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Evaluation of organic pollution index and the bacteriological quality of the water of the Lake of birds (ELTarf East-Algerian)

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- ✓ Lake of Birds
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Abstract

The region of EL-Tarf (ExtremeEast – Algerian) is composed of a variety of Wetlands, lake of birds is part of this complexit is an ecosystem of freshwater classified as a Ramsar site in 1999, known for its biodiversity. The water pollution of this ecosystem is a reality and represents a serious environmental problem because on the one hand discharges of domestic wastewater in lake, and secondly the intensive farming at the edges of the lake (cattle, sheep).To protect this aquatic ecosystem it has become essential to make this pollution measurable by the evaluation of the index of organic pollution which is calculated according to the method of Leclercq Maquet (1987), the results show a high organic pollution and also the bacteriological results shows a very important fecal contamination expressed by high rates in total coliforms, fecal coliforms, and fecal streptococci. The Principal Component Analysis (PCA) revealed two gradientsthe first one reflects the degree of organic pollution while the second describes the metallic pollution of waters in order to give answers to the main causes of pollution.

1. Introduction

The quality of surface waters and groundwater of a geographical region can be affected by anthropogenic activities [1], by proliferation of different sources of pollution (fertilizers and pesticides, untreated wastewater discharge, uncontrolled solid waste discharge, urbanization, etc.) constitutes a threat [2]. The lack of public awareness of the protection of the environment, lead to an imbalance of the ecosystem and generate polluting elements [3].

In general, the quality of surface water may result from anthropogenic and natural constraints [4]. Protection of environment requires protecting the water quality of the watershed from urban or industrial pollutions [5], many wastewaters entering the aquatic environment contain plant nutrients: various organic materials and nutrients mainly nitrates and phosphates [6]. Many of organic substances are readily biodegradable and can be broken down and eliminated through natural self-purification capacity of aquatic environments. However, when in excess their decomposition may lead to asphyxia of aquatic wildlife, the control of water quality requires a good knowledge of the origins of their pollution and the effects of that pollution on the environment [7].

Many works also related the study different effects of industrial and urban discharges on the evolution of the quality of surface waters and pollution of aquatic ecosystems [8-9].

Lake of birds is a freshwater which is part of the wetland complex North –East of Algeria, known for its biodiversity [10], in this context a diagnostic of the current situation of pollution and monitor its evolution are a great necessity for the preservation of this ecosystem, the main objective is to study the impact of anthropogenic activities on the quality of the surface waters of lake of birds, through the evaluation of the index of organic pollution (IOP), the evaluation of fecal pollution, and the statistical method Principal Component Analysis (PCA).

2. Experimental details

2.1. Presentation of the study area

EL Tarf region is located between latitude 36° 75′00″ and longitude 08° 16′66″ in the extreme north east of Algeria, it is composed of a mosaic of the ecosystem which gives it a great importance in the mediterranean (Figure 1), this wet complex is composed of a variety of wetlands, the main areas are: lake Tonga, lake Obeira,

lake Mellah, lake of birds and marshes of mekhada, this wet complex confers has the region an international reputation, lake of birds classified wetland of international importance (36 ° 42 'N, 08 ° 07'E) is located at a distance of 45 kilometers respectively west of El Kala and east of Annaba near the national road N° 44 natural conditions very favorable and a wealth of exceptional biological [11].
Lake of birds takes its name from its ornithological wealth especially in winter, ramsar site in 1999, it is located outside the boundaries of the national park of El Kala (NPEK) despite its size reduced in summer it is home to the nesting of many rare species, its flora is also very rich and for some species is the only station [11].

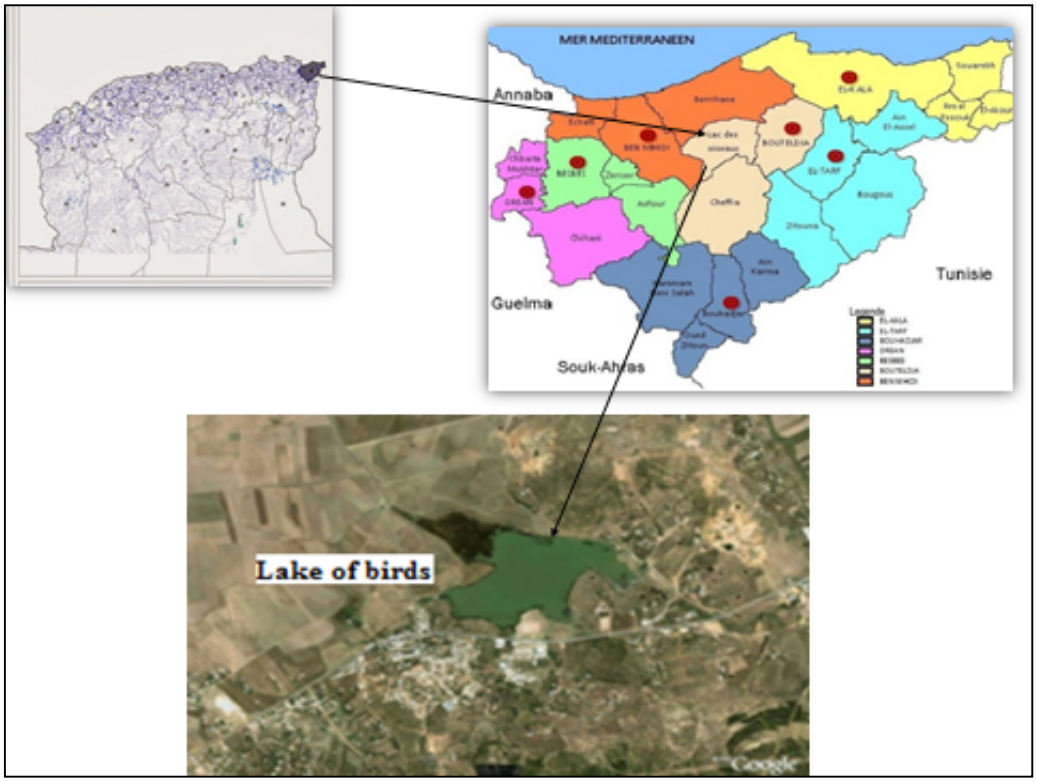

Figure 1: Presentation of the study area

2.2. Material
For a more representative sample, we had chosen three sites (Figure 2) due to their accessible locations for sampling, according to certain populations of high density, geographical situations by contribution to household wastewater and the water along some areas of hydrophytes plants.
Point A: near to a water source these geographic coordinates are (N 36° 46.981' E 008° 07. 823').
Point B: near a Scirpaie area these geographic coordinates (N 36°46. 928' E008° 07. 323').
Point C: near to a central sewer of the municipality (domestic effluents of the urban area) these geographic coordinates (N 36° 46.784' E 008°07.149').
The sampling of surface water from three sites was regularly made monthly for physicochemical parameters and these a sonal for bacteriological analyses. Analyses focused on twenty (20) physicochemical parameters which are: temperature, pH, dissolved oxygen, conductivity, nitrate, nitrite, ammonium, phosphates, biochemical demand oxygen, chemical demand oxygen, turbidity, suspended matters, silica, iron, copper, zinc, lead, cadmium, manganese, aluminum using standardized methods [12].
For bacteriological analyses, the samples of water intended for this reason have been collected aseptically in sterile bottles of 250 ml, according to the standards Rodier [12], transported to the laboratory in a cooler to maintain the temperature at 4°C.

2.3. Methods
To determine the degree of the water pollutions of the lake of Birds we based on the organic pollution index (OPI): The data processing method is based on the organic pollution index was proposed for the first time by Leclercq and Maquet (1987), this index allows to evaluate the chemical quality of the water impacted by the organic quality, The principle of OPI is to distribute the values of the pollutants in 05 classes corresponding for each parameter to average [13].

Figure 2: The sampling points of the lake of birds (Google-Earth)

Table 1: The quality grid(OPI)

Parameters / classes	BOD5mg-O_2/l	Ammonium mg-N/l	Nitrites µg-N/l	Phosphates µg-P/l
5	<2	<0.1	5	15
4	2-5	0.1-0.9	6-10	16-75
3	5.1-10	2.4	11-50	76-250
2	10.1-15	2.5-6	51-150	251-900
1	>15	>6	>150	>900

OPI = average of the class numbers of the 04 parameters

Table 2: Classes of OPI and degrees of pollution

Average of classes	Level of organic pollution
5.0-4.6	Nothing
4.5-4.0	Low
3.9-3.0	Moderate
2.9-2.0	Strong
1.9-1.0	Verystrong

- The bacteriological analysis focuses on the enumeration of total germs (TG), total coliforms (TC), fecal coliform (FC), fecal streptococci (FS) by the technique of membrane filtration [12].
- The study of the typology of lake water pollution was based on a Principal Component Analysis (PCA). The eigenvalues the factor maps and the correlation circles were obtained with the STATISTICA version 7 software.

3. Results and discussion

Monitoring the overall quality of lake waters by calculating the OPI and assessing the bacteriological quality highlighted the following.

3.1. Organic Pollution Index (OPI)

The water analyzed at the three sampling points is characterized by strong organic pollution throughout the study period (OPI = 2.75) (Table 3) except during the month of March where we recorded an increase in the OPI level of point A (OPI = 3), which classifies these waters in the class of moderate pollution, it can be noted that this improvement remains low and the only record during the period of study, due to a high organic load present in the site degrading its quality caused mainly by wastewater which is released directly into the lake, this is the first cause of the pollution of this water resource that contains different pollutants (residues of household products, discharges of toilets charged with various organic materials and fecal germs, significant amounts of

nitrogen and phosphorus), grazing on the edges of the lake, resulting in the pollution of water, and also the spreading of manure at the edges of the lake (point A), and the droppings of the birds of water. Another important factor is the climate influenced by the effect of the temperature, therefore, an intense evaporation generating a high concentration of nutrients [14]. Phosphorus is one of the most important nutrients in nature; it represents an essential element to the growth of the algae, bacteria, and protozoa [9]. Such an organic pollution by nutrients especially the nitrogen compounds: nitrites and phosphate and ammonium are harmful to aquatic life. The organic pollution index (OPI) is, therefore, a revealing indicator of pollution of organic origin (domestic or agricultural) [15].

Table 3: Organic pollution index (OPI)

Sampling points	Organic pollution index (OPI)
Point A	2 .77
Point B	2.75
Point C	2.75

3.2. Bacteriological quality of the waters of the lake of birds

The results of counting total germs (TG), total coliform (TC), fecal coliform (FC), and fecal streptococci (FS) are graphically represented in figures 3, 4, 5 and 6 show that:

- Total germs grow in aerobic conditions. Their presence is an indicator of bacterial pollution [16], the results obtained show that the total germ contents during the study period vary between maximum values of 1984×10^6 germs/ml recorded at point C in the summer, and minimum values of 98×10^6 germs/ml also recorded at point C in Winter, according to (Figure 3) a very high contamination is observed by total germs in spring and summer, which means organic contamination at sampling points A, B, C where point C is near to a central sewer of the municipality therefore direct and permanent discharge into the lake. Significant contamination was also recorded in autumn and winter but lower than in spring and summer these variations could be related to dilution by rainwater and runoff.
- Total coliform results (Figure 4) show that the highest values recorded during the spring and summer seasons at all sampling points with maximum values of 1685×10^6germs/ml are at B, and minimum values of total coliforms 87×10^6 germs/ml recorded at point C inwinter.
- High load of fecal coliforms (Figure 5) is observed in summer in all sampling points A, B, and C respectively, with maximums of 1245×10^6 germs/ml , 1230×10^6 germs/ml, 1243×10^6germes/ml, and the low value of 77×10^6 germs/ml is recorded in winter at point C.

This large load of total coliforms and fecal coliform contamination is caused by the excrement of livestock (cattle, sheep) directly to or near the lake, run-off from farms contaminated with animal manure, discharges of domestic waste water into the lake, the droppings of the birds of water are also highly contaminated with fecal coliforms, the higher the animal density the fecal coliform concentration is higher [17].

- Streptococci are largely of human origin, but some bacteria classified in this group can also be found in animal feces, or are found on plants, they are nevertheless considered as indicators of fecal pollution [18-19], their interest lies in the fact that they are resistant to desiccation, so they provide additional information on pollution, high concentrations of fecal streptococci (Figure 6) are observed in spring and summer at all sampling points with a maximum of 452×10^4germs/ml recorded at C in the summer season, and low values recorded in autumn and especially in winter with the recorded minimum of 29×10^4germs/ml at point A,this high pollution originates mainly from the discharge of domestic wastewater.

3.3.Statistical treatment of the data

3.3.1. Correlation Study and Principal Component Analysis

To better evaluate the effect of anthropogenic activities on lake water quality, we used a statistical method called Principal Component Analysis (P.C.A) this last allows to transform the quantitative variables initials , all more correlated between them, with new quantitative variables not correlated ,this analysis has been performed on a data matrix consisting of 36 samples.

(3 stations x 12 levies) during which the 24 variables (temperature, pH, conductivity, dissolved oxygen, NH_4^-, NO_2^-, NO_3^-, PO_4^{3-}, turbidity, Fe, Mn, Al, SiO_2, BOD_5, COD, suspended matters (SM) , Pb, Cd, Zn, Cu, total germs, total coliforms, fecal coliforms, fecal streptococci) have been measured, the results of the study of the correlation between the dependent variables are collected in Table 4, the significant values are represented in bold ($p< 0.05$) and for a number of individual n = 3.

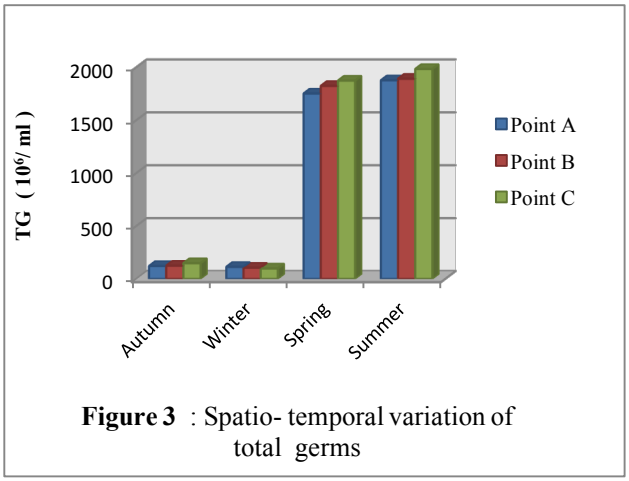

Figure 3 : Spatio- temporal variation of total germs

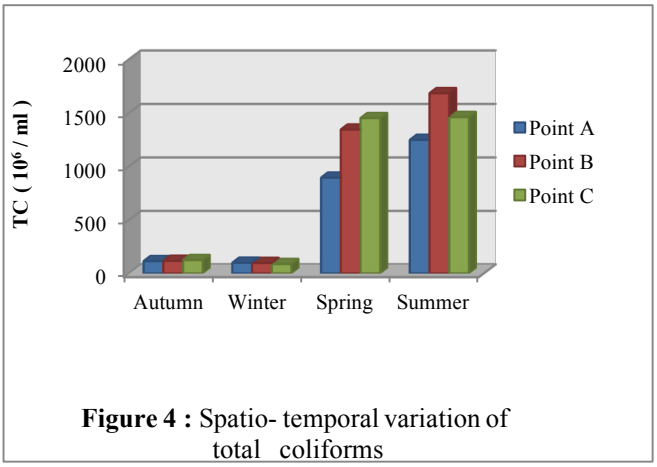

Figure 4 : Spatio- temporal variation of total coliforms

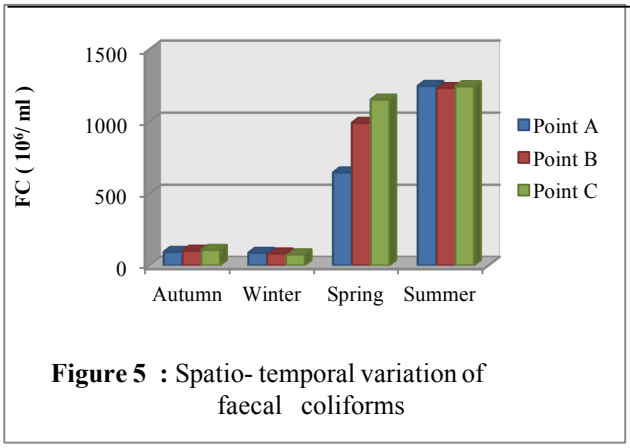

Figure 5 : Spatio- temporal variation of faecal coliforms

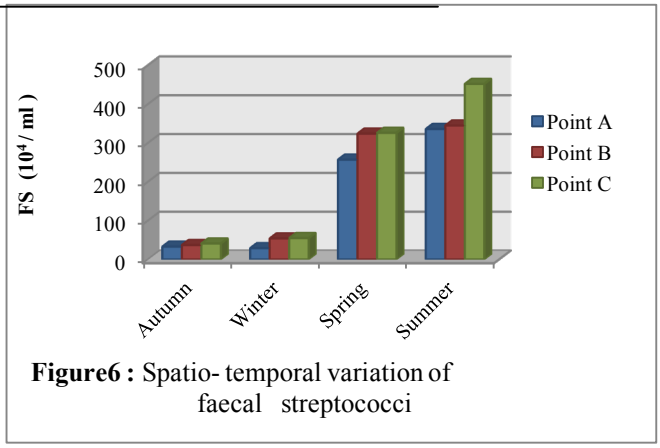

Figure6 : Spatio- temporal variation of faecal streptococci

Table 4: Matrix of correlation between the variables on all studied stations

	T°	pH	EC	O_2	NH_4^+	NO_2^-	NO_3^-	PO_4^{3-}	Turb.	Fe	Mn	Al	SiO_2	BOD5	COD	SM	Pb	Cd	Zn	Cu	GT	CT	FC	FS
T°	1	-0.24	0.75	-0.15	0.05	-0.71	0.95	-0.71	0.97	-0.4	-0.83	-0.9	-0.62	-0.8	-0.16	-0.53	-0.66	-0.99	**-1**	-0.32	-0.4	-0.4	-0.4	-0.4
pH		1	0.46	1	-0.98	-0.51	-0.52	-0.52	-0.47	-0.8	0.74	-0.21	0.91	-0.39	-0.92	-0.7	0.89	0.11	0.3	-0.84	-0.8	-0.8	-0.8	-0.8
EC			1	0.54	-0.62	**-1**	0.52	**-1**	0.57	-0.9	-0.25	-0.97	0.05	**-1**	-0.77	-0.96	-0.01	-0.83	-0.7	-0.86	-0.9	-0.9	-0.9	-0.9
O_2				1	-1	-0.59	-0.44	-0.6	-0.39	-0.85	0.68	-0.31	0.87	-0.47	-0.95	-0.76	0.84	0.02	0.2	-0.89	-0.85	-0.85	-0.85	-0.85
NH_4^+					1	0.67	0.35	0.68	0.29	0.9	-0.6	0.4	-0.81	0.56	0.98	0.82	-0.78	0.08	-0.1	0.93	0.9	0.9	0.9	0.9
NO2-						1	-0.47	**1**	-0.52	0.93	0.19	0.95	-0.11	0.99	0.81	0.97	-0.05	0.8	0.7	0.89	0.93	0.93	0.93	0.93
NO_3^-							1	-0.46	**1**	-0.1	-0.96	-0.72	-0.83	-0.59	0.14	-0.25	-0.86	-0.91	-1	-0.02	-0.1	-0.1	-0.1	-0.1
PO_4^{3-}								1	-0.51	0.93	0.18	0.95	-0.12	0.99	0.81	0.98	-0.06	0.79	0.7	0.9	0.93	0.93	0.93	0.93
Turb.									1	-0.15	-0.94	-0.76	-0.79	-0.63	0.09	-0.3	-0.83	-0.93	-1	-0.07	-0.15	-0.15	-0.15	-0.15
Fe										1	-0.19	0.76	-0.48	0.87	0.97	0.99	-0.42	0.51	0.4	1	**1**	**1**	**1**	**1**
Mn											1	0.49	0.95	0.33	-0.42	-0.04	0.97	0.75	0.8	-0.27	-0.19	-0.19	-0.19	-0.19
Al												1	0.21	0.98	0.58	0.85	0.26	0.95	0.9	0.7	0.76	0.76	0.76	0.76
SiO2													1	0.03	-0.67	-0.34	**1**	0.51	0.6	-0.55	-0.48	-0.48	-0.48	-0.48
BOD5														1	0.72	0.93	0.09	0.87	0.8	0.82	0.87	0.87	0.87	0.87
COD															1	0.92	-0.63	0.29	0.1	0.99	0.97	0.97	0.97	0.97
SM																1	-0.28	0.64	0.5	0.97	0.99	0.99	0.99	0.99
Pb																	1	0.56	0.7	-0.5	-0.42	-0.42	-0.42	-0.42
Cd																		1	1	0.44	0.51	0.51	0.51	0.51
Zn																			1	0.29	0.37	0.37	0.37	0.37
Cu																				1	1	1	1	1
GT																					1	**1**	**1**	**1**
CT																						1	**1**	**1**
FC																							1	**1**
FS																								1

The values in bold mean significant correlations

The conductivity of the water is regulated by the levels of phosphate, nitrite, and BOD_5 (r = -1.00), a positive correlation between nitrite and the phosphate (r = 1.00), the Association of nitrite with phosphate would seem to show a possible source agricultural or domestic wastewater.

Significant associations were observed between nitrate and turbidity on the one hand and between the SiO_2 and Pb on the other hand.The two elements NO_3^- and Pb are part of substances called toxic may be found in the

waters of the lake because of human activities and of a lead pollution, this last used as antiknock in combustibles of motors of vehicles. Contamination is direct by runoff of rainwater, also with urban and industrial wastewater no treatments [20], because the lake is near the national road n°44.
Strong and positive correlations are observed between iron and indicator bacteria of fecal contamination which are TG, TC, FC and FS (r = 1.00).

3.3.2. Eigenvalues
An eigenvalue represents the variation of individuals on the corresponding axis, in order to facilitate their interpretation, these values are expressed as a percentage of the total eigenvalues (Table 5).

Table 5: Eigenvalues and variance of factors

	Eigenvalues	**% Total variance**	**Cumul eigenvalues**	**Cumul %**
F1	15.12059	63.00245	15.12059	63.0024
F2	8.87941	36.99755	24.00000	100.0000

The table above shows that the F1 axis explains more than half (63%) of the total variance of the data with an eigenvalue equal to 15.12 and the F2 axis indicates 37% of the total variability of the data With an eigenvalue of 8.87. Thus, 100% of the variability of the data table is extracted by the factorial plane F1x F2, consequently, the analysis of the results of the PCA will be done by limiting it self to these first two axes (Figure 7).

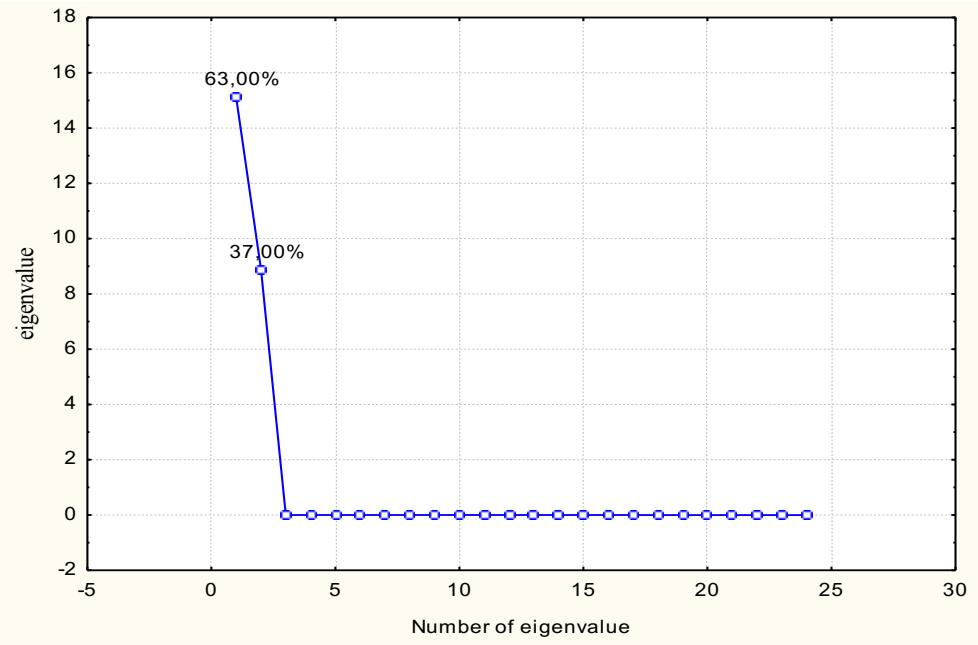

Figure 7:graphic representation of the eigenvalues calculated

3.3.3. *The factorial plan F1xF2*
The correlations between the variables and the first two axes F1 and F2 are given in Table 6. These axes show a good distribution and representation of the studied variables.
The main inertia axis F1 is 63.00% of the variance; it is positively defined by conductivity and dissolved oxygen but negatively by NH_4^+, NO_2^-, PO_4^{3-}, Fe, Mn, Al, BOD_5, COD, SM, Cu, total germs, total coliforms, fecal coliforms, and fecal streptococci (Figure 8), this axis shows 17 variables whose coefficients are greater than 0.6, these variables are mainly dependent on anthropogenic activity, particularly human (agricultural and domestic wastewater), thus the axis F1 can be assimilated to an axis reflecting the degree of organic pollution. Where as the F2 axis (37% of the variance) is constituted in its positive part by certain heavy metals (Mn, SiO_2, Pb, Cd, Zn) and pH, its negative part is composed of temperature, NO_3^- and turbidity, the axis F2 can be assimilated to an axis that reflects the degree of metal pollution.
The factorial card F1×F2 (Figure 9) shows that 63% of individuals are well represented by the axis F1 and 37% of individuals are well represented by the axis F2, therefore, the individuals best explained by the axis F1 are point A and point C. The individuals best explained by the F2 axis are point B.

Table 6: The correlations between the variables and the main axes

	F1	F2
T°	0.530	**-0.848**
pH	0.697	**0.717**
EC	**0.956**	-0.292
O_2	**0.761**	0.648
NH^+_4	**-0.822**	-0.569
NO_2^-	**-0.973**	0.233
NO_3^-	0.250	**-0.968**
PO_4^{3-}	**-0.975**	0.222
Turb	0.302	**-0.953**
Fe	**-0.989**	-0.150
Mn	0.039	**0.999**
Al	**-0.850**	0.527
SiO_2	0.339	**0.941**
BOD_5	**-0.931**	0.364
COD	**-0.923**	-0.385
SM	**-1.000**	0.001
Pb	0.283	**0.959**
Cd	-0.636	**0.772**
Zn	-0.507	**0.862**
Cu	**-0.973**	-0.233
TG	**-0.989**	-0.150
TC	**-0.989**	-0.150
FC	**-0.989**	-0.150
FS	**-0.989**	-0.150

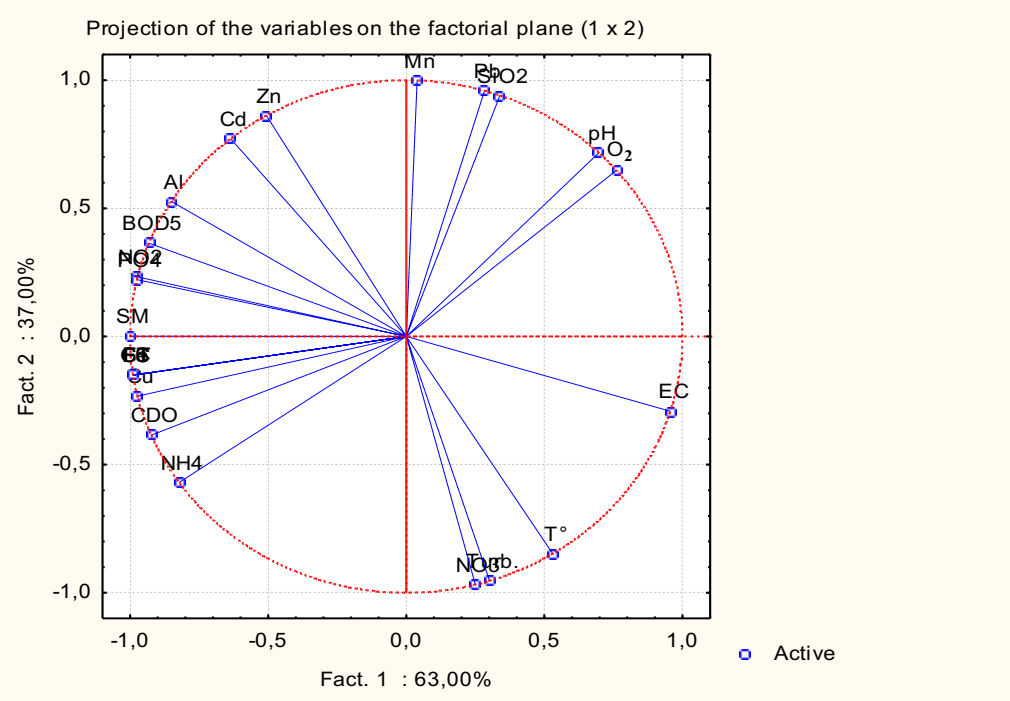

Figure 8: Representation of the variables on the factorial plan F1 and F2

The most polluted study points are point B and point C on the negative side of the F1, while the least polluted is point A on the positive side. The graphical representation of the individuals shows three groups of water:

Group 1: Represented by point C, this group distinguishes the station most impacted by domestic pollution loaded with organic pollutants characterized by relatively high levels of NH_4^+, COD, suspended matters and low dissolved oxygen, reflecting organic pollution, and very high levels of pathogenic bacteria fecal coliforms and fecal streptococci indicators of a fecal contamination, this group is characterized also by the micro-elements (Fe, Cu).

Group 02: The waters taken from point B, are highly affected by urban activity, and therefore not very mineralized. These waters have high concentrations in PO_4^{3-}, NH_4^+, Suspended mattersand heavy metals (Al, Cd, Zn).

Group 03: Point A is characterized by high nitrate levels (fertilizers natural manures on the edge of the lake) agricultural pollution, a high temperature and conductivity, characterized also by the presence of heavy metals (Mn, Pb), this group weakly affected by anthropogenic activity and strongly affected by lead pollution.

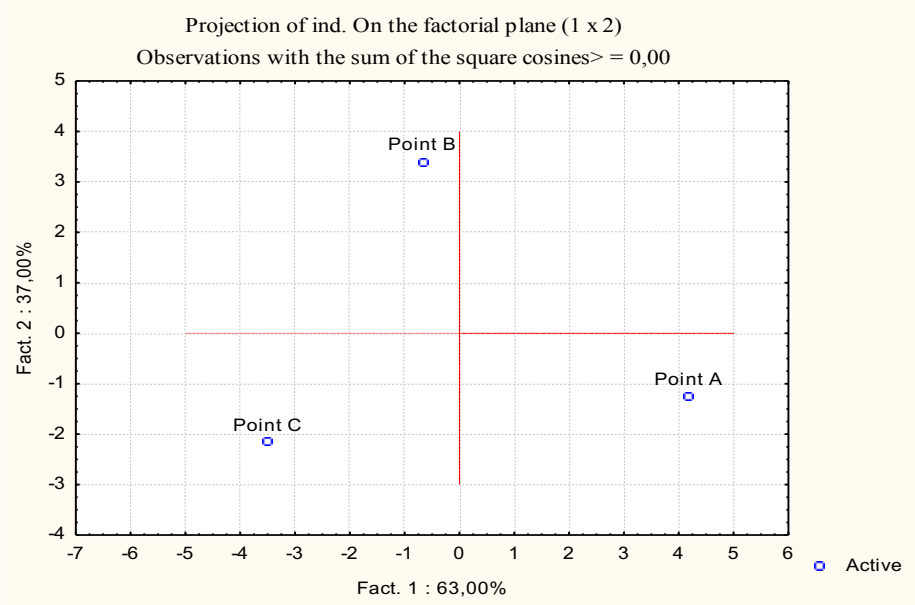

Figure 9: Representation of sampling points on the factorial plan F1 and F2

Conclusion

It according to present study that the organic pollution index calculated for all the points of sampling of the lake indicates a strong organic pollution throughout the period of study, this pollution appears to be of urban origin , discharges of domestic sewage containing nutrients (nitrite, nitrate, phosphate), and also origin agricultural. All of the bacteriological results show that the surface waters of the lake of birds show signs of degradation since all sampling points showed concentrations that exceed the current standards for the pathogens indicators of fecal contamination (total coliforms,fecal coliforms, and fecal streptococci), including the impact of effluents from surrounding areas that generate large quantities of wastewater without any prior treatment, so the microbiological pollution is another form of organic pollution. Principal components analysis carried on a matrix of raw data with 24 variables resulted in two axes summarize the essential information of this matrix: the axis F1 which can be assimilated to an axis reflecting the degree of organic pollution and the axis F2 would reflect the degree of metal pollution. The points are well typed and so well structure by their physicochemical and bacteriological data.

The results of this work confirm therefore a risk of degradation the water of this wetland.

These results must be taken advantage of by actions to preserve the lake of the birds (site RAMSAR) is renowned for its ornithological richness.

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References espace

1. N.H. Tran, K.Y.H Gin, H.H. Ngo, *Science of The Total Environment*.Volume 538, (2015) 38-57.
2. N. Nouayti, D. Khattach, M. Hilal*, J. Mater. Environ. Sci*. 6 (4) (2015) 1068-1081.
3. A. Brahimi, A.Chafi, *J. Mater. Environ. Sci*. 5 (5) (2014) 1671-1682 .
4. F. Lakhili, M. Benabdelhadi, N. Bouderka, H. Lahrach, A. Lahrach, *European Scientific Journal april 2015 edition vol*.11, No.11. 11 ISSN: 1857 – 7881 (Printe) - ISSN 1857- 7431.
5. A.Toumi, A. Reggam, H. Alayat, M. Houhamdi, *J. Mater. Environ. Sci.*7 (1) (2016)139-147.
6. J. C. Lacaze*,* L'eutrophisation des eaux Marines et Continentales. *Edition marketing S. A. ISBN:* 2-7298-4670 0, (1996) 167.
7. L. Audoin, *Rev. Sci. Tech .Off. int. Epiz.* 10(3) (1991) 629-654.
8. A. Bengherbia, F. Hamaidi, R. Zahraoui, M. S. Hamaidi, S. Megateli, *Lebanese Science Journal*, 15, No. 2, (2014) 39-51.
9. A. Reggam, H. Bouchelaghem, M. Houhamdi, *J. Mater. Environ. Sci.* 6 (5) (2015) 1417-1425.
10. L. Sayad, M. Houhamdi, N. Drouiche, N. Mouchara*, Proceeding. CIGRE.ENSH. Blida*. (2009) 36-41.
11. DRE d'EL Tarf, Etude d'amenagement du complexe humide de la zone nord-est de la wilaya d'EL -Tarf (Lac Tonga, Lac Oubeira, Lac des Oiseaux et marais de Mekhada). Volume 1 (2012) 64p.
12. J. Rodier, B. Legube, N. Merlet, L'analyse de l'eau, 9ème édition. Ed. Dunod Paris. (2009).
13. S. Bahroun, H. Kherici bousnoubra, *Larhyss Journal,* 09 (2011) 171-178.
14. M. Djidel, Pollution minérale et organique dans les eaux de la nappe superficielle de la cuvette d'Ouargla (Sahara septentrional, Algérie). *Thèse de doctorat, université Badji Mokhtar –Annaba Algérie* (2008) 164p.
15. V.O.Gaëtan, Comparaison de la potentialité et de la vulnérabilité de plusieurs sources dans le bassin du Viroi. *Mémoire de fin d'études, université libre de Bruxelles.* (2008) 43 p.
16. C.M. Bourgeois, J. F. Mescle, J. Zucca, Microbiologie alimentaire: aspect microbiologique de la sécurité et de la qualité des aliments. Tome 1. Edition: Lavoisier. Tec et Doc,1991 P: 260- 261.
17. M. Patoine, *Revue des sciences de l'eau*. 24 (4) (2011) 421-435.
18. E. Geldreich, A. Kenner, *Applied Microbiologies.* 512 (1) (1964) 63-69.
19. OMS 1994. Directives de qualité pour les eaux de boisson; Volume 1- Recommandation. Organisation mondiale de la santé 2e édition.
20. A. Chaouay, R. Okhrib, M. Hilali, L. Bazzi, A. Chahid, F. Khiri, *J. Mater. Environ. Sci.* 7(8) (2016) 2748-2759.

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