophic level allows us to discriminate and determine the mineral elements that deteriorate water quality and threaten aquatic life [4, 5], It is the concentration of these elements that defines and illustrates the quality of water [4] and whether it threatens aquaculture life or not. These mineral elements are diverse, in a dissolved or suspended state (bicarbonates, sulfates, magnesium, sodium, calcium, phosphorus, potassium, nitrogen, iron, and aluminium), they arrive from soil and subsoil, wildlife, and vegetation; also they come from precipitation and runoff, as well as physical, chemical, and biological processes occurring in the body of water itself. The products resulting from human activities (such as nitrogen, phosphorus, ammonium, etc.) can be added to these substances of natural origins or industrial and agricultural activities (toxic substances, heavy metals, pesticides, etc.) [6]. However, anthropogenic activity remains the leading cause of natural water quality's degradation, it changes the hydrological water conditions, and this, in turn, alters the aquaculture activities resulting in decreased fish productivity, the change in species composition avifauna, eutrophication, disturbance of the trophic chain and an overall loss of biodiversity[7,8].

Water quality monitoring, through the study of physicochemical parameters, is essential to evaluate the state of an aquatic ecosystem exposed to anthropogenic factors. The most widely measured quality parameters that govern aquatic life are pH, temperature, electrical conductivity (EC), dissolved oxygen (DO), transparency,

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turbidity, total dissolved solids (TDS), nitrogen, and phosphorus, etc. These abiotic factors are usually the driving forces of the environment, and disturbance of certain parameters can lead to ecological inequalities, for example, excessive nitrate and nitrite accumulation in surface waters cause eutrophication, ammoniacal nitrogen may deplete DO in natural waters by microbial nitrification reactions [9]. However, anthropic activity is the primary source of water quality degradation. As the majority of world countries, Morocco does not escape lake water pollution's problem, Dayet Er-Roumi Lake (Site of Biological and Ecological Interest) is the unique natural lake remaining in the Khmisset region, it plays a vital role. When it comes to food and socio-economic, it serves as a dwelling place for lake populations; it contains fish and crustaceans that are considered as food sources for the people of the region, etc. These significant roles explain the high concentration of people around and in this body of water. The lake and its shoreline have become a receptacle for solid and liquid waste. These wastes and products are being released daily into the lake or the shore, which constitutes a potential source of chemical pollution of the lake. In these total absence conditions of hygiene and sanitation measures around the lake, pollution and contamination risks are very high.

Recent studies [10], [11] have revealed that lake Dayet Er-Roumi presents high mineralization (an important salinity, with a dominance of chlorides) and significant metal pollution (Mn, Al, Zn, and Pb, etc.) in the water as well as in the sediment [10,12], which reflects the direct influences of human activities (uncontrolled use of fertilizers and phytosanitary products (herbicide and fungicide, etc.), wastewater (septic tank), and domestic discharges, etc.) on the ecological quality of the lake. An additional entire diagnosis of the current pollution state and rigorous monitoring of its evolution is fundamental and indispensable to safeguard and protect this ecosystem. The perspective of our study consists of evaluating the physicochemical properties of the lake's water during two seasons, autumn and spring of the year 2019, and studying anthropogenic activities effect on the quality of the lake's waters.

2 Material and Methods

2.1 Study area study

Dayet Er-Roumi Lake (33°45'N -06°12'W) is located, on the alluvial coastal plain among Rabat to the West and the Middle Atlas Mountains to the East, 15 km southwest of Khémisset. This lake is situated on three rural communes: Ait Houderrane, Ait Ouahi, and Ait Ouribel. It is discriminated by a semi-arid climate with a minimum winter temperature of 7°C, a maximum summer temperature of 38°C, and a middling rainy regime. The lake has an area of about 90 ha and a maximum depth of 13.5 m in the middle of the lake, also it has 2 km long and a 400 m to 700 m width [13]. This lake ecosystem is fed by groundwater and two tributaries (Figure 1).

2.2 Samples and sampling techniques

The samples were collected from different points of the lake. In general, the choice of sampling sites was based on juxtaposed anthropogenic activities. On whole, there are seven sampling points (S1-S7), five stations in the lake (S1-S5) represent the sites that are most probably to be affected by anthropogenic activities (the houses, hotel, camping, etc.), for the other two chosen points they are representing the lake's tributaries (S6 and S7) (Figure 1). The water samples were taken by a Van d'Horn bottle at different depths to get a composite sample, the sampling was carried out during the autumn season (low water period) and spring season (high water period), of the year 2019.

The analyses of diverse physicochemical parameters were carried out following the method reported by Rodier [14] and Afnor [15]. In situ parameters such as electrical conductivity (EC) and the potential of hydrogen (pH) were measured in the field. The other parameters, such as nitrates, nitrites, sulfates, ammonium orthophosphates, and chlorides, were analyzed in the laboratory after samples preservation (the samples are stored at 4° c).

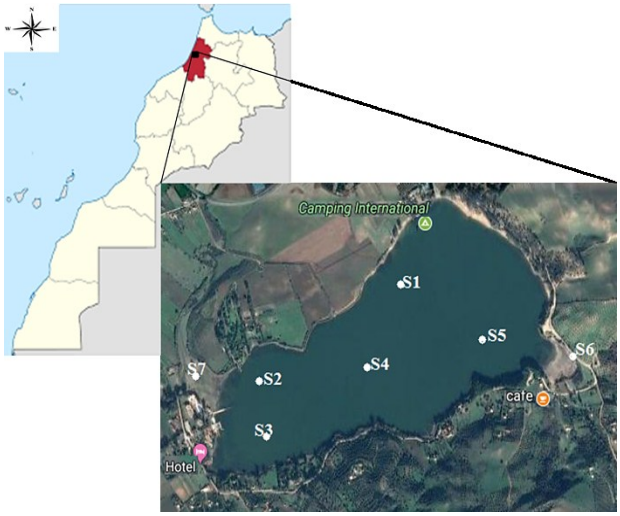

Fig.1. Study area and location of sampling points.

2.3 Statistical Analysis

The statistical analysis was realized using ANOVA to identify and determine the correlation between selected water quality parameters, test if there's an existence of important and significant differences between averages or not; also the correlations between the parameters provide us with the information on the strength of possible associations between them [16]. The Ascending Hierarchical Classification Cluster (ACH) was used to determine and evaluate if there is a possibility to group the samples into statistically distinct hydrochemical groups that could be significant in the geologic context [17] and to evaluate the different groups of variables depending on the average values of various parameters.

3 Results and discussion

3.1 Physico-chemical characteristics of water

3.1.1 In situ parameters: potential hydrogen (pH) and electrical conductivity (EC)

The pH measures the hydrogen ion concentration in water; water's pH value indicates whether the water is acidic or alkaline. In this work, the hydrogen ion concentration (pH) fluctuates between 8.04-9.23 and 8.45-9.45 during autumn and spring respectively (Fig. 2). The absolute maximum value was recorded at station two (S2) during spring, while the absolute minimum value was measured at affluent (station 7). A higher value was observed during the spring, this is due to the period of precipitation which induces leaching of the grounds and subsequently water very charged in ion. Based on these results, we found that the pH is beyond the limits of the standards [18] and [19], Most of the data lie on the alkaline side indicating that the lake waters are highly basic.

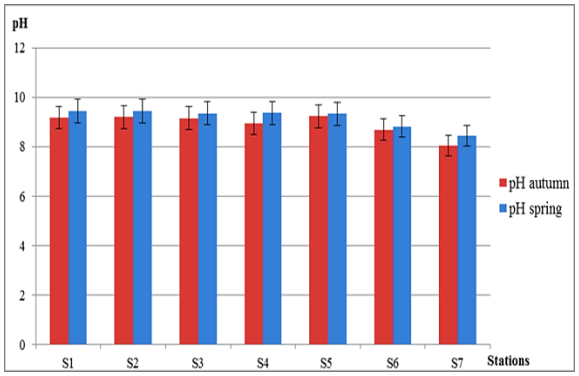

Fig.2. variation Spatio-temporal of potential hydrogen (pH).

It was known that electrical conductivity is a quantify of the capacity of an aqueous solution to transport an electric current that relies on the existence and total concentration of ions, their flexibility, and mobility, as well as the temperature [20]. In the present study, the maximum value of EC was 4163.67 us/cm recorded at station 6 (affluent) during spring, while the minimum value was 1407 us/cm registered at the seventh station during autumn (fig.3). From these results, we can deduce that the Electrical Conductivity (EC) highly exceeds the limits of the standards [18] and [19]. These results enabled us to observe that the Waters of this lake are extremely mineralized and very charged with different ions (Ca^{2+}, Mg^{2+}, Cl^{-}, Al, etc.).

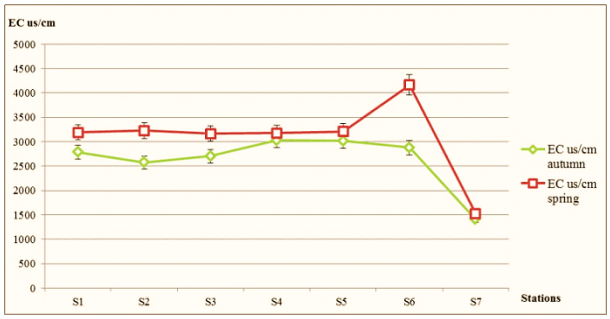

Fig.3.variation Spatio-temporal of electrical conductivity (EC).

3.1.2 Variation of major ions (NO_3^-, NO_2^-, *NH4+, PO43–,* SO_4^{2-}*, and* Cl^-*)*

The concentration of nitrites varies between 0.01-0.08 mg/ l during autumn while it ranges between 0.05-0.21 mg/ l during spring (Fig. 4). During the autumn season, the lowest value was recorded at affluent (S7) while during the spring season at the same station, the highest concentration was observed. This shows us the effect of the rains that shovels all the agricultural substances (fertilizers, etc.). In general, the recorded values didn't pass the limits [18] and [19].

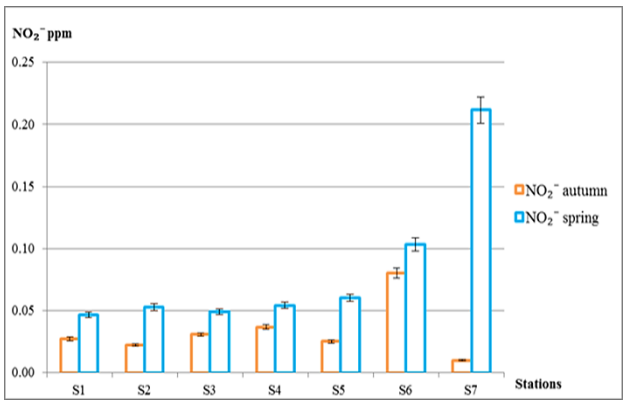

Fig.4. variation Spatio-temporal of nitrite levels.

Nitrate's concentration in the Lake water ranges between 0.5 and 4 mg/ l during autumn and varies between 8-11.51 mg/ l during spring (Fig. 5). The absolute maximum value was measured at station 7(affluent) during spring. The concentration of nitrate exceeds the recommended standards [18] and [19], which indicates the leaching of agricultural land, wild-animal wastes, etc.

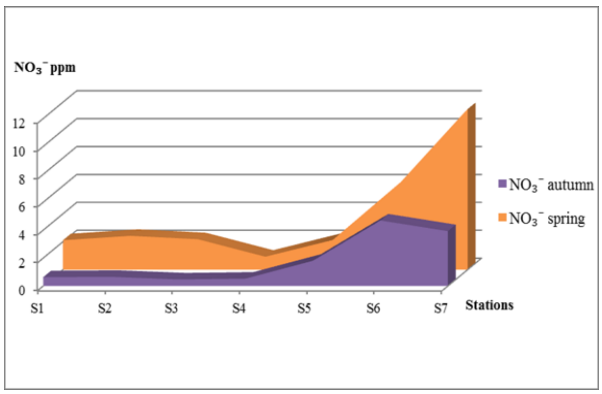

Fig.5. Spatio-temporal variation of nitrates.

Figure 6 represents the ammonium concentration changes during the period of study. Ammonium concentration increased to a maximum value during autumn at affluent (station 6) and a minimum value during autumn at station 1. In general, the recorded values didn't exceed the recommended standards [18] and [19].

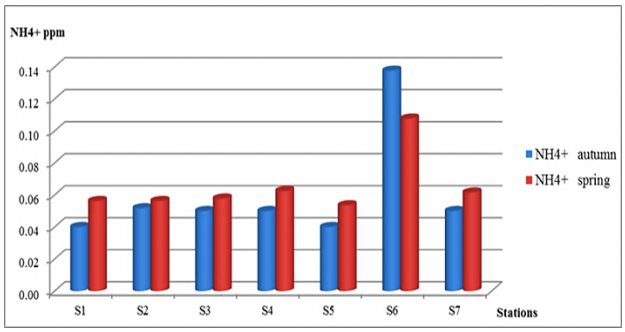

Fig.6. Spatio-temporal variation of ammonium.

The concentrations of orthophosphates oscillate between 0.05 mg/l and 0.66 mg/l. The highest value (0.66 mg/l) was noted during the autumn season; this value demonstrates the effect of human activities (domestic waste, non-rational use of pesticides and fertilizers, etc.).The recorded concentrations slightly pass the limits [18] and [19].

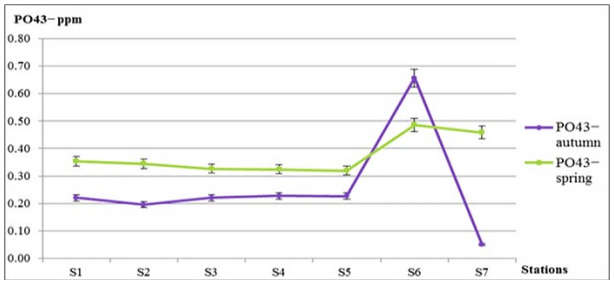

Fig.7. Spatio-temporal variation of orthophosphates.

The water contains chlorides but in very variable proportions; chloride's content generally increases with the mineralization degree of the water [21]. The chlorides concentrations in the Lake water ranges between 308.44 and 1128.99 mg/l during autumn, while it varies between 294.65 and 1004.06 mg/l in Lake water during spring (Fig. 8). The absolute maximum value was measured at station 6 (affluent) during autumn.

The recorded chloride level was higher than the recommended standards [18] and [19] in the entire sampling points during the spring and autumn. This high concentration of chlorides is mainly associated with natural through-fields (Triassic evaporite rocks), in addition to the significant involvement of anthropogenic activities (agriculture, domestic waste, etc.).

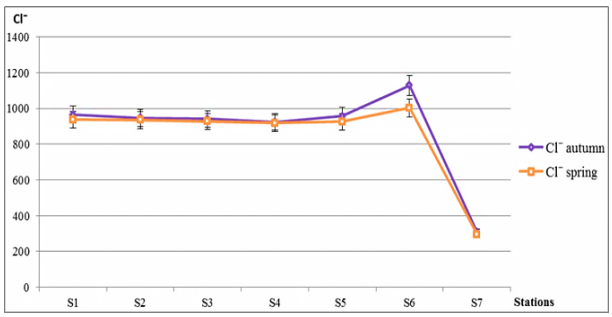

Fig.8. Spatio-temporal variation of chlorides.

Seasonal variation of sulfate content exhibits high values during spring at station 1 (94.76 mg/l) compared with the low value measured at station 6 (47.65 mg/l). The low sulfate value was measured during autumn (Fig. 9). In general, the recorded values did not exceed the recommended standards [18] and [19].

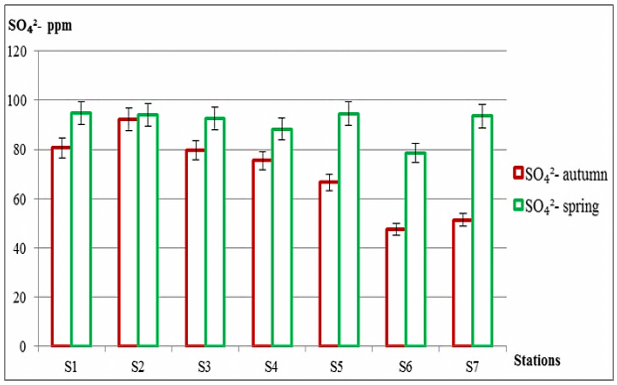

Fig.9. Spatio-temporal variation of sulfate.

3.2 Correlation between different parameters in the water of Lake Dayet Er-Roumi

In order Statistical analysis has been carried out by Pearson's correlation coefficient among the various physicochemical parameters (such as temperature, pH, Cl^-, etc.) to develop a significant correlation among the parameters. The results are described below, based on the table, we observed that there are strong and great correlations between the various parameters: Nitrates have a strong negative correlation with pH (r= -0.963**), Nitrites also have a strong negative correlation with pH (r=-0.984**) and a strong positive correlation with Nitrates (r= 0.967**). For the orthophosphates, a strong positive correlation has been observed with ammonium (r= 0.97**).We also note a strong positive correlation of Chlorides between pH (r= 0.767*) and electrical conductivity(r=0.984**). For sulphates, they are a strong negative correlation between different ions: nitrates (r=-0.771*), Nitrites(r=-0.821*) and ammonium (r=-0.84*). According to these results, we note a strong significant correlation between pH and chloride, as well as between chloride and electrical conductivity; however, an essential contribution of chlorides induces an increase of pH and also of electrical conductivity. These great concentrations are probably due to the geological nature of the crossed fields, not to forget the involvement of human activities in this increase. Similarly, we found that there is a significant correlation between orthophosphates and ammonium and between nitrates and nitrites because these various physic-chemical parameters act and behave in synergy; these correlations are highly significant which highlights and witness the affinity among these elements.

Table 1. Correlation among the studied physicochemical parameters.

	pH	CE	$NO3^-$	$NO2^-$	NH_4^+	PO_4^{3-}	Cl^-	SO_4^{2-}
pH	1	0.675	-0.963**	-0.984**	-0.444	-0.244	0.767*	0.75
CE		1	-0.597	-0.549	0.348	0.523	0.984**	0.049
$NO3^-$			1	0.967**	0.512	0.35	-0.68	-0.771*
$NO2^-$				1	0.587	0.401	-0.652	-0.821*
NH_4^+					1	0.97**	0.231	-0.84*
PO_4^{3-}						1	0.429	-0.723
Cl^-							1	0.201
SO_4^{2-}								1

** The correlation is significant at the 0.01 level.
* The correlation is significant at the 0.05 level.

A comparison was made among various parameters from different samples, and then the parameters were assembled according to their resemblances and their similitudes to each other. In the present work, to classify and arrange the parameters into distinct hydrochemical groups, the dendrogram method Q-mode HCA was used. For this analysis, we applied Ward's linkage method [22]. A classification scheme using Euclidean distance (straight line distance among two points in c-dimensional space defined by c variables) for affinity and resemblance measurement, Jointly with Ward's method for linkage, produces the most distinctive and particular groups where each member within the group (or cluster) is plus analogous and similar to its fellow members than to any member outside the group [23].

The eight hydrochemical parameters measured (EC, pH, NO_3^-, NO_2^-, NH4+, PO43–, Cl^-, and SO_4^{2}-) were utilized in this analysis. According to figure 10, there are three groups or clusters:

group 1: composed of nitrates, nitrites, orthophosphates, ammonium, sulfate, and pH;

group 2: combines the pH and chlorides;

group3: composed of EC and pH.

Many very significant relationships have been identified between all the measured variables: an important relationship between pH and EC and also among pH and chlorides.

pH, EC, and chloride contents are high; this is due to the geological (triassic evaporite rocks) and geographical position, discharges of domestic wastewater, and contamination of groundwater that feed the lake [24]; also contamination of the lake and its tributaries by septic tanks, because of the bad sewage systems, agricultural fertilizers, and the dissolution of clay formations could be responsible for this elevation.

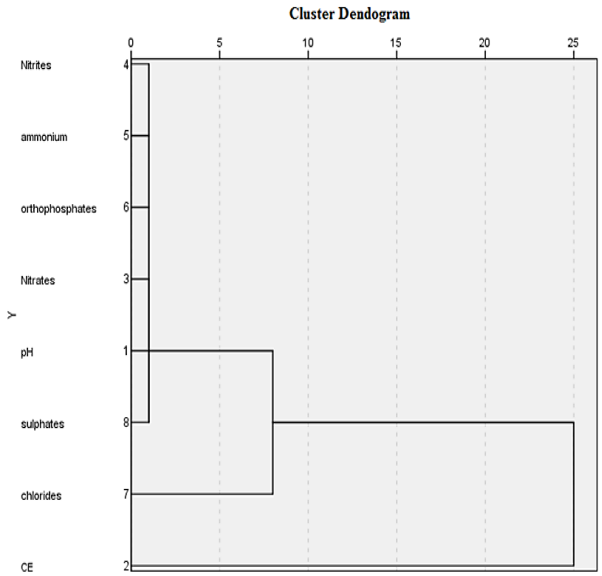

Fig.10. Dendrogram of selected parameters in water samples using ward's method.

4 Conclusion

Nowadays, the safeguard and the protection of the aquatic ecosystems became a fundamental necessity for the biodiversity of the fauna as well as flora. The spatio-temporal study of Lake Dayet Er-Roumi's water quality made it possible to make a physicochemical characterization. This characterization shows that the pH, the electrical conductivity, and the chlorides present very high values that are vastly exceeding the recommended standards, which has a direct effect on aquatic life. Monitoring other concentrations such as nitrates and orthophosphates shows average values with low concentrations of sulfates, nitrites, and ammonium. These results show that the waters are very loaded, daily control and management are necessary to preserve and protect this SIBE.

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