World Journal of Fish and Marine Sciences 6 (6): 564-572, 2014
ISSN 2078-4589

DOI: 10.5829/idosi.wjfms.2014.06.06.86180

Water Quality Assessment of Burullus Lake Using Multivariate Analysis

[1]Wael S. ElTohamy, [2]Nagwa E.M. Abdel Aziz, [1]Ahmad E. El Ghobashy and [3]Ahmad Alzeny

[1]Zoology Department, Faculty of Science, Damietta University, Damietta, Egypt
[2]National institute of Oceanography and Fisheries, Balteem, Egypt
[3]National Institute of Oceanography and Fisheries, Alexandria, Egypt

Abstract: Burullus Lake is the second largest lake of the Egyptian northern lakes along the Mediterranean coast. It is mainly affected by uncontrolled creeping of development areas and growing inflow of untreated agricultural, municipal and industrial drainage water. Water quality was monitored at 10 stations representing the eastern, central and western basins. Samples were collected monthly from April 2013 to March 2014 for twelve parameters used to evaluate the status of the water quality. The Multivariate statistical techniques were used to assess the water quality at Burullus Lake. From the descriptive statistics results, the highest values of nutrients and phytoplankton biomass occurred during spring and autumn months and this trend was explained by the excess agricultural activities during this period which brought high load of nutrients into the Lake through the inorganic fertilizer. According to the criteria established for eutrophication description based on the level of phytoplankton biomass; the Lake can be safely classified as polytrophic, as high concentrations of chlorophyll-a (>10 μg l^{-1}) were reported permanently all the year round. The first four axes obtained by the PCA explained 81.5% of data variations, of which 43.8% of variance was explained by the first axis. The final results of PCA revealed that the environmental stress excreted on the Lake follows the order: domestic and agricultural wastes > seawater intrusion > temperature variations. According to results of CA, four significant cluster groups of sampling stations were detected on the basis of similarity of their water quality and the highest wastes stress exerted on the Lake caused by domestic wastes.

Key words: Lake Burullus · Multivariate Statistical Analysis · Water Quality · Egypt

INTRODUCTION

Coastal lagoons rank among the most productive ecosystems on Egypt. They are shallow brackish or marine bodies separated from the sea by a barrier island, spit, reef, or sand bank and connected to the open sea by one or more restricted tidal inlets [1]. Lagoonal environments are vulnerable to environmental changes [2] to enhanced anthropogenic pressure, which can lead to eutrophication [3].

Lake Burullus; a lagoon on Egypt's Mediterranean coast between the Rosetta and Damietta Nile Arms provides rich fishing grounds for the inhabitants of the surrounding villages. Since many of the irrigation canals of the Nile Delta end in the lake, it suffers from increasing pollution. In the western part of the lake, land – winning projects of recent years have turned an increasing amount of the lake into agricultural land; this part receives fresh Nile water from Brimbal Canal. The central basin receives the drainage water from many agricultural drains. The eastern basin receives water directly from the sea and therefore, water in this basin is much salty. Industrial, agricultural and domestic wastes discharges have increased the levels of pollution in the lake [4]. Several studies have been focused on the water quality status of Burullus Lake [4-9]. However, none of these studies applied an appropriate statistical techniques that provide representative and reliable information to evaluate the water quality of the lake. For this reason, we attempt in this study to evaluate the importance of water quality parameters and identify the potential factors contributing to the variations in the Burullus Lake. This may be the application of multivariate methods including principal component analysis (PCA) and cluster analysis (CA) as statistical tools can provide a valuable technique in the interpretation of complex of data of the water quality

Corresponding Author: Wael S. ElTohamy, Department of Zoology, Faculty of Science, Damietta University, Egypt. E-mail: waelsalah@du.edu.eg.

parameters [10, 11]. The first aim of this is to describe the studied physicochemical parameters using the appropriate descriptive statistics to find similarities and dissimilarities shared by the parameters of different sampling stations. The second objective of this study is to analyze the data using the principal component analysis and cluster analysis through the values of physicochemical parameters and macronutrients with the focus on reducing the dimension of the large data sets obtained from the 10 different stations during one year cycle for simpler interpretation.

MATERIALS AND METHODS

Study Area: Lake Burullus is located in the central part of the northern shoreline of the Nile Delta between longitudes 30° 30 and 31° 10 E and latitudes 31° 20 and 31°35´ N, it covers a surface area of about 410 km^2, with an average depth varies between 0.5 and 3 m, the deepest part lies in the western basin, while the eastern basin is shallow. It has an irregular elongated shape and it connects to the Mediterranean Sea at the eastern side through a narrow passage (50 m width and 250m long). The Lake serves as reservoir of drainage waters from agricultural areas through eleven drains in addition to the freshwater from Brimbal Canal situated in the western part of the lake (Figure 1). The lagoon has a length of about 47 km and the width varied between 6 and 16 km, with an average of about 11km. The Lake renewed its water six times a year [12]. i.e. the flushing rate is 61 days. Approximately 75 islands are scattered throughout Burullus Lagoon, with various surface areas.

The lake is classified during the present study into three basins: Eastern basin (stations 1, 2, 3 and 10) affected by seawater also four drains discharge in it. Middle basin (stations 4, 5 and 9) affected by wastewater input from several drains. Western basin (stations 6, 7 and 8) receives its water mainly from Brimbal canal and Drain 11 (Fig. 1).

Water Samples Collection and Analysis: Sampling was carried out monthly from April 2013 to March 2014 on the surface water at ten stations which selected to represent the different ecological entities. Water temperature, transparency, salinity, conductivity, dissolved oxygen, pH, nutrients (phosphate, nitrate, nitrite, ammonia and silicate) and chlorophyll-a were determined at each station monthly.

The surface water temperature and pH were measured in the field. Water transparency was measured by white enameled Secchi disc. Salinity and conductivity were determined argentometrically and dissolved oxygen by Winkler's method according to APHA methods [13]. Determination of nutrients and chlorophyll-a are followed the procedures by Strickland and Parsons [14].

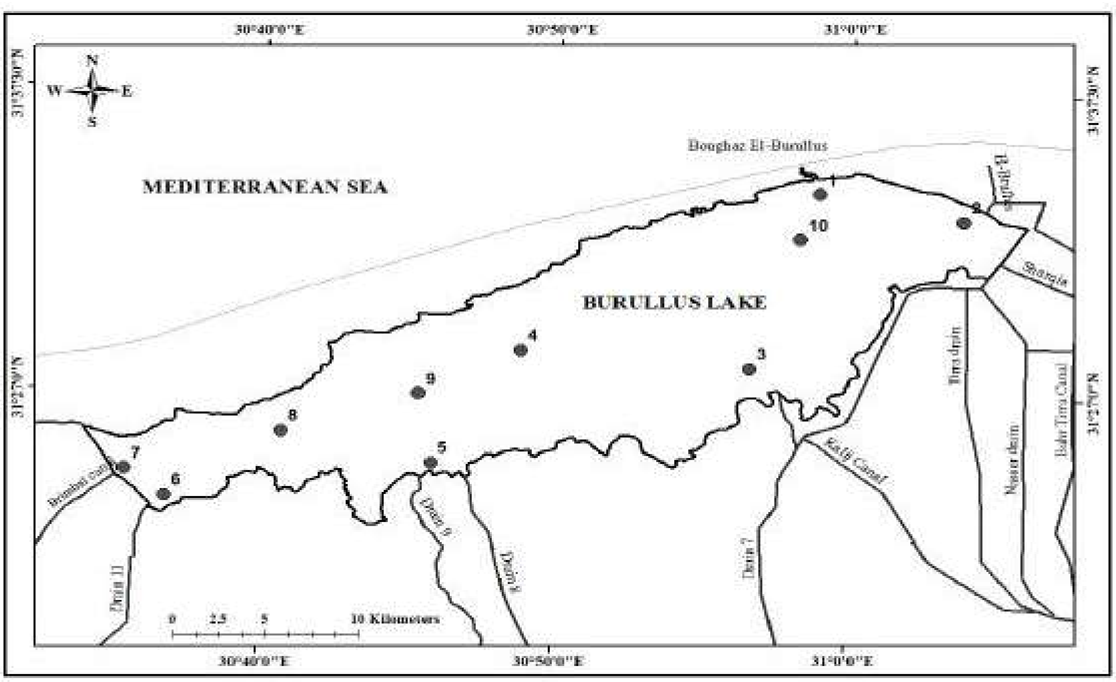

Fig. 1: Burullus Lake and location of water sampling stations

Statistical Analysis: Descriptive statistics (mean, minim and maximum) were calculated for the physicochemical variables in the water samples. The Pearson correlation coefficient was used to define the relationship between each two variables under study. All the pervious analyses were performed by SPSS 18.

A principal components analysis (PCA) using the CANOCO 4.5 package [15] was used to ordinate the 120 sample units and 12 environmental variables on a few factorial axes to describe the relationships between these variables and sampling units. The PCA was performed from the linear correlation matrix of the environmental variables after logarithmic transformation of the data [16].

Cluster analysis (CA) was performed by using Statsoft Statistica 8.0. 360-English edition to explore the similarities between stations by grouping them according to the similarity of physicochemical variables. Hierarchical clustering CA was performed on the normalized data set using Euclidean distances as a measure of similarity.

RESULTS AND DISCUSSION

Water Analysis Results: The surface water temperature exhibited the classical seasonal variations known in the Egyptian coastal waters, reporting seasonal averages of (14-16°C) in Winter, (18-22°C) in Spring, (23-25°C) in Autumn and (27-30°C) in Summer. The spatial differences in surface water temperature was negligible most of the year; 1-3 °C was the average of differences between the 10 sampling stations in the same season, such differences may be related to differences in the time of sampling during the day time and/or the differences in water depth at the sampled stations.

The Secchi disc measurements reflected a dominating low transparency in the whole area especially at stations 3, 4 and 5 and highest transparency was noticed at stations 6, 7 at the western basin and at station 10 at the eastern basin. Generally, the transparency values were lower during spring and summer due to the high load of drainage water which increase with increasing agricultural activities during spring and summer. Also the discharged water usually carries a huge amount of organic and suspended materials that decrease transparency.

The pH values lies on the alkaline side (7.8-9.2) with a mean 8.5, which was within the limit of guidelines for aquatic life survival [17]. A slight increase was observed over the last two decades, due to the increased photosynthetic activity of planktonic algae [18].

The surface salinity of the Lake appeared to be widely variable both temporally and spatially reflecting changes in the volume and dispersion of the discharged wastewater from the drains, fresh Nile water from Brimbal Canal at the west and sea water from the sea outlet at the east. Spatially, the seasonal values fluctuated between a minimum average of 3.4 and 2.4 ppt at stations 5, 6 at the western basin and a maximum average of 29.5 and 23.1 ppt at stations 1 and 10 at the eastern basin. Temporally, summer represented the maximum average (12.6 ppt), while winter was the minimum (8.8ppt) during the study period. According to the previous references, the salinity of the lagoon increased from year to year which creates high brackish water conditions especially in the eastern basin (> 17 ppt) [19].

Conductivity values follow that of salinity. Spatially, the measured values fluctuated between a minimum average of 6.4 ms cm^{-1} and 4.6 ms cm^{-1} at stations 5, 6 and a maximum average of 70.9 ms cm^{-1} and 43.6 ms cm^{-1} at stations 1 and 10. Temporally, summer represented the maximum average (22.7 ms cm^{-1}), while winter was the minimum (19.6 ms cm^{-1}).

The dissolved oxygen values showed a markedly wide range of variations (4.1 and 10.5 mgl^{-1}). The minimum oxygen value was recorded at station 5 in winter and the maximum ones was found at station 1 before El Boughaz site during autumn. In general, the annual average of 7.2 mgl^{-1} indicated the lagoon water as well oxygenated ecosystem. The seasonal pattern demonstrated generally high values at most sampling stations during all seasons with small decrease during summer (Table 1) relative to the high temperature. Breitburg [20] proposed the oxygen decrease with the elevated surface temperature during summer. This can be attributed to the fact that during summer, the oxygen stability is low and its utilization rate increased through biochemical reactions at high temperatures [21].

Nutrient concentrations were high most of the year and demonstrated exceedingly wide variations according to time and space (Table 1).

Nitrate values ranged between 23 and 994.2 μgl^{-1} with annual average 232.1. Generally spring and autumn are characterized by higher concentrations of nitrate. Also stations 2, 5, 9 characterized by markedly higher concentrations of Nitrate (annual averages 645.8, 407.8, 214.1 μgl^{-1}), while station 1 by the lowest average value (85.3 μgl^{-1}).

Nitrite values ranged between 7.6 and 275.4 μgl^{-1} with an annual average of 79.3 μgl^{-1}. The highest values recorded at station 2 during autumn and the lowest at station 1 also during autumn. Spatially stations 2 and 5 represented the highest nitrite values all the year (annual averages 203.4, 194.2 μgl^{-1}), while stations 1, 8, 9, 10 represented the lowest averages.

Table 1: Descriptive statistics of the twelve variables measured in waters of ten stations of Lake Burullus

Stations	Temp (°C)	SDT(cm)	pH	Con(ms cm^{-1})	Sal(ppt)	DO(mg l^{-1})	NO_3(µg l^{-1})	NO_2(µg l^{-1})	NH_4(µg l^{-1})	SiO_3(µg l^{-1})	PO_4 (µg l^{-1})	Chl-a (µg l^{-1})
Station 1 Sp	18.7	22.3	8.8	88.4	32.2	10.1	119.9	28.4	283.3	1766.0	7.8	10.3
Station 1 Su	27.3	27.3	8.6	71.7	32.9	5.9	94.9	14.9	89.3	2813.3	14.9	25.4
Station 1 A	23.8	24.3	8.5	66.2	29.1	10.5	103.2	7.6	83.3	2199.7	186.7	31.8
Station 1 W	14.7	21.7	8.6	57.4	23.6	7.6	23.0	15.9	75.3	1012.7	11.6	33.0
Station 2 Sp	18.7	23.3	8.6	14.1	8.1	8.1	748.2	96.5	567.0	3721.7	79.2	130.4
Station 2 Su	26.7	8.0	8.6	10.1	5.7	6.1	483.7	194.2	744.0	3578.0	45.1	113.4
Station 2 A	23.3	14.3	8.5	18.1	8.8	7.8	994.2	275.4	504.0	5472.0	1598.9	110.8
Station 2 W	14.5	25.7	8.6	18.1	10.6	6.3	357.1	247.3	187.3	4506.3	106.0	65.4
Station 3 Sp	18.8	9.0	8.8	14.4	8.3	7.5	172.0	45.8	223.7	2358.3	41.3	87.2
Station 3 Su	27.8	11.7	8.7	33.6	21.2	4.6	160.6	21.2	116.3	5979.7	18.9	33.1
Station 3 A	24.2	16.7	8.6	29.8	15.2	7.4	297.7	102.3	114.3	4310.0	193.3	60.6
Station 3 W	14.7	17.7	8.5	9.3	5.2	6.6	392.0	164.4	272.7	1257.0	45.9	34.2
Station 4 Sp	20.0	10.3	8.2	10.1	5.7	8.6	94.4	22.4	169.3	3907.3	68.4	26.4
Station 4 Su	28.7	9.0	8.4	11.8	6.7	5.9	76.3	35.5	132.3	3210.3	59.0	20.6
Station 4 A	24.5	11.7	8.5	10.2	5.8	7.8	97.3	9.2	123.3	2805.3	221.4	29.9
Station 4 W	15.0	16.7	8.6	8.7	4.8	5.9	42.0	17.6	126.0	550.7	23.3	63.1
Station 5 Sp	21.3	11.0	8.5	5.7	3.1	8.3	329.6	113.9	2635.3	3501.7	123.0	91.1
Station 5 Su	28.5	10.7	8.6	7.1	3.9	5.3	342.1	204.1	824.0	2226.7	73.9	64.3
Station 5 A	24.5	18.3	8.4	5.9	3.2	6.9	639.4	268.0	1152.3	6653.3	565.9	117.5
Station 5 W	15.2	15.0	8.1	6.5	3.5	4.1	320.1	190.7	986.0	2026.7	220.3	72.4
Station 6 Sp	21.5	20.7	7.8	3.9	2.1	6.6	224.8	81.3	1379.3	1830.7	88.9	18.8
Station 6 Su	29.2	26.7	8.2	4.7	2.5	5.8	144.7	64.2	820.3	3254.0	45.0	39.7
Station 6 A	24.3	45.0	7.8	2.8	1.4	5.7	478.1	213.8	815.0	4451.0	113.6	35.9
Station 6 W	15.8	51.7	7.8	6.8	3.7	5.8	240.6	160.9	258.7	978.3	2269.2	34.1
Station 7 Sp	21.7	24.0	8.6	7.0	3.9	7.1	83.9	17.5	79.3	1619.0	53.3	43.0
El Station 7 Su	29.3	38.3	8.2	16.5	9.7	6.5	51.1	17.6	46.0	1594.3	34.1	34.9
Station 7 A	24.7	65.0	7.9	9.0	5.0	8.2	135.6	61.9	64.7	2470.3	198.3	35.7
Station 7 W	16.3	67.7	7.9	19.3	7.7	5.9	186.0	110.2	59.0	1430.0	76.2	32.2
Station 8 Sp	20.8	10.3	8.6	10.8	6.1	6.5	157.7	14.4	120.0	3388.0	84.8	26.7
Station 8 Su	29.3	14.0	8.7	11.0	6.3	9.8	148.8	20.3	82.3	3433.3	44.7	58.8
Station 8 A	24.8	20.0	8.8	9.4	5.2	8.8	47.5	14.0	67.3	2778.7	122.9	57.0
Station 8 W	15.5	21.7	9.0	12.2	6.9	8.0	30.5	19.0	111.3	754.3	19.3	102.3
Station 9 Sp	20.7	12.7	8.5	8.6	4.8	7.5	228.4	50.5	263.3	3075.0	104.4	46.2
Station 9 Su	28.3	21.7	8.7	10.0	5.6	7.8	272.0	9.5	86.0	2870.0	82.9	28.4
Station 9A	24.8	22.7	8.6	8.4	4.6	7.4	239.9	115.9	132.3	3275.0	239.2	52.2
Station 9 W	15.2	21.7	8.8	7.3	3.9	9.2	116.2	58.8	66.0	388.0	44.8	83.7
Station 10 Sp	18.8	10.0	8.5	33.6	21.0	7.4	135.0	22.4	122.3	2356.7	14.4	10.9
Station 10 Su	27.2	12.3	9.2	50.6	31.4	6.2	320.8	15.7	99.3	3202.3	25.4	30.7
Station 10 A	23.8	16.7	8.7	40.3	21.8	6.6	125.2	17.9	91.3	3163.7	195.9	22.9
Station 10 W	14.8	36.7	8.3	50.0	18.3	7.0	30.8	11.5	55.3	1410.7	13.1	8.6
Mean	21.9	22.1	8.5	20.5	10.2	7.2	232.1	79.3	0.4	2.8	264.4	50.6
Min	14.5	8	7.8	2.8	1.4	4.1	23	7.6	46	388	7.8	8.6
Max	29.3	67.7	9.2	88.4	32.9	10.5	994.2	275.4	2635.3	6653.3	2269.2	130.4

Temp = Temperature. SDT = Secchi Disk Transparency. Cond = Conductivity. Sal= Salinity. DO = Dissolved Oxygen. Chl-a = Chlorophyll-a. Station key: Sp = sampled during spring months; Su = sampled during summer months; A = sampled during autumn months; W = sampled during winter months.

Ammonia concentrations were generally high, showing the widest range of variation among all nutrients and fluctuating between 46 µgl^{-1} at station 7 during summer and 2635.3 µgl^{-1} at station 5 during spring. The seasonally average concentration reached the highest values during spring (584.3 µgl^{-1}). Regarding the spatial distribution, the highest annual average concentration (1399.4 µgl^{-1}) was found at station 5 in front of Drain 9. Near El-Boughaz (station 1) and Near Brimbal fresh water canal (station 6), the values were low amounting to (132.8 and 62.3 µgl^{-1}).

Phosphate seasonal average concentrations ranged from 7.8 to 565.9 µgl^{-1}; except for the highest average values in autumn (1598.9µgl^{-1}) at station 2 in front of Burullus Drain and in winter (2269.2 µgl^{-1}) at station 6 in front of Brimbal Canal. During the year the annual average phosphate was 264.4 µgl^{-1}. Generally autumn represented the maximum average values of phosphate during the year.

Silicate concentrations (388- 6653.3 µgl^{-1}) reflected wide temporal and spatial variations. The highest content was recorded at station 5 during autumn, while the lowest value at station 9 during winter. Spatially stations 2, 3 showed the highest annual average values (4319.5 and 3476.3 μgl^{-1}) and stations 6, 7 showed the lowest values (2628.5 and 1778 μgl^{-1})

Chlorophyll-a was measured as an index of the phytoplankton biomass and can be used as an effective measure of trophic status [22, 23]. The high chlorophyll-a concentrations indicate poor water quality and low levels frequently suggest good conditions [22, 24], whereas values between 4-10 $\mu g\ l^{-1}$ are considered as levels of eutrophication and those >10 $\mu g\ l^{-1}$ as polytrophication [25]. Accordingly, polytrophic levels were reported permanently (20.6-130.4 $\mu g\ l^{-1}$) at all stations and frequently at stations 1, 10(8.6-33 $\mu g\ l^{-1}$). The maximum chlorophyll-a (130.4 $\mu g\ l^{-1}$) recorded at station 2 during spring and the minimum (8.6 $\mu g\ l^{-1}$) at station 10 during winter. Great differences were recorded between the stations, therefore three groups of chlorophyll concentrations can be considered in the Lake, representing different rates of primary production. The highest biomass at stations 2, 5 (annual average 105 and 86.3 $\mu g\ l^{-1}$) was associated with drains, the lower biomass was recorded in the stations affected by marine water and away from the direct impact of drains at stations 1, 10 (annual average 25.1 and 18.3 $\mu g\ l^{-1}$), the other group of phytoplankton biomass ranged between the two groups.

Human activities in Burullus Lake have caused drastic changes in the environment, expressed mainly by salinity changes, high nutrient levels and intensive phytoplankton growth. The nutrient concentrations ranges reported as criteria of eutrophication in coastal waters were: > 20.7 μgl^{-1} for NH_4, > 32.86 μgl^{-1} for NO_3 [26, 27], > 14.2 μgl^{-1} for PO_4 [27, 28] and 1.99 μgl^{-1} for chlorophyll-a [29]. According to these values, all stations can be classified as eutrophic.

Correlation Analysis Results: As shown in table 2, high numbers of correlations found between the monitored variables. The greatest number of significant correlations occurred for phytoplankton biomass, which in general positive between this variable and pH, dissolved oxygen and nutrients. On the other hand, only transparency, salinity and conductivity had a significant negative correlation with phytoplankton biomass. Thus we can safely conclude that, the intensive phytoplankton production in the Lake is attributed to the excessive enrichment of nutrient salts through the discharged water from drains. This could be clearly deduced from the significant negative correlation of chlorophyll-a with salinity, which serves as indication of fresh water discharge and significant positive correlations between chlorophyll-a and nutrients. Also, the highly significant negative correlation of salinity with most nutrients is another indication of the controlling of the Lake water quality by the fresh water discharge.

Table 2: Correlation analysis of the twelve variables of Lake Burullus

	Temp	SDT	pH	Con	Sal	DO	NO_3	NO_2	NH_4	SiO_3	PO_4	Chl-a
Temp	1.00											
SDT	-0.17	1.00										
pH	0.08	-0.59**	1.00									
Con	-0.01	-0.05	0.26**	1.00								
Sal	0.02	-0.11	0.31**	0.98**	1.00							
DO	0.07	-0.11	0.45**	0.19*	0.20*	1.00						
NO_3	0.16	-0.04	-0.30**	-0.28**	-0.26**	-0.09	1.00					
NO_2	-0.22*	0.04	-0.34**	-0.42**	-0.44**	-0.24**	0.60**	1.00				
NH_4	0.06	-0.15	-0.31**	-0.42**	-0.44**	-0.31**	0.44**	0.55**	1.00			
SiO_3	0.36**	-0.17	-0.06	-0.06	0.02	-0.12	0.47**	0.22*	0.21*	1.00		
PO_4	0.09	0.10	-0.243**	-0.40**	-0.44**	-0.12	0.35**	0.35**	0.32**	0.18	1.00	
Chl-a	0.13	-0.25**	0.34**	-0.33**	-0.29**	0.35**	0.31**	0.28**	0.21*	0.09	0.19*	1.00

Temp = Temperature. SDT = Secchi Disk Transparency. Cond = Conductivity. Sal= Salinity. DO = Dissolved Oxygen. Chl-a= chlorophyll-a. *. Correlation is significant at the 0.05 level**. Correlation is significant at the 0.01 level

Table 3: Eigen values of the first four PCA axes and their cumulative percentage variance

Axes	1	2	3	4
Eigenvalues	0.438	0.167	0.112	0.097
Cumulative percentage variance	43.8	60.5	71.7	81.5

Table 4: Correlation coefficients between environmental variables and the four PCA axes

	Correlation with all parameters			
Variables	Axis1	Axis2	Axis3	Axis 4
Temperature	0.0049	0.1046	-0.0038	-0.4332
Transparency	0.0704	0.1525	0.1857	0.4962
pH	-0.3471	-0.0214	-0.2786	-0.5125
Conductivity	-0.5729	-0.018	0.6355	-0.0071
Salinity	-0.6259	-0.124	0.6397	-0.188
Dissolved oxygen	-0.1417	0.064	-0.2142	-0.3657
NO_3	0.7738	-0.3835	0.176	0.1486
NO_2	0.6248	-0.2862	0.3422	-0.2963
NH_4	0.4851	-0.1215	-0.0903	0.0573
SiO_3	-0.1922	0.3127	0.2967	-0.3121
PO_4	0.4624	0.307	0.1832	-0.1886
Chlorophyll-a	0.3653	-0.2844	-0.3558	-0.4245

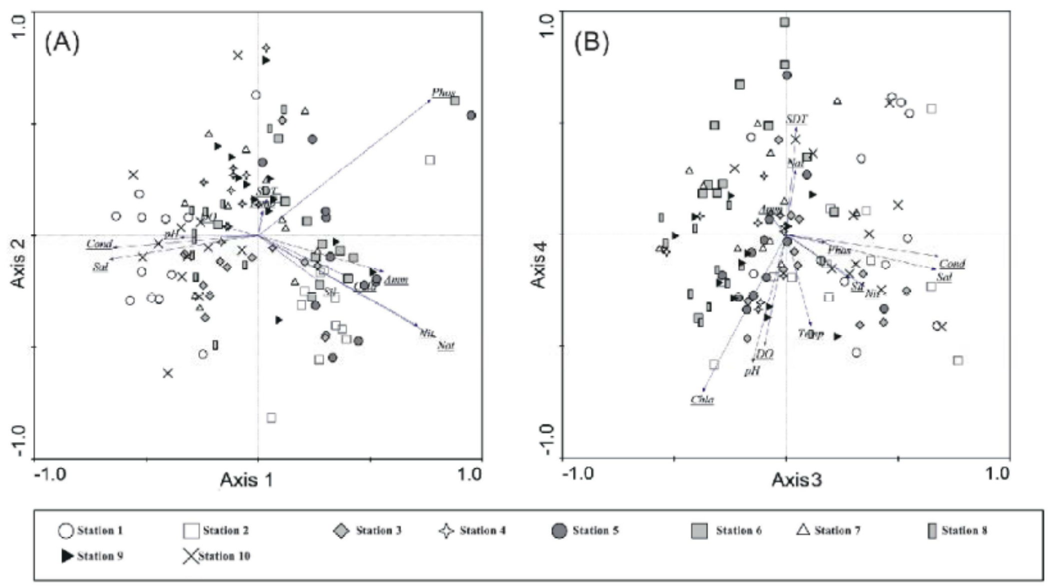

Fig. 2: PCA bi-plot based on the correlation matrix of the environmental parameters. A: Axis1 vs. Axis2; B: Axis 3 vs. Axis 4. Temp (temperature), SDT (Secchi disk transparency), Sal (salinity), cond (conductivity), Si (SiO3), Am (NH4), Nit (NO2), Nat (NO3), Phos (phosphate) and Chla (chlorophyll-a).

Principal Component Analysis (PCA) Results: PCA was applied to the multivariate data consisting of the twelve parameters. The first four PCA factors explained 81.5 % of the data variations (Table 3). Correlations for each of the variables with each factorial axes are shown in table 4 and figure 2 (bi-plots). The first axis (explain 43.8% of variance) contained large negative loading on salinity and conductivity and positive loading on nitrite, nitrate, ammonia, phosphate and phytoplankton biomass. In another words, the first PCA axis shows the inverse relationship between salinity and the other five variables, with higher correlation values indicating the association of this axis with the domestic-type wastewater and agricultural runoffs. Most of sampling units from station 2, station 5, station 6 and station 7 were positively correlated with this axis, indicating worse lake water quality. On the other hand, sampling units from station 1, station 10 and station 8were negatively correlated with this axis (Figure 2A), indicating better Lake water quality. Second axis (16.7% of variance) showed only one reasonable positive loading on silicate. Third axis (11.2 % of variance) included variables characteristics of intrusion of seawater (positive loading on salinity and conductivity) and agricultural runoffs (positive loading on silicate and nitrite), the higher correlations values of salinity and conductivity compare to that of nitrite and

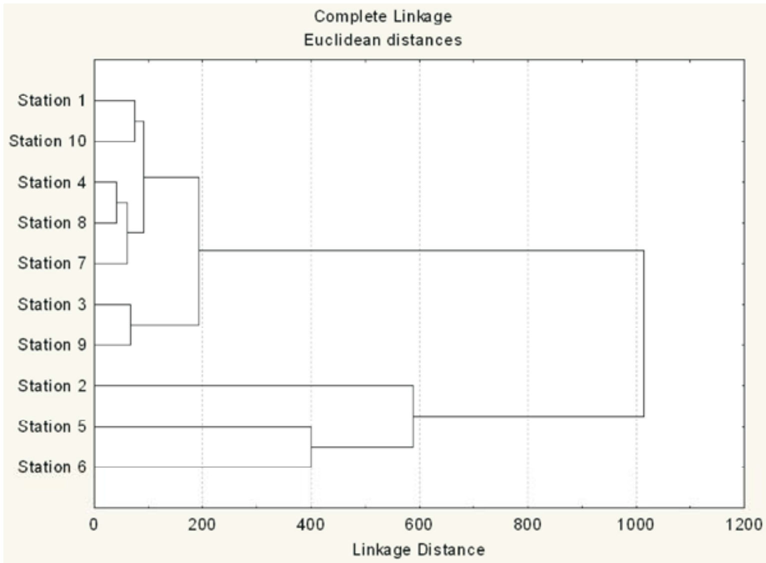

Fig. 3: Cluster analysis results on water samples of ten stations of Lake Burullus.

silicate, indicating the association of sampling units of this axis with the prevalence of seawater properties. The majority of sampling units from station 1, station 2 and station 3 were positively correlated with this axis (Figure 2B), indicating better lake water quality. The fourth axis (9.7% of variance) was positively correlated with water transparency and negatively correlated with temperature, pH, dissolved oxygen and phytoplankton (Table 4), indicating the association of this axis with the changes in environmental variables which undoubtedly related to the seasonal temperature fluctuations. Based on the results of principal component analysis, it can be inferred that domestic and agriculture wastes exert the highest environmental stress on Lake Burullus, followed by the seawater intrusion from the Mediterranean Sea. Finally, small stress induced by seasonal temperature variations.

Cluster Analysis (CA) Results: Methods of complete linkage and Euclidean distances were applied during the cluster analysis using average concentration values of each variable, the results are presented in Figure 3. The first cluster group contained station 1and station 10. These stations are located in areas lies under the effect of seawater intrusion and consequently this cluster represents the sites with the seawater properties of Lake Burullus. The second cluster contains station 4, station 8 and station 9. These stations are nearly far from the direct effect of discharged wastes. So, stations of cluster one and two represent the zones with good water quality of Lake Burullus. Third cluster is comprised of station 3 and station 7. Station 2, station 5and station 6comprise the fourth cluster. Stations of both cluster three and four are located in zones with high loading of domestic and agricultural wastes with the predominance of domestic wastes and consequently these two clusters represent the stations with the highest environmental stress of Lake Burullus. Based upon the results of the cluster analysis, it can be established that the source of environmental stress on Lake Burullus arises mainly from the wastewater discharge that take place through the several drains that end up in the Lake. In this regard, it can be seen that the highest wastes stress exerted on the Lake caused by domestic.

REFERENCES

1. Gonenc, I.E. and J.P. Wolflin, 2004. Coastal lagoons: ecosystem processes and modeling for sustainable use and development, CRC Press, pp: 528.
2. Lloret, J., A. Marín and L. Marín-Guirao, 2008. Is coastal lagoon eutrophication likely to be aggravated by global climate change? Estuarine, Coastal and Shelf Science, 78: 403-412.
3. Viaroli, P., M. Bartoli, G. Giordani, M. Austoni and J. Zaldivar, 2005. Biogeochemical Processes in Coastal Lagoons: from Chemical Reactions to Ecosystem Functions and Properties, in: P. Magni, J. Hyland, G. Manzella, H. Rumohr, P. Viaroli and A. Zenetos, (Eds.), Indicators of Stress in the Marine Benthos, Torregrande-Oristano, Italy, pp: 27-30.

4. El Nemr, A., 2003. Assessment of heavy metal pollution in surface muddy sediments of Lake Burullus, southeastern Mediterranean, Egypt. Journal of Aquatic Biology and Fisheries, 7: 67-90.
5. El-Reefy, H., H. Badran, T. Sharshar, M. Hilal and T. Elnimr, 2014. Factors affecting the distribution of natural and anthropogenic radionuclides in the coastal Burullus Lake. Journal of environmental radioactivity, 134: 35-42.
6. Okbah, M., 2005. Nitrogen and phosphorus species of Lake Burullus water (Egypt). Egyptian Journal of Aquatic Research, 31: 186-198.
7. Ahmed, M., M. Abdel-Moati, G. El-Bayomi, M. Tawfik and S. El-Kafrawi, 2001. Using geo-information and remote sensing data environmental assessment of Burullus Lagoon, Egypt. Bulletin of the National Institute of Oceanography and Fisheries (Egypt), 27: 133-155.
8. Radwan, A. and L. Shakweer, 2004. On the present status of the environmental and fishery of Lake Borollus. 2. A. Distribution and concentrations of trace elements in the water and bottom sediments of Lake Borollus. Egyptian Journal of Aquatic Research, 30: 43-98.
9. Ali, E., 2011. Impact of drain water on water quality and eutrophication status of Lake Burullus, Egypt, a southern Mediterranean lagoon. African Journal of Aquatic Science, 36: 267-277.
10. Badillo-Camacho, J., E. Reynaga-Delgado, I. Barcelo-Quintal, P.F.Z. del Valle, U.J. López-Chuken, E. Orozco-Guareño, J.I. Alvarez Bobadilla and S. Gomez-Salazar, 2015. Water Quality Assessment of a Tropical Mexican Lake Using Multivariate Statistical Techniques. Journal of Environmental Protection, 6: 215-224.
11. Mohamed, I., F. Othman, A.I. Ibrahim, M. Alaa-Eldin and R.M. Yunus, 2015. Assessment of water quality parameters using multivariate analysis for Klang River basin, Malaysia. Environmental Monitoring and Assessment, 187: 1-12.
12. Darrag, A., 1985. The Occurrence and Distribution of Some Trace Metals ''Fe, Mn and Cu'' in lake Burullus and Their Relation to Organic Matter. Ph.D. thesis, Alexandria University, Egypt, pp: 388.
13. American Public Health Association, 1980. Standard methods for the examination of water and wastewater, 15th ed. American Public Health Association, Inc., Washington, D.C.
14. Strickland, J.D.H. and T.R. Parsons, 1972. A Practical Handbook of Seawater Analysis. 2nd ed. Fisheries Research Board of Canada, Ottawa, pp: 310.
15. Ter Braak, C.J.F. and P. Smilauer, 2002. CANOCO 4.5: Biometrics. Wageningen University and Research Center, Wageningen, pp: 500.
16. Sousa, W., J.L. Attayde, E.D.S. Rocha and E.M. Eskinazi-Sant'Anna, 2008. The response of zooplankton assemblages to variations in the water quality of four man-made lakes in semi-arid northeastern Brazil. Journal of Plankton Research, 30: 699-708.
17. Organization, W.H., 2004. Guidelines for drinking-water quality. 3rd ed: recommendations: World Health Organization, 1: 515.
18. Al-Sheikh, H. and A. Fathi, 2010. Ecological studies on lake Al-Asfar (Al-Hassa, Saudi Arabia) with special references to the sediment. Research Journal of Environmental Sciences, 4: 13-22.
19. Zalat, A. and S.S. Vildary, 2005. Distribution of diatom assemblages and their relationship to environmental variables in the surface sediments of three northern Egyptian lakes. Journal of Paleolimnology, 34: 159-174.
20. Breitburg, D., 2002. Effects of hypoxia and the balance between hypoxia and enrichment, on coastal fishes and fisheries. Estuaries, 25: 767-781.
21. Younis, A. and E. Nafea, 2012. Impact of environmental conditions on the biodiversity of Mediterranean Sea lagoon, Burullus protected area, Egypt. World Applied Sciences Journal, 19: 1423-1430.
22. Island, V., 2010. Chlorophyll-a dynamics in relation to environmental parameters in a tropical lagoon. Journal of American Science, 6: 327-337.
23. Lee, R.E., 1999. Phycology. Cambridge University Press, New York, pp: 614.
24. Otero, E. and K.K. Carbery, 2005. Chlorophyll a and turbidity patterns over coral reefs systems of La Parguera Natural Reserve, Puerto Rico. Revista de Biologia Tropical, 53: 25-32.
25. Wasmund, N., A. Andrushaitis, E. Łysiak-Pastuszak, B. Müller-Karulis, G. Nausch, T. Neumann, H. Ojaveer, I. Olenina, L. Postel and Z. Witek, 2001. Trophic status of the south-eastern Baltic Sea: a comparison of coastal and open areas. Estuarine, Coastal and Shelf Science, 53: 849-864.
26. Vucak, Z. and J. Stirn, 1982. Basic physical, chemical and biological data reports, RVA mohorov ICIC'Adriatic Cruises 1974-76. Hydrographic Institute of Yugoslav Navy, Split, pp: 175.
27. Ignatiades, L., M. Karydis and P. Vounatsou, 1992. A possible method for evaluating oligotrophy and eutrophication based on nutrient concentration scales. Marine pollution bulletin, 24: 238-243.

28. Marchetti, R., l984. Quadro analitico complessivo dei resultati delle indagini condotte negli anni 1977-1980 sul problema dell'eutroiizzazione nelle acque costiere dell'Emilia-Romagna: Situazione e ipotesi di intervento. In. Bologna, Regione Emilia Romagna, pp: 308.

29. Vollenweider, R.A., A. Rinaldi, R. Viviani and E. Todini, 1996. Assessment of the state of eutrophication in the Mediterranean Sea. MAP Technical Reports Series, UNEP/FAO, Athens, 106: 1-449.