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# Assessment of Pollution in Sidi M'Hamed Benali Lake (Algeria) Based on Bioindicators and Physicochemical Parameters

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*A B S T R A C T*

This study was carried out to investigate the degree, the nature and the origin of pollution in Sidi M'hamed Benali Lake using the physicochemical parameters, saprobic index and cladocerans. For this purpose, water and zooplankton sampling was collected from six sites in lake during five seasons. The average seasonal values of physicochemical parameters showed that the lake undergoes a slight anthropogenic and natural pollution in the dry and wet periods. Presence of certain toxic substances ($CN^-$, Cr, Ni) require us to be more careful in irrigation, bathe and the consumption of fishes of that reservoir. Overall, oligo-mesosaprobic to beta-mesosaprobic rotifers have been prevailing in all five seasons indicating that the water was slightly or moderate polluted. The presence of *Bosmina longirostris*, *Daphnia longispina*, *Daphnia cuculata*, *Daphnia ambiga* and *Sididae diaphonosoma brachyrum* indicate bacterial contamination with the intense development of the phytoplankton in the lake, especially in springs and summer. Pearson correlation analysis revealed significant correlation between all of the physicochemical parameters. However, it revealed no significant correlation between zooplanktons occurrence and the majority environmental variables values. In present investigation, the Lake water is relatively little exposed to pollution and does not undergo strong organic pollution.

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## INTRODUCTION

The surface water is an essential resource of the life. It deserves a very detailed attention, considering which it very faded and is seriously threatened by the natural processes (weathering processes, precipitation rate, soil erosion) and the anthropogenic activities [1]. The latter, induce strong alterations of physicochemical characteristics and of biocenose diversity that could have dangerous consequences for the whole ecosystem [2-4]. Thus, they generate polluting elements which damage their use for drinking, bathing, industrial, agricultural, reaction or other purposes [5, 6].

In order to provide a complete array of information for the assessment of water quality, the best way is to compile a range of different physical, chemical and biological parameters [7, 8]. Zooplankton is a good indicator of changes in water quality because it is strongly affected by environmental conditions and responds quickly to changes in environmental quality [3, 4, 7, 9, 10]. Among zooplankton, some cladocères as *Bosmina longirostris* and *Chydorus sphaericus* are commonly used as eutrophic indicators of conditions [10]. The rotifers with their high population turnover rates are particularly sensitive to water quality changes. They are good indicators of saprobity [11].

The Sidi M'Hamed Benali (SMB) Lake is a decantation barrage. Constructed in 1945 to attenuate the force of the current due to the rise of water during the rainy season, and prevent the flooding in the center of the Sidi Bel Abbes city. The overflow is diverted through an underground channel 5 km to feed the Sarno Wadi dam by water at least limpid, used directly for

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irrigation and indirectly (after treatment) as drinking water.

The lake constitutes essentially of deposit lake and alluvia ancient, with a calcareous crust. The remaining material is a combination of marl and clay. It is surrounded by a very rich vegetation, and presents an important richness of aquatic ecosystems (fishes, planktons, ducks…). But still not far around the lake, fields of cultivation of cereals are spread out. These fields lead the contamination of the lake by excess fertilizers and pesticides. Thus, he receives various pollutants its watershed and particularly the Mekerra wadi which became an open sewer [12].

During almost all the time and particularly during the summer season, it constitutes a relaxation center (bathe, fishing, camping). Anthropogenic activities on the lake are numerous: agricultural activities, anarchistic and abusive and not regulated fishing (the growing number of fishermen) and the high number of visitors involving automatically heaps of rubbish and waste of bivouac, behind them and washing of cars. Then this ecosystem is submitted to both influences, urban and rural. The pollution involves an imbalance of these ecosystems and pushed us to make this study.

The present study was made to assess water quality of the SMB Lake of the Sidi Bel Abbes city using the physicochemical parameters and bioindicators organisms (rotifers and cladocerans). It is necessary to determine the degree, the nature and the origin of pollution and its impact on the fauna and the flora.

## MATERIALS AND METHODS

The study area is located at 4 km northern part of Sidi Bel Abbes city. It covers an area of 40 ha, located at an altitude of 460 m (coordinated geographical: $X_1$= 195.3, $Y_1$= 220.7; $X_2$=195.9, $Y_2$=221.6). The lake is located at the outskirts of the mountainous massif of Tessala, Hajar, and Meraei Kerrouche, which is a southern watershed feeding the different bodies of water in the region during the rainy periods. It has a capacity of about 3 million $m^3$ and a maximum depth of 30 m. It's subject to a semi-arid climate with cool winters and dry season followed by a short rainy season. The highly variable rainfall from year to year, on average 400mm. Six sites were chosen in the littoral zone of the lake (Figure 1). The sampling of physicochemical parameters and zooplankton was carried out every other month, from March 2011 to August 2012 except July and August 2011 (five seasons: spring, autumn, winter 2011 and spring, summer 2012), about 2 - 4 m of distance towards the broad and 20 -30 cm of depth. All the samples were taken in the morning between 8:00 to 10:00am. The water samples were carried in one liter glass bottle sterile and kept in a low temperature (stored in ice) until the samples were transferred to laboratory for further analysis. The water temperature was recorded in situ with a mercury thermometer. The parameters such as dissolved oxygen (DO), electrical conductivity (EC), salinity, and the total dissolved solids (TDS) were measured with a multi- parameter HACH (SensIONTM156). Turbidity is measured with a turbidimeter HACH (2100N, turbidimeter). Carbonate alkalinity ($CO_3^{-2}$), bicarbonate alkalinity ($HCO_3$), total hardness and chloride ($Cl^-$) were carried out according to colorimetric methods stated in literature [13]. Nitrates ($NO_3^-$), nitrites ($NO_2^-$), sulphate ($SO_4^{-2}$), orthophosphates ($PO_4^-$), cyanide ($CN^-$), zinc (Zn), nickel (Ni), chromium (Cr), copper (Cu) and total iron (Fe) were quantified with spectrophotometry (spectrophotometer HACH DR/EL2) used a case HACH DR/EL2, when which each of them has kits, a wavelength and a specific method of analysis.

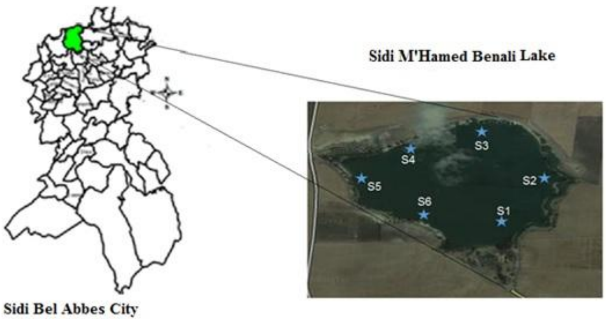


**Figure 1**: Sampling sites at the SMB Lake.

The sampling of zooplankton was carried out horizontal line through 55 µm mesh plankton net. The end of net comprises a recipient equipped with the same net whose concentrated species were emptied in a clean glass bottle. The collected samples were brought to laboratory and filtered with the same net (55 µm). The zooplankton recuperate was anaesthetized immediately in saturated $CO_2$ solution (V/V: mineral water + commercial soda-water) and fixed by 4% formaldehyde according to literature recommendations [3, 4]. The identification of the individual is carried with a binocular loupe (Olympus, SZ60) or a contrasting phase microscope (Olympus BX50). Rotifers and cladocerans were identified to various taxonomic levels (genera or species). Several identification keys were used for these determinations [13-19]. The rotifers were classified in different classes according to their saprobic valences determined [11].

Numerical data were presented as seasonal average and standard deviation (SD) by using Excel 2010. The Pearson correlation coefficient at a confidence limit of 95% and the value of $p<0.05$ was applied using Systat

13.0 to study the relation between all of the physicochemical parameters of water and also the zooplankton occurrence and the environmental parameters.

## RESULT AND DISCUSSION

The hydrobiological regime of the SMB Lake during the period of study is characterized by large variations of physicochemical parameters. Descriptive statistics of the physicochemical parameters including the seasonal average and standard deviation are summarized in Table 1.

The values of average seasonal water temperature obeys perfectly to the seasonal variation, the lowest temperatures were found in winter (13.91°C) and the highest in summer (25.36°C), thus distinguishing between a warm and a cold season. The seasonal variability of the water temperature is related exclusively to the time concept and not to sampling stations [20-22]. However, several authors [23-25]showed that it varies regularly on the longitudinal profile of a lake according to the atmospheric temperature and the weather conditions. Its condition is based on the possibilities of development and the duration of the biological cycle of each species.

The water pH values are in alkaline zone. Their average seasonal values varied from 7.57 to 8.58 and it doesn't present very important fluctuations except for the summer which records the highest values. Arrignon [26] and Rodier *et al*. [24] showed that the pH values varied from 5-9 are most favorable for fish life. However, according to reported literature [21], pH values of 6.5 to 7.8 for water is the most favorable for fish production and 7.5 to 8.5 for average fish production. Thus, the present values of pH may be considered as suitable for fish life and production.

In the present investigation, the values of mean seasonal water EC content ranged from 1468.46–1691.33 US/Cm. It is proportional to the time. The increase in mineralization in summer would be favored by the reduction in the flow of water (a minimum capacity of the lake); this is according to literature [20, 28] and with the acceleration of the mineralization of the organic matter by a bacterial process [20, 29]. Rodier *et al*. [24], estimate that the EC higher than 1000 µS/cm corresponds to a high mineralization and a rate higher than 1500 µS/cm makes that water as not easily usable in the irrigated zones. From that we can deduce that the water of SMB Lake was charged with minerals (dissolved salts) and normally would not be used for the irrigation.

The Salinity varies between 0.73 to 0.9%, it is influenced by precipitations and liberate of fish. The values, showed salinity is proportional to time for seasons. The curve takes a right form of the autumn at the winter.

The average concentrations of the TDS are proportional to the time. It is higher in summer (853.17 mg/l) and lower in spring 2011 (748.19 mg/l). Generally, the TDS concentrations in the lake are essentially influenced by extreme anthropogenic activities and runoff with high suspended matter [30].

Except for spring 2011 (509.58 mg/l), a total hardness undergoes a reduction in the autumn to spring then it marks a peak of 542.89 mg/l in summer. Generally, the total hardness is depending on the

**Table 1**: Descriptive statistics of physicochemical water parameters for five seasons of investigation period

| Seasons | Spring 2011 | | Autumn | | Winter | | Spring 2012 | | Summer | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameters | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| T (°C) | 21.33 | 5.45 | 19.78 | 5.34 | 13.91 | 4.44 | 20.18 | 4.58 | 25.36 | 2.44 |
| pH | 7.93 | 0.29 | 7.60 | 0.25 | 7.93 | 0.14 | 7.57 | 0.20 | 8.58 | 0.97 |
| EC (US/Cm) | 1468.46 | 56.46 | 1586.72 | 51.79 | 1619.28 | 26.52 | 1681.45 | 19.28 | 1691.33 | 12.26 |
| Hardness (mg/l) | 509.58 | 31.98 | 572.22 | 4.20 | 556.67 | 31.23 | 441.67 | 10.93 | 542.89 | 83.33 |
| Turbidity (UNT) | 6.02 | 2.42 | 7.11 | 4.31 | 5.90 | 4.50 | 3.91 | 2.07 | 6.93 | 0.42 |
| Salinity (‰) | 0.73 | 0.06 | 0.80 | 0.00 | 0.80 | 0.00 | 0.83 | 0.06 | 0.90 | 0.00 |
| TDS (mg/l) | 748.19 | 5.68 | 789.06 | 28.29 | 806.22 | 14.33 | 838.56 | 10.47 | 853.17 | 3.50 |
| $CO_3^{-2}$ (mg/l) | 19.17 | 6.87 | 46.11 | 23.35 | 29.44 | 5.85 | 16.11 | 3.47 | 29.17 | 8.46 |
| $HCO_3^-$ (mg/l) | 143.13 | 20.87 | 130.67 | 2.52 | 145.00 | 14.53 | 110.00 | 6.01 | 185.28 | 17.21 |
| $Cl_2$ (mg/l) | 0.10 | 0.02 | 0.12 | 0.01 | 0.16 | 0.15 | 0.27 | 0.14 | 0.28 | 0.14 |
| DO (mg/l) | 7.56 | 0.20 | 6.73 | 0.12 | 9.95 | 2.09 | 5.63 | 0.25 | 5.65 | 0.17 |
| $NO_3^-$ (mg/l) | 3.86 | 1.22 | 3.61 | 0.27 | 4.30 | 0.60 | 3.23 | 0.44 | 3.19 | 0.13 |
| $NO_2^-$ (mg/l) | 0.23 | 0.08 | 0.04 | 0.01 | 0.06 | 0.01 | 0.29 | 0.01 | 0.30 | 0.00 |
| $SO_4^{-2}$ (mg/l) | 69.96 | 3.11 | 68.89 | 1.58 | 69.67 | 1.64 | 63.50 | 3.98 | 70.00 | 0.67 |
| $Cl^-$ (mg/l) | 516.94 | 82.92 | 495.67 | 14.50 | 439.17 | 71.83 | 454.56 | 68.84 | 592.50 | 31.61 |
| $PO_4^-$ (mg/l) | 1.40 | 0.44 | 0.99 | 0.29 | 0.82 | 0.53 | 0.72 | 0.46 | 1.21 | 0.93 |
| Fe (mg/l) | 0.03 | 0.02 | 0.06 | 0.02 | 0.07 | 0.01 | 0.07 | 0.00 | 0.05 | 0.02 |
| Cn (mg/l) | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| Cr (mg/l) | 0.01 | 0.00 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0,00 | 0.01 | 0.01 |
| Cu (mg/l) | 0.24 | 0.19 | 0.14 | 0.07 | 0.06 | 0.01 | 0.15 | 0.04 | 0.30 | 0.05 |
| Ni (mg/l) | 0.03 | 0.01 | 0.02 | 0.00 | 0.03 | 0.01 | 0.05 | 0.5 | 0.03 | 0.00 |
| Zn (mg/l) | 0.03 | 0.01 | 0.02 | 0.01 | 0.02 | 0.00 | 0.02 | 0.01 | 0.02 | 0.00 |

geology of the area with which the surface water is associated [30].

The values of average seasonal water turbidity are irregular in the time. It is higher in autumn and the lowest in spring 2012. The turbidity in water is caused by the substances not present in the form of true solution.

The highest average concentration of $CO_3^{-2}$ was 46.11 mg/l in autumn and the lowest was 16.11 mg/l in spring 2012.

The average concentration of $HCO_3^-$ ranged from 110 mg/l (spring 2012) to 185.28 mg/l (summer). On the basis of average value of $HCO_3^-$, the lake water can be classified under high category of nutrient types after the classification [31] as the alkalinity values were > 100 mg/l. On the basis of literature [32] classification it can be safely termed as hard water type. Thus lake water can be regarded to be of high productive value.

The high $HCO_3^-$ was recorded in summer, according to which was possibly due to the low rainfall and evaporation of water which cause a low volume of water causing an increase in alkalinity. This is according to observations have been made [21, 33, 34].

The average concentration of the $Cl_2$ undergoes a seasonal variation proportional to time. The average concentrations increase, slightly in autumn and the winter and strongly in spring and summer. The source would be the products of cars scrubbing [24] ; generally it is the dry period where there are many tourists.

The values of DO increased in the wet period (maximum peak of 9,95 mg/l) comparing to the dry period (minimal peak of 5,63 mg/l). According to literature [24], this solubility is function to the temperature, the atmospheric partial pressure and salinity. When the temperature rises, the DO content decreases because of its lower solubility, but also a cause of the consumption increased by the living beings and the bacteria which multiply. Consequently the reduction of nitrates to nitrite and sulphates to sulphide can be favored. The rates of DO are inversely proportional to the temperature and salinity. High DO during winter was observed by several authors [29, 35-37]. Admittedly the air and water temperature are the factors controlling the concentration of DO in to freshwater but these are not the only factors. The other factors responsible for reduction of dissolved oxygen contents are wind action and anthropogenic activities [21, 36].

The values of $Cl^-$ were increased in the wet period comparing to the dry period. It was highest during summer (592.5 mg/l) which may be due to gradual decrease in the amount of water and increased amount of excreta laid by the various aquatic fauna [21, 38]. The minimum values of $Cl^-$ during rainy season was due to the addition of rain water. As the $Cl^-$ content is indicator of the index of pollution of animal origin, high $Cl^-$ content indicates deterioration of water quality [21].

The averages of $NO_3^-$ calculated on the whole of the SMB Lake vary during the annual cycle: the highest contents are observed in winter (4.30 mg/l) and the lowers concentrations are observed in summer (3.19 mg/l). The increase in $NO_3^-$ during rainy season could be attributed to the scrubbing of fertilizers used in the agricultural grounds located on lakesides and the training of waste of vegetable and animal. However the decrease in $NO_3^-$ during summer, is probably associated with active uptake of this element by the phytoplankton and the plants (this period is characterized by a very strong vegetation), and due to the action of denitrifying bacteria which are quite active at high temperature (this is according to [39]). According to the results we notice a decrease in the $NO_3^-$ concentrations and an increase in those of $NO_2^-$. Also this reduction in the $NO_3^-$rates could be due to the DO low level and since the $NO_3^-$ represent the most oxygenated form of nitrogen, can play in period of weak oxygenation the part of oxygen donor, thus avoiding the anaerobiose, according to [2, 21]. These seasonal variations were mentioned by several authors in the literature [2, 40].

The seasonal average values of $NO_2^-$, weaker are observed in autumn and winter are oscillate between 0.04 and 0.06 mg/l, respectively, on the other hand, the highest median values are noticed in spring 2011, 2012 (0.23 and 0.29 mg/l, respectively) and in summer (0.30 mg/l). Thus in the wet period, the water of that lake is much impoverished out on nitrous nitrogen due to the effect of dilution ensures permanently by precipitations (rain) on the one hand and the good oxygenation of water, on the other hand, supporting thus the oxidation of nitrite to nitrate and the biological oxidation of ammonium to nitrite.-According to [24], in the absence of pollution, the contents are maintained on very low levels (about 0.01 mg/l). Below a hundredth of mg/l, water can be regarded as pure or being under the action of an active self-purification, in the presence of some tenth of mg/l pollution is sensitive, this one becomes significant beyond 1 mg/l. According to these data we note that water of lake is slightly polluted by $NO_2^-$.

Unlike $NO_3^-$, $PO_4^-$ show seasonal variations marked relatively by a trend to increase in dry period compared to the wet period by a difference of more than of 1 mg/l. This element, comes from a multiplicity of sources, in particular the decomposition of organic matters (at high temperature), the scrubbing of agricultural land rich in phosphate fertilizers (during rainy season), and also come from waste waters and salting out of the phosphorus trapped in large quantity in the sediments [41, 42].

The seasonal average concentrations of $SO_4^{-2}$ approach. They are very comparable. These rather important contents certify the impact of waste waters rich in these ions coming from the habitats and, also testify to the effect of the contributions of agricultural origin [ 29].

The average of the CN- rate is zero in spring 2011 and summer, and it records a value of 0.1mg /l for rest of seasons.

The average of the Fe total rate is higher in winter and spring 2012 and lower in spring 2011. The average concentration of Cr ranged from 0.01 to 0.02 mg/l. The Cu concentrations increase in the dry period comparing to the wet period whose maximum value is noticed in summer. The seasonal values of Ni show that this element is weak in autumn and higher in spring 2012. The average of the Zn is similar except spring 2011. According to literature [24], these values obtained do not have any toxicity on fauna and the watery flora. The accumulation of heavy metals along the SMB Lake may depend largely on common sources of pollution, which are identified as agricultural runoff and domestic sewage.

Rotifers species classified according to the saprobic index proposed by Sladecek [11] show that, in the SMB Lake, oligo-betamesosaprobic and beta-mesosaprobic rotifers account for the major fraction of the zooplankton (35 and 28%, respectively). Followed by oligo-mesosaprobic species (14%), then beta-oligomesosaprobic indicators (10%) who's the species *Kerratella cochlearis* belongs (most frequent during the whole investigation period). Followed by the beta-alphamesosaprobic with a percentage of 7%. However, just some inventory species are alpha-mesosaprobic and beta-xenosaprobic (*Epiphanes santa* and *Polyarthra minor*, respectively), they are presents by same and a weak frequency (3%).

Regarding the seasonal fluctuation (Figure 1), of saprobity index, the species oligo-betamesosaprobic is maintained in the course of time. According to literature [11], this medium has a $DBO_5$ ranging between 1 and 5mg/l.

Admittedly, rotifers are good indicators of saprobity [11], but this does not exclude the importance of the cladocerans like indicators of water quality. Several researchers [10, 43, 44] determined the quality of several lakes by basing on the presence of some cladocerans (exp. daphniidae, bosminidae, sididae, chydoridae, llyocryptidae) known by their bacterivore activity, phytophagous and détritivores. Wylie and Currie [45] showed that 16 to 21% of carbon necessary to the cladocerans would come from their activity of predation on the bacteria.

For some investigation *Bosmina longirostris* is the most frequent species, which is quantitatively dominated zooplanktons in the majority of the stations is a species bacterivore, phytophagous and détritivores [43] and indicatrix of the eutrophic conditions [10]. According to literature [7], it is classified among the indicating species of the betamesosaprobic mediums.

The presence of several species of daphniidae (*Daphnia longispina*, *Daphnia cuculata*, *Daphnia ambiga*) with a frequency at least important, especially in springs can be also explained by the presence of the bacteria in significant amount (important bacterial load) and phytoplanktons. Because that species have bacterivore activity and are phytophagous [43, 44]. The presence of the bacteria was confirmed by the appearance of the species of sididae diaphonosoma brachyrum [43], this at the end of the spring 2011 at the beginning of the winter and the summer. According to literature [43], the majority of the identified species of cladocerans could indicate a bacterial contamination and the intense development of the phytoplanktons in the lake.

Pearson correlation analysis effectuates between the different studied water quality parameters (Table 2) shows strong significant correlation between all of the parameters. This indicates showed that the entire parameters share a common origin source except $CN^-$, Cr, Ni and Zn did not show a significant correlation with all of the parameters. There is interaction between zooplankton occurrence and the water quality parameters (Tables 2 and 3). These interactions are directly or indirectly subjected to the complex influences, they are results in quantitative and qualitative changes [30, 46-48]. Zooplankton occurrence showed no significant negative correlated with EC which is poorly negatively correlated. It is also showed no significant negative correlation with hardness, turbidity, salinity, TDS and $CN^-$ which are moderately to poorly negatively correlated. However, they showed significant negative correlation with Fe and $CO_3^{-2}$ which are poorly negatively correlated.

Zooplankton occurrence showed no significant positive correlation with the rest of the parameters, which are moderately (water temperature, pH) to poorly correlated (DO, $HCO_3^-$, $SO_4^{-2}$, Cr, Ni, $Cl^-$), the exception has to do with the $NO_2^-$ and Cu where they showed significant positive correlation with species which are moderately correlated.

## CONCLUSION

This work forms part of the framework of the evaluation of physicochemical, biological quality and the level of contamination of this water reserve. The

**Table 2:** Total correlation between water physicochemical parameters and zooplankton occurrence

| Parameters | T C | pH | EC | Hardness | Turbidity | Salinity | TDS | OD | Fe | $Cl_2$ | $CO_3^{-2}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T | 1 | | | | | | | | | | |
| pH | 0.129 | 1 | | | | | | | | | |
| EC | 0.106 | 0.242 | 1 | | | | | | | | |
| Hardness | -0.022 | -0.130 | -0.216 | 1 | | | | | | | |
| Turbidity | -0.130 | 0.216 | 0.036 | 0.408 | 1 | | | | | | |
| Salinity | 0.225 | 0.345 | 0.753 | -0.003 | 0.123 | 1 | | | | | |
| TDS | 0.249 | 0.207 | 0.933 | -0.071 | 0.081 | 0.858 | 1 | | | | |
| DO | -0.385 | -0.046 | -0.231 | 0.237 | -0.248 | -0.397 | -0.322 | 1 | | | |
| Fe | -0.140 | -0.313 | 0.554 | 0.234 | 0.226 | 0.504 | 0.547 | -0.004 | 1 | | |
| $Cl_2$ | 0.227 | 0.380 | 0.613 | -0.256 | -0.129 | 0.464 | 0.603 | -0.174 | 0.248 | 1 | |
| $CO_3^{-2}$ | -0.105 | 0.026 | 0.158 | 0.596 | 0.548 | 0.079 | 0.169 | 0.066 | 0.182 | 0.008 | 1 |
| $HCO_3^-$ | 0.182 | 0.697 | -0.068 | 0.235 | 0.330 | 0.314 | 0.095 | -0.095 | -0.282 | -0.028 | 0.015 |
| $NO_3^-$ | -0.264 | -0.022 | -0.084 | 0.251 | -0.111 | -0.125 | -0.157 | 0.527 | 0.101 | -0.164 | -0.052 |
| $NO_2^-$ | 0.389 | 0.220 | 0.093 | -0.496 | -0.189 | 0.276 | 0.235 | -0.571 | -0.289 | 0.376 | -0.509 |
| $SO_4^{-2}$ | 0.128 | 0.259 | -0.239 | 0.519 | 0.407 | 0.078 | -0.129 | 0.276 | -0.114 | -0.373 | 0.325 |
| $CN^-$ | -0.231 | -0.128 | 0.640 | -0.038 | 0.288 | 0.384 | 0.539 | -0.104 | 0.690 | 0.129 | 0.336 |
| Cr | -0.055 | -0.236 | 0.490 | -0.435 | -0.371 | 0.227 | 0.409 | 0.274 | 0.448 | 0.407 | -0.280 |
| Cu | 0.667 | 0.289 | 0.021 | 0.018 | 0.003 | 0.211 | 0.139 | -0.379 | -0.227 | 0.188 | -0.191 |
| Ni | -0.261 | -0.008 | 0.215 | -0.246 | -0.064 | 0.033 | 0.191 | -0.208 | 0.163 | 0.543 | -0.133 |
| Zn | 0.011 | 0.099 | -0.499 | 0.034 | 0.247 | -0.353 | -0.512 | 0.073 | -0.082 | 0.007 | -0.144 |
| $Cl^-$ | 0.255 | 0.266 | -0.152 | 0.384 | 0.226 | 0.215 | 0.058 | -0.473 | -0.252 | 0.149 | 0.062 |
| $PO_4^-$ | 0.237 | -0.025 | -0.483 | 0.302 | -0.362 | -0.167 | -0.352 | 0.159 | -0.168 | 0.129 | -0.079 |
| Occurrence | 0.470 | 0.332 | -0.196 | -0.445 | -0.316 | -0.236 | -0.204 | 0.068 | -0.518 | 0.144 | -0.523 |

**Table 2:** Continue.

| Parameters | $HCO_3^-$ | $NO_3^-$ | $NO_2^-$ | $SO_4^{-2}$ | $CN^-$ | Cr | Cu | Ni | Zn | $Cl^-$ | $PO_4^-$ | Occurrence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $HCO_3^-$ | 1 | | | | | | | | | | | |
| $NO_3^-$ | -0.190 | 1 | | | | | | | | | | |
| $NO_2^-$ | 0.104 | -0.279 | 1 | | | | | | | | | |
| $SO_4^{-2}$ | 0.397 | 0.397 | -0.174 | 1 | | | | | | | | |
| $CN^-$ | -0.363 | 0.048 | -0.150 | -0.087 | 1 | | | | | | | |
| Cr | -0.439 | 0.159 | 0.005 | -0.250 | 0.240 | 1 | | | | | | |
| Cu | 0.167 | 0.237 | 0.571 | 0.355 | -0.167 | -0.148 | 1 | | | | | |
| Ni | -0.163 | 0.030 | 0.206 | -0.649 | 0.048 | 0.163 | -0.150 | 1 | | | | |
| Zn | 0.104 | -0.053 | -0.060 | -0.048 | -0.404 | -0.215 | -0.087 | 0.201 | 1 | | | |
| $Cl^-$ | 0.425 | 0.036 | 0.460 | 0.207 | -0.352 | -0.529 | 0.635 | 0.160 | 0.021 | 1 | | |
| $PO_4^-$ | 0.049 | 0.129 | 0.123 | 0.061 | -0.429 | -0.311 | 0.213 | 0.102 | 0.382 | 0.342 | 1 | |
| Occurrence | 0.045 | 0.224 | 0.512 | 0.084 | -0.382 | 0.045 | 0.554 | 0.020 | 0.297 | 0.055 | 0.251 | 1 |

**Table 3**: Probabilities Matrix of Bonferroni zooplankton occurrence and environmental parameters

| Parameters | T | pH | EC | Hardness | Turbidity | Salinity | TDS | DO | Fe | $Cl^2$ | $CO_3^{-2}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Occurrence | 0.066 | 0.209 | 0.466 | 0.084 | 0.233 | 0.380 | 0.449 | 0.803 | 0.040 | 0.594 | 0.037 |
| Parameters | $HCO_3^-$ | $NO_3^-$ | $NO_2^-$ | $SO_4^{-2}$ | $CN^-$ | Cr | Cu | Ni | Zn | $Cl^-$ | $PO_4^-$ |
| Occurrence | 0.867 | 0.404 | 0.043 | 0.758 | 0.145 | 0.868 | 0.026 | 0.940 | 0.264 | 0.839 | 0.348 |

result of physicochemical parameters revealed a well-defined seasonal variation. The average seasonal values during the sampling period showed that the lake undergoes a slight anthropogenic and natural pollution in the dry and wet period. Presence of certain toxic substances (CN-, Cr, Ni) require us to be more careful in the use of that reservoir. The biotic index reveals that lake belongs to the oligo-mesosaprobic medium to beta-mesosaprobic, contains water slightly polluted to moderately polluted, and is relatively weak on organic matter load degradable. However, the presence of some cladocerans indicates bacterial contamination with the intense development of the phytoplanktons in the lake, especially in springs and summer. The Pearson correlation analysis revealed significant correlation between all of the parameters and no significant

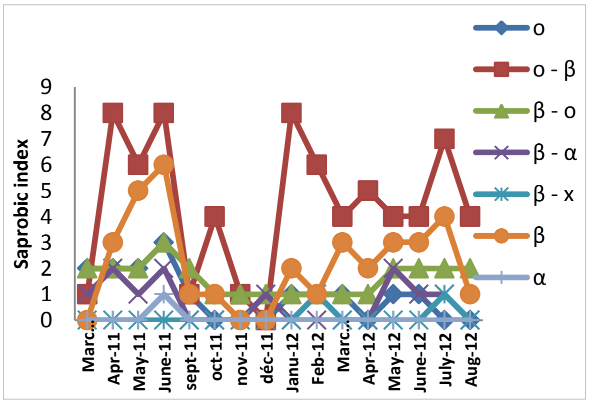


**Figure 2**: Temporal variation of the saprobic index during investigation period.

correlation between zooplankton occurrence and the values of the majority environmental variables. In conclusion, the analyses of physicochemical parameters and the predominance of the typical species of the mediums low in putrescible organic matters reveals that the lake is little exposed to pollution and does not undergo strong organic pollution.

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**Persian Abstract**

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**چکیده**

این مطالعه برای بررسی درجه، طبیعت و منبع آلودگی در دریاچه ی Sidi M'hamed Benali با استفاده از پارامترهای فیزیکی شیمیایی، شاخص saprobic و cladocerans انجام شد. برای این منظور، آب و جانوران ریز شناور بر سطح دریا از شش نقطه در دریاچه در طول پنج فصل جمع آوری شد. مقادیر میانگین فصلی پارامترهای فیزیکی شیمیایی نشان داد که دریاچه متحمل آلودگی های نسبتا انسانی و طبیعی در بازه های زمانی خشک و مرطوب می شود. حضور اجزای سمی مشخص ($CN^-$, Cr, Ni) به ما می گوید که که در آبیاری، استحمام و مصرف ماهی های استخر محتاط باشیم. به طور کلی، روتیفر oligo-mesosaprobic به beta-mesosaprobic در هر پنج فصل متداول شده که مشخص می کند آب کمی یا نسبتا آلوده شده است. حضور *Bosmina longirostris*، *Daphnia longispina*، *Daphnia cuculata*، *Daphnia ambiga* و *Sididae diaphonosoma brachyrum* *آلودگی باکتریایی را با توسعه ی شدید فیتوپلانکتون در دریاچه، مخصوصا در بهار و تابستان مشخص می کند.آنالیز همبستگی پیرسون ارتباط قابل توجه بین پارامترهای فیزیکی شیمیایی را نشان داد. با وجود این، هیچ رابطه ی معناداری بین* وقوع جانوران ریز شناور بر سطح دریا و مقادیر متغیرهای گسترده ی زیست محیطی آشکار نشد. در پژوهش حاضر، آب دریاچه به طور نسبتا کمی در معرض آلودگی قرار دارد و متحمل آلودگی آلی قوی نیست.