Seasonal Bacteriological and Physico-Chemical Analysis of Lake Timsah, Ismailia, Egypt

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Abstract: In recent years, Lake Timsah in Ismailia city has been subjected to significant environmental changes caused by various anthropogenic activities. The seasonal physico-chemical and bacterial analysis were integrated for assessing lake water quality. Forty-eight water samples were collected from Lake Timsah during February-December 2012. Seasonal analyses of physico-chemical and bacteriological characteristics of the collected samples were assessed. Dissolved oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of tested samples showed the highest values in winter season, ranged between 2.00 ml/l - 9.6 ml/l, 4.4 - 22 MgO_2/l, and 13.2 - 55.2 mg/l, respectively. In winter, CCA (Canonical Corresponding Analysis) indicates that *Staphylococcus aureus* and *Vibrio cholerae* were strongly correlated with salinity and pH; Total Coliform (TC) and *Salmonella* sp. with PO_4. In spring, CCA were estimated correlation of TC with ammonia; *Escherichia coli* with nitrate and nitrite; *Aeromonas* sp. with pH and salinity and *Salmonella* sp. with transparency. In summer, TC correlated with phosphate; *S. aureus* with salinity; and *Shigella* sp. with pH. In autumn, *S. aureus* had correlated with pH. Overall, the study concluded that the quality of lake water has deteriorated to the extent of being unfit for different purposes. Urgently restoration and effective management needed for its sustained existence and continued provisioning of various economic goods and ecosystem services.
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Keywords: Water pollution, Lake Timsah, physicochemical characteristics, bacteria.

1. Introduction

Lake Timsah represents an important touristic and economical resource. It contains many of the tourist beaches and excellent long time ago, characterized as a pure and distinctive place on the Suez Canal. Unfortunately, lake is being polluted by municipal, industrial and agricultural drainage that affects its physico-chemical characteristics and microbiological quality **(Wright *et al.*, 2009).**

The expanding coastal populations and emerging land-based activities, have contributed to the ever increasing pressure on coastal waters. The contaminants include water-borne disease-causing pathogens such as viruses, bacteria, protozoa and worm eggs, which can be found in both human and animal feces **(Elmanama *et al.*, 2005 and Thomas, 2009)**.The industrial waste water represents the main source of water pollution in different parts of the world, e.g. Poland **(Niewolak, 2000)**; Nigeria **(Akaninwor*et al.*, 2007)**; Brazil **(Gunkel *et al.*, 2007)** and Egypt **(Sabae *et al.*, 2006)**.

Bacterial population in the semi-enclosed bays is comparatively higher than the open sea, since the coastal human habitation depends more on these water-bodies for fishing as well as navigation purposes. They also release their domestic wastes directly into the bay, which ultimately degrade the quality of water and increase the bacterial concentration **(Dunn *et al.*, 2012)**.

Assessment of microbiological quality and health risks associated with marine water contact is normally achieved by fecal indicator bacteria including total coliform, fecal coliform, fecal streptococcus, *Aeromonas* sp. **(Thomas, 2009 and Bahgat, 2011).** Global estimates indicate that each year more than 120 million cases of gastrointestinal disease and 50 million cases of severe respiratory diseases are caused by swimming and bathing in wastewater-polluted coastal waters **(Shuval, 2003; Boehm, 2007; Elmir *et al.*, 2007 and Wright *et al.*, 2009).**

In this study assesses seasonal water quality of Lake Timsah water in Ismailia city and relates the physicochemical and bacteriological characteristics of water with standard guidelines for safe usage.

2. Material and methods

2.1. Sampling

Forty-eight marine water samples were collected from Lake Timsah, Ismailia city; sampling sites were

chosen to cover all sites along the coast of Lake Timsah (Fig.1). Samples were collected on a seasonally basis during February–December 2012 from subsurface (1.5 m) of the selected stations (St.), along away 100 meters from the beach of Lake. The samples were taken into pre-sterilized bottles kept in iceboxes, which were further transported laboratory for physico-chemical and bacteriological analysis.

2.2. Physico-Chemical Analysis

Temperature, pH, salinity and transparency of the collected samples were measured in the sites. Water samples were analyzed for Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Nitrate (NO^-_3), nitrite (NO^-_2), ammonia (NH^+_4), and phosphate (PO^-_4) according to standard methods **(APHA, 1998).**

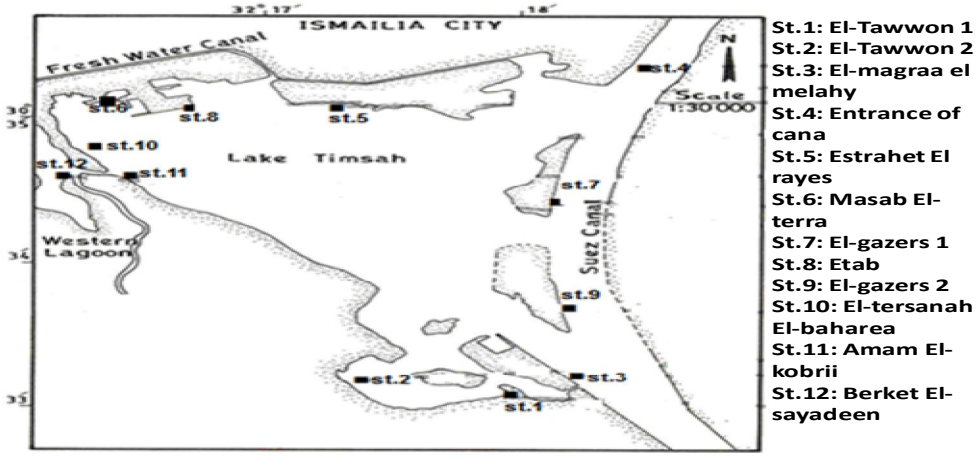


Figure 1. Lake Timsah map showing the sampling locations.

2.3. Bacterial Analysis

Samples were examined for enumeration of indicator bacteria including; Total Coliform (TC), *Escherichia coli*, Fecal Streptococci (FS) and some pathogenic bacteria (*Staphylococcus aureus*, *Salmonella* sp., *Shigella* sp., *Aeromonas* sp. *and Vibrio cholerae*) using a membrane filtration technique **(APHA, 1998)**. Briefly, marine water sample (100 ml) was filtered through a gridded sterile cellulose-nitrate membrane filter (0.45 µm pore size, 47 mm diameter, Sartorius type filters) under partial vacuum (Millipore, Befrid, UK). The membrane filters were immediately removed with sterile forceps and placed on the following media with rolling motion to avoid entrapment of air: m-Endo agar was used for TC detection after 24 hr at 37 °C. Difco TM -MFC (m-fecal coli) agar were used for detection of *E. coli* after 24 hr at 37 °C, ME (m-*Enterococcus*) agar were used for detection and enumeration of FS, after 48 hr at 37 °C. Manitol salt agar and Verdi Brilliant agar were used for detection and enumeration of *S. aureus* (yellow colonies) and *Salmonella* sp. at 37 °C for 24 hr. For detection of *Shigella* sp., *Aeromonase* sp. and *V. cholerae*, Salmonella-Shigella (SS) agar, bile salt irgas an brilliant green agar and thiosulfate citrate bile salts sucrose agar, respectively were inoculated and incubated at 37°C for 24 hr.

2.4 Enumeration of colonies

Ten random characteristic colonies from each sample were subcultured, confirmed and the final counts were calculated as Colony Forming Units (CFU) per 100 ml according to **WHO (2003)**. Final counts were calculated as described by **El-Shenawy and Farag (2005)**.

$$\textbf{Bacterial colony (CFU) per100 ml} = \frac{\textbf{Bacteial colony counted}}{\textbf{ml of sample filtered}} \times \frac{\textbf{No. of colony right in conirmatory test}}{\textbf{No. of total confirmatory test colony}} \times \textbf{100}$$

2.5 Statistical Analysis

Standard deviation and two-way analysis of variance ANOVA test were used for correlating the data and elimination of variance is observed in results. Bacterial count was transformed prior to statistical treatment and results were analyzed by standard deviation and ANOVA test **(Gomez and Gomez, 1984).**The matrix of (bacterial) analyses and physico-chemical characteristics of the investigated samples were subjected to CCA (Canonical Corresponding Analysis) using CANOCO (Canonical Community Ordination) program **(Braak, 1987).**

3. Results

3.1 Physico-Chemical Analysis

The seasonal variations of physico-chemical characters of the collected samples during February-

December 2012 were plotted in Figure (2), while, the data of regional variations of lake samples were not shown. The mean pH values of the investigated samples were in acceptable range fluctuated between 7.9 - 8.5; the later values obtained in summer (Fig. 2A). The seasonal average of temperature degrees noticed between 16.1 to 29.6 °C; the highest degree were obtained in summer (Fig. 2A). The lowest seasonal average of salinity was noted in spring (4.77 Psu) while, the highest salinity were obtained in summer and autumn (Fig. 2A). Regarding to transparency, the lake is considered a low transparent water body; the average Secchi disc reading ranged from 0.77 to 1.68 m in spring and autumn, respectively (Fig. 2A).

The seasonal average of DO values ranging between 4.20 mg/l in autumn and 6.32 mg/l in spring (Fig. 2B). Furthermore, the variations of Biological Oxygen Demand (BOD) values in samples were observed between 9.3- 13.7 mg/l in autumn and summer, respectively (Fig. 2B). The seasonal Chemical Oxygen Demand (COD) values of collected samples recorded between 13.4 to 47.9 mg/l in autumn and winter, respectively (Fig. 2B).

Generally, the seasonal distributions of the different nitrogenous components (NH^+_4, NO^-_2 and NO^-_3) are presented in Figure (2C). The seasonal average of NH^+_4concentrations fluctuated between 3.33 - 4.18 µg/l in autumn and winter, respectively. While, the average of NO^-_2 ranged from 0.94 to 1.13µg/l in summer and autumn, respectively. Furthermore, the average of NO^-_3 observed between 6.13 - 7.01µg/l during summer and autumn, respectively. The mean seasonal variations of PO^-_4 noticed in range of 0.8 to1.38 µg/l in summer and autumn, respectively (Fig. 2C).

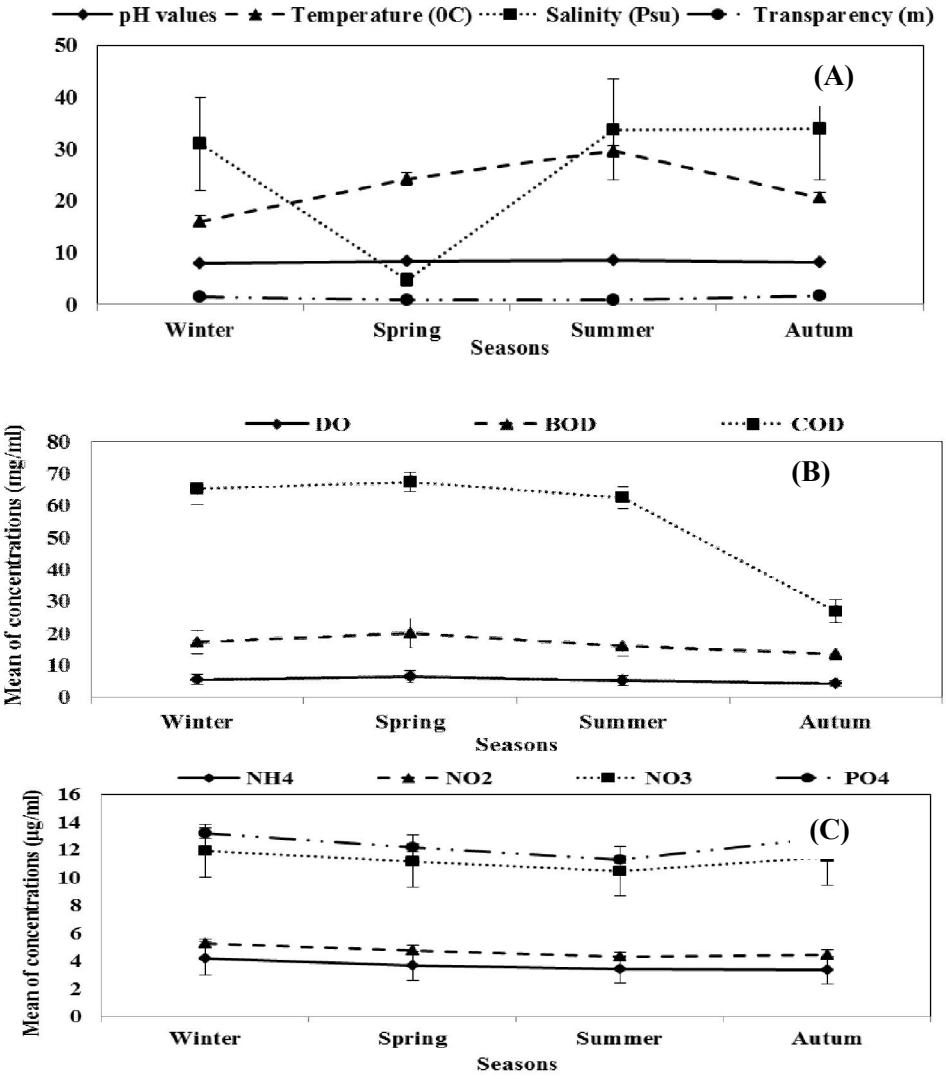


Figure 1. Seasonal mean of physico-chemical parameters of Lake Timsah samples.

3.2 Bacteriological Analysis

Table 1. Regional and seasonal variations of indicator bacteria in Lake Timsah samples.

Stations (St.)	TC				*E. coli*				FS			
	W	SP	SU	A	W	SP	SU	A	W	SP	SU	A
1	150±2	13±2.5	992±2.5	190±2	60±2	10±3	11±3.5	11± 3.5	11±3.5	11±3.5	11±3.5	11±3.5
2	80±2	10±2	900±1	30±3	13±2	9±1.5	13±3	13±3	13±3	13±3	13±3	13±3
3	320±2.5	20±2	1030±3	40±2.5	220±4	11±1.5	12±3.5	12±3.5	12±3.5	12±3.5	12±3.5	12±3.5
4	210±2	30±2.5	900±3.5	200±2.5	160±1	12±3	12±3	12±3	12±3	12±3	12±3	12±3
5	170±2	20±3.5	251±4	230±1	200±2	13±3.5	9±2	9±2	9±2	9±2	9±2	9±2
6	750±1	31±4	69±2	998±3	380±3.5	20±3	89±2.5	89±2.5	89±2.5	89±2.5	89±2.5	89±2.5
7	90±2	11±2	150±2.5	500±2	10±2.5	10±3	33±1	33±1	33±1	33±1	33±1	33±1
8	800±1.5	10±1	78±2	800±3	40±3	9±3	24±2	24±2	24±2	24±2	24±2	24±2
9	830±2.5	22±1	370±2.5	220±3	10±2.5	12±3	11±3	11±3	11±3	11±3	11±3	11±3
10	450±3.5	33±2	1599±2	450±3.5	160±3	10±3.5	172 ±2.5	172±2.5	172±2.5	172±2.5	172±2.5	172±2.5
11	900±1	3902±3.5	7183±2	4109±3	650±2.5	753±2	1400 ±3	1400±3	1400±3	1400±3	1400±3	1400±3
12	4000±3.5	4251± 2.5	7448±2	6800±2	710±3.5	918±2.5	1460 ±1.5	1460±1.5	1460±1.5	1460±1.5	1460±1.5	1460±1.5
Total mean	729±2.63	696±2.72	1752 ± 2.77	1216 ± 5.11	219±1.93	149± 2.71	697 ± 3.31	379 ±3.04	98±2.48	196±5.92	185±3.84	142±2.95
Station effect (F- St.)	23.1^{***}				10.5^{***}				4.4^{***}			
Season effect (F-Seas.)	2.7^{*}				3.4^{*}				0.9^{ns}			
Station and Season effect (F- St.* Seas.)	56386.5^{***}				55351.1^{***}				4919.9^{***}			

TC: Total Coliform, FS: Fecal Streptococci, W: Winter, SP: Spring, SU: Summer, A: Autumn.
Values are presented in mean (CFU/100ml) ± Standard deviations.
*Indicates significant at $P<0.05$, **Indicates significant at 0.01, highly significant $P<0.001$, ^{ns}Indicates not significant.

Table 2. Regional and seasonal variations of pathogenic bacteria in Lake Timsah samples.

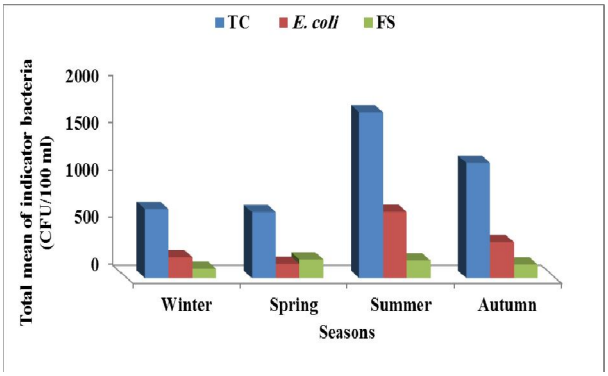
Stations (St.)	*S. aurues*				*Salmonella* sp.				*Shigella* sp.				*Aeromonas* sp.				*V. cholerae*			
	W	SP	SU	A	W	SP	SU	A	W	SP	SU	A	W	SP	SU	A	W	SP	SU	A
1	40± 2	60±2	665±3	300±3	10±2	15±1	482±4	200±4	7±1	5±1	90±2	40±1	80±2	27±2	60±3	780±2	7±1	2± 1	1±1	20±2
2	30± 3	200±4	700±3	800±3	12±2	3±2	420±3	90±4	3±2	6±1	30±1	70±2	350±2	4±2	9 ±2	489±3	9±1	1± 1	1±1	10±2
3	20± 3	209±2	650±3	300± 3	10±4	10±2	90±2	130±3	5±1	6±2	220±2	50±1	20±3	50±4	10±2	1000±3	12±2	1± 1	1±1	400± 1
4	20± 1	212±3	410±3	400± 2	9±1	14±3	150±3	290± 4	1±1	2±1	50±4	30±4	11±2	12±3	90±2	400±2	6±3	1± 1	1±1	20±3
5	30± 4	280±4	460±3	800±3	9±3	26±2	140±1	600± 2	1±1	1±1	160± 1	70±1	11±3	0±2	110±1	300±4	10±5	3± 2	1±1	50±2
6	30± 3	399±2	900±2	3000± 2	40±3	5±2	280±1	93±2	17±3	23±2	170±3	500±1	9±1	120±2	200±4	2000±3	4±1	2± 1	1±1	500± 4
7	30± 4	270±3	760±3	900± 4	12±3	40±2	340±2	140±3	11±1	15±2	130±1	30±3	12±2	11±3	60±2	1500±4	7±2	1± 2	1±1	9±2
8	42± 3	290±2	800±2	3000± 2	13±2	30±2	420±3	580±2	12±2	20±3	130±1	90±4	30±3	80±2	820±1	1000±2	9±2	5± 3	1±1	9±3
9	50± 2	271±4	560±3	500±3	8±4	20±3	50± 4	150±3	18±1	29±1	110±2	60±2	9±1	90±3	110±3	300±4	12±2	1± 1	2±1	30±
10	31± 4	340±2	1100±2	1010± 4	30±4	35±3	150±2	700±1	9±1	10±1	80±4	90±2	10±3	50±3	60±2	1200±2	11±2	1± 2	1±1	150± 4
11	60± 2	700±3	820±4	2089± 3	40±3	170± 2	200±2	8000± 4	90±3	130± 2	120±2	1300±2	12±2	1±2	700±2	15000±4	18±4	1± 1	8±1	200± 4
12	11± 2	1300±3	1950±5	5000± 2	190±4	80±2	410±2	9000± 4	110±1	150± 4	120±2	4000±3	80±2	27±2	60±3	780±2	17±1	7± 3	12±2	300± 2
Total mean	33± 3	380±7.5 4	814±3.2 1	1509± 4.51	31±2. 9	37±2	261±2. 6	1664± 3	23±1. 4	32±2	117±2. 1	527±2.4 1	50±2.2 5	37±2.3 9	285±2. 5	3687±42. 2	10±2. 2	2± 1	2±0. 6	141± 3
Station effect (F- St.)	3.4^{***}				2.06^{*}				1.5^{ns}				2.1^{*}				1.21^{ns}			
Season effect (F-Seas.)	8.9^{***}				3.9^{***}				5.1^{***}				3.06^{*}				4.8^{***}			
Station and Season effect (F- St.* Seas.)	15.4^{***}				826937^{***}				583682^{***}				9288^{***}				5096.4^{***}			

W: Winter, SP: Spring, SU: Summer, A: Autumn.
Values are presented in mean (CFU/100ml) ± Standard deviations.
*Indicates significant at $P<0.05$, **Indicates significant at 0.01, highly significant $P<0.001$, ^{ns}Indicates not significant.

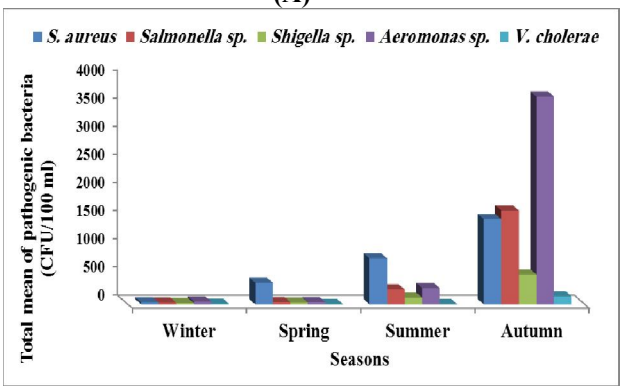
The regional and seasonal variations of indicator bacteria (Total Coliform; TC, *Escherichia coli* and Fecal Streptococci; FS) counts in lake samples during 2012 were summarized in Table 1. In general, the maximum number of indicator bacteria was reported in winter and summer collected samples, while the lowest number of bacteria was reported in spring. Bacterial count for all water samples were compared with the **WHO (2003)** guideline value (Table 1). WHO maximum acceptable limit of TC in marine water is 500 colonies per ml. Mostly, water samples collected in different seasons were contaminated with high amount of bacterial population than WHO acceptable limit except, St. 7 was within the permissible level during studied seasons. *E. coli* counts in the stations 1, 2, 3, 7, 8 and 9 were within the permissible level (<100CFU/100ml). The remaining water samples exceeded the desirable limit in different seasons. For FS counts, the higher number were observed in St.10, 11 and 12 in successive proposed seasons that exceeded WHO acceptable limit; <100CFU/100ml as shown in Table (1). Statistical analysis showed significant relationship between indicator bacteria and different stations, in addition, different stations with seasonal data (P<0.001). But, the insignificant effects were observed between FS and different seasons as shown in Table 1.

Table 2 lists the counting of pathogenic bacteria including; *S. aureus*, *Salmonella* sp., *Shigella* sp., *Aeromonas* sp. and *V. cholerae*. In autumn collected samples, regardless of total mean of pathogenic bacteria counts, the most abundant bacteria are *Aeromonas* sp.(3687 CFU/100ml), followed by *Salmonella* sp. (1664 CFU/100ml), *S. aureus* (1509 CFU/100ml), whereas *V. cholerae* are present with lowest abundance (141 CFU/100ml). Conversely, in winter collected samples, total mean count of pathogenic bacteria decreased (Table 2).Collected samples from St.6, St.11 and St.12 were found maximally polluted with *S. aureus* in spring, summer and autumn as shown in Table 2.The maximum number of *Salmonella* sp. (9000 CFU/100ml, St.12), *Shigella* sp. (4000 CFU/100ml, St.12), *Aeromonas* sp.(15000 CFU/100ml, St.11) and *V. cholerae* (500 CFU/100ml, St.6) was reported in autumn collected samples. The statistical analysis of seasonal change showed the significant data (P< 0.001). Furthermore, all tested pathogenic bacteria showed significantly regional and seasonal variations (Table 2). *S. aureus* and *Aeromonas* sp. showed significant relation with different stations, while, *Shigella* sp. and *V. cholerae* observed insignificant relationship.

Generally for indicator bacteria, total mean count of TC is the highest among studied seasons (Fig2a). While for pathogenic bacteria, *Aeromonas* sp. and *S. aureus* were the highest; the former bacteria in winter and autumn and the later in spring and summer (Fig 2b). In conclusion, bacteriological characteristics observed for Lake Timsah water quality is alarming, especially in both stations St.11 and St. 12.



(A)



(B)

Figure 2. Seasonal variations of indicator bacterial count in Lake Timsah.

3.3. CCA analysis

Statistical analysis of interrelationships between the seasonal variations with physico-chemical parameters and bacterial abundance using CCA correlation was derived (Fig. 3). A positive correlation is expressed by relatively long vector which roughly pointed into the same direction, whereas arrow pointing into the opposite direction indicates a negative correlation. In winter, *S. aureus* (B4) and *V. cholerae* (B8) strong influenced with salinity and pH, TC (B1) and *Salmonella* sp. (B5) with PO^{-}_{4} (Fig. 3A). Whereas, the strongest positive correlation is between TC (B1) with NH_4, *S. aureus* (B2) with NO^{-}_{2} and NO^{-}_{3}, *Salmonella* sp. (B5) with transparency and *Aeromonas* sp. (B7) with pH and salinity observed in spring (Fig. 3B). In summer, positive correlation was estimated between TC (B1) with PO^{-}_{4}, *S. aureus* (B4) with salinity, *Shigella* sp. (B6) with pH (Fig. 3C). In contrast, in autumn, abundance of all collected bacteria are negatively correlated with the above-mentioned parameters, except *S. aureus* (B4) correlated with pH (Fig. 3D).

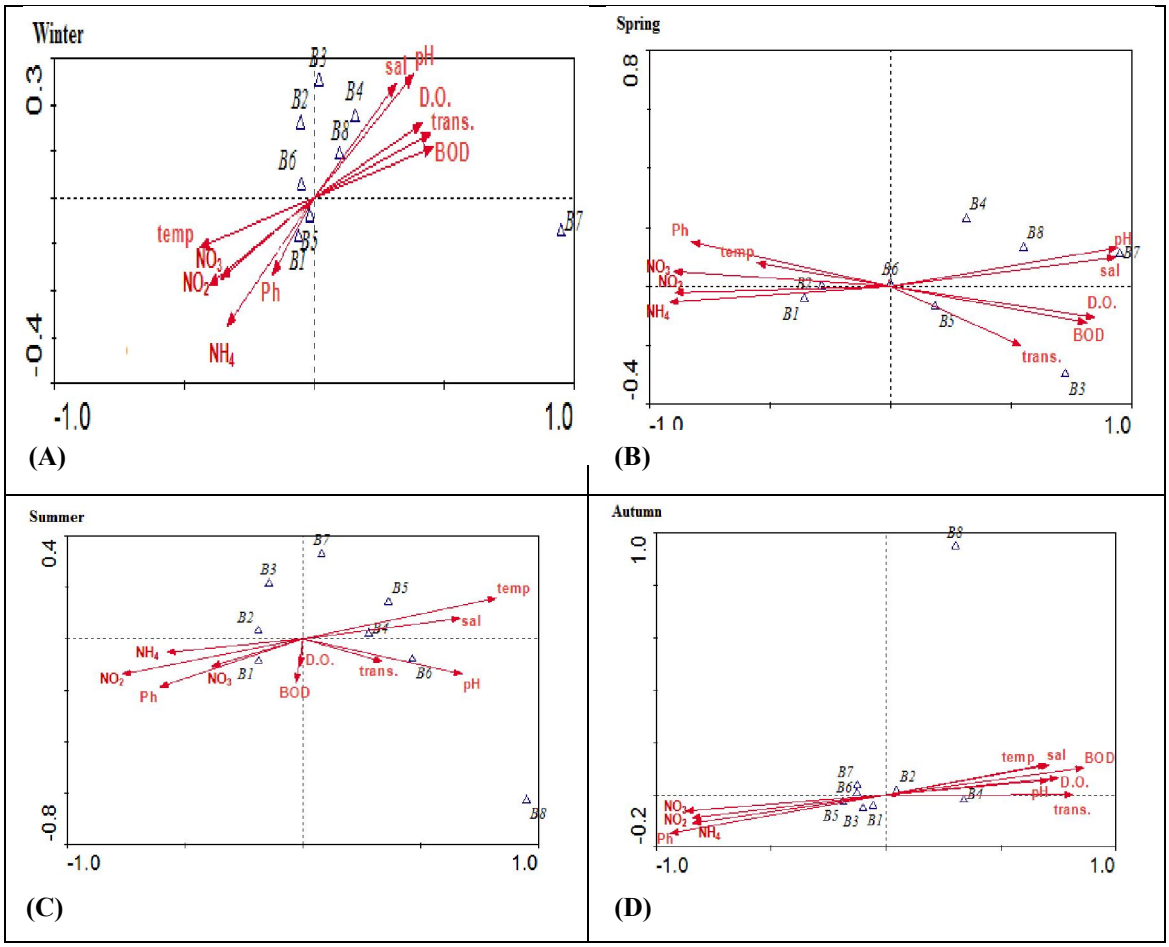


Figure 3. Biplot of Canonical Correspondence Analysis (CCA) showing the seasonal relationships between bacterial isolates and physico-chemical water characteristics in Lake Timsah. (**B1**): Total Coliform, (**B2**): *E. coli*, (**B3**): Fecal streptococci, (**B4**): *Staphylococcus aureus*, (**B5**): *Salmonella* sp., (**B6**)*: Shigella* sp., (**B7**): *Aeromonase* sp. and **(B8)**: *Vibrio cholerae*.

4. Discussion

In this study, the seasonally variation of the physico-chemical and bacteriological parameters of Lake Timsah water were estimated for assessment of the water quality.

Temperature and pH are factors of great important for aquatic ecosystem, as they affect the organisms, as well as the chemical and physical characteristics of water (**WHO, 2003**). Recorded water temperature and pH showed obvious seasonal variation with minimum in winter and maximum in summer. The effect of temperature on bacteria due to seasonal change also corroborated the finding of **Kaiser *et al.* (2009)** and **El-Sherbiny *et al.*(2011)**. The pH values of collected samples were within the permissible limit. This was positively correlated by the pH of Ismailia Canal water where the pH ranged from 7.7 to 8.17 **(Abdo *et al.*, 2010).**Relatively lower pH values may reflect the decreased productivity of the lake as a result of the polluted water discharged into the Lake **(Hassanin, 2006).**

Salinity is also among the most important factors and exerts various effects on the vitality of marine organisms. The highest value of salinity obtained in summer – autumn period. In this case, it is logical to consider the possibility of salinity rising; due to the increase in the evaporation rate and shallowness of water. Additionally, salinity readings were lowered in spring may be due to the fresh water discharge from sewage and agriculture drainage and the village tours presented at these sites **(Bahgat, 2011).**

The proposed stations were characterized by lower transparency water body especially during spring (0.77 m). **El-Shenawy (2005)** indicated that the lowering of transparency values of Lake Timsah may be due to decrease in water level and flourishing of phyto-zooplankton.

The seasonal variations of BOD, COD and OD values during the period of investigation showed general decrease in autumn. On the other side, the higher values of these parameters were recorded during spring- summer period. Raising of BOD values may be a attributed to the photosynthetic activity and abundance of phytoplankton during hot period, especially in spring **(Abdo, 2005)** while, increasing of the obtained COD values might be attributed to the increase in air and water temperature, increased biological activity, respiration of organisms, as well as the increasing the rate of organic matter decomposition (**Kaiser*et al.*, 2009 and Bahgat, 2011)**.

The level of the oxygen in marine water (5 to 10 mg/l) is an indicator of healthy state of water and values below 5 mg/l are hazardous **(USEPA, 1999).**The Dissolved Oxygen (DO) content in the water samples, except autumn collected water samples were within the permissible level. These results were positively correlated with the dissolved oxygen values in the marine water of Lake Timsah, which ranged from 5.6 to 10.2 mg/l **(Kaiser *et al.*, 2009).** The decomposition and oxidation of organic matter reduce the solubility of oxygen in water. The reason for the low dissolved oxygen content was due to high decomposition of organic matter, which indicates a high pollution load in the water. The deficiency of the oxygen in the water is shelter for bacteria and other pathogens, which are anaerobic and injurious to human health.

There was a noticeable variation in ammonia (NH_4) levels; the lowest ammonia content was recorded in autumn. This is probably due to the utilization of NH_4 by phytoplankton. On the other hand, the increase in NH_4 may be due to the reduction of NO_3 to NH_4 via a denitrification process (**Seitzniger, 1988**). The nitrite content revealed a higher value in autumn than in the other seasons, probably due to the effect of the huge amounts of drainage water discharged into the lake, as well as the decrease in the uptake by phytoplankton. Narrow variations in nitrite values were observed in the other seasons, perhaps as a result of NO_2 reduction to ammonia under anaerobic conditions. This can be explained by the fact that the lower nitrite values were accompanied by an increase in NH_4. The higher values of NO_3 could be interpreted on the basis of the decomposition of the organic matter as well as the large amounts of drainage water. On the other hand, the lower values during summer are mostly due to its assimilation by phytoplankton and aquatic plants. **(Al-Yamani, 2006; Abdo, 2010 and El-Sherbiny, 2011).**

Phosphorous is an important element which controls the reproduction and growth of aquatic organisms. Many organisms utilize both organic and inorganic forms of phosphorous, however inorganic phosphorous seems to be more appreciated by plants than organic phosphorous (**Riley and Chester, 1971**). It is interesting to note that the increasing values of reactive phosphate were determined in the autumn and winter seasons. The higher concentrations of reactive phosphate are mostly due to the effect of drainage water enriched with phosphorous compounds. In contrast, the mentioned parameter reveals a significant decrease during the summer and spring seasons on the basis of the increasing uptake by phytoplankton. The lower content of total phosphorous in summer could be due to the decomposition of organic remains.

The occurrence of indicator bacteria is used as sanitary parameters for evaluation of water quality **(WHO, 2003)**. Bacterial diversity in surface water usually is highly responsive to perturbation, shifting with tidal cycling **(Chauhan *et al.*, 2009)**, salinity fluctuations **(Crump *et al.*, 2004)**and dissolved organic matter concentrations**(Nelson, 2009)**. All these may be reflected in the higher diversity of the subsurface layers which were characterized by the dominance of TC bacteria.

In the present study indicator bacteria showed irregular pattern of their occurrence in different samples. Mostly, water samples collected in different seasons were contaminated with high amount of bacterial population than WHO acceptable limit (TC; < 500 CFU/100ml, *E. coli* and FS; < 100 CFU/100ml). The irregular variations in the indicator bacteria due to seasonal change also corroborated the finding of **(Abdelzaher *et al.*, 2010; Dick *et al.*, 2010 and Bahgat, 2011).**This assumes that stations were contaminated with sewage and excessive fishing activities. Many authors have referred to both recreational activities during the long summer season, hence, untreated wastes discharged from vessels and boats into the coastal water, or, raw wastes (sewage and agriculture) were disposed in these stations **(Kaiser *et al.*, 2009 and Bahgat, 2011)**.

The application of multivariate techniques (CCA) revealed and confirmed that the seasonal variation of physico-chemical factor controls the dominance of the tested bacteria in Lake Timsah. Many authors have reported correlations of physic-chemical parameters in water meeting the bacterial regulations **(Lotfy *et al.*, 2011; Momtaz *et al.*, 2013; Wose *et al.*, 2012; Altuğ, 2012 and Khalil *et al.*, 2013).**

Conclusion

In conclusion, the obtained results demonstrated that the seasonal variation of physico-chemical characteristics of Lake Timsah may lead to different

bacterial communities. Multivariate statistical analysis indicated that, PO^{-}_{4}, NO^{-}_{2}, NO^{-}_{3}, salinity and pH had remarkable effects on bacterial community structure in lake water. Furthermore, the bacteriological parameters revealed that the Lake Timsah water is highly affected with high bacterial population at any point of lake. The microbial quality of water also revealed abundant growth of pathogenic bacteria population. Thus, continuous monitoring of Lake water must be done to ensure the safety of lake Timsah water for proposing in recreational and fishing activities.

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