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Research Article
Bacteriological Monitoring for the Northern Khors of Lake Nasser, Egypt

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Abstract
Lake Nasser and its khors are important source of fresh water and freshwater fish in Egypt, therefore, the water management and quality control should be carefully considered to avoid any defectiveness at an appropriate time. Thus, this study was planned to evaluate microbial loads for water (surface and bottom water layers), sediments and plants in Northern khors of Lake Nasser (El-Ramla, Kalabsha, Wadi Abyad and Rahma) during two seasons, winter and spring, 2015. The physicochemical and bacteriological analyses indicated that, Among khors, El-Ramla khor (the nearest one to the high dam, Aswan city and then increased the activity of fishing) recorded the highest total dissolved solids as well as total and faecal coliform bacteria (means of 174.3 mg L^{-1}, 312 and 45 MPN/100 mL, respectively). Winter season recorded higher microbial loads. In addition, bacteriological analyses for sediment and plant samples showed that, total diazotrophs were found in high numbers reaching $>1.9\times10^{9}$ CFU g^{-1} sediment and 7.7×10^{7} CFU g^{-1} plant compared to total bacteria which reached $>3.2\times10^{9}$ CFU g^{-1} sediment and 4.4×10^{7} CFU g^{-1} plant. In general, the results indicated that, microbial loads in water, sediments and plants affected by human activities (fishing and tourism) and environmental conditions. Also, the water quality of the Northern khors of Lake Nasser is acceptable in respect to physico-chemical parameters but not bacteriological parameters and it is acceptable for irrigation water not for drinking water.

Key words: Lake Nasser khors, bacteriological monitoring, bacterial water quality, diazotrophs

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Lake Nasser represents the main source of the Egyptian freshwater budget (95%) and has a number of side extensions known as khors (side channels). It is representing about 79% of total lake surface and about 55% of total lake volume (Entz, 1973). The total numbers of longer khors reached about 85 khors, 48 of which are on the Eastern side and 37 on the Western side (Heikal, 2010). Among those khors, Kalabsha, El-Allaqi, Tushka, El-Sabakha, Singari, Korosko etc. (Latif, 1984). Khors considered a favourite habitats for fish, so they play a major role for fish productivity (El-Shabrawy and Dumont, 2003). Several studies investigated the morphology and ecology of Lake Nasser (Entz, 1973, 1976; Latif, 1974, 1984; Khalifa *et al*., 2000; El-Shabrawy, 2014).

Water quality of the Lake Nasser is affected by many factors including water levels, inflows, water circulation, thermal stratification, loadings and sedimentation (Heikal, 2010; El-Shabrawy, 2014). In fact, physico-chemical analyses give some information on water quality in aquatic system, such as temperature, pH, dissolved oxygen, turbidity, conductivity, biochemical oxygen demand, chemical oxygen demand, forms of nitrogen, forms of phosphorus, heavy metals etc. Although, several studies investigated physical and chemical properties of Lake Nasser (Latif and Elewa, 1977; Latif *et al*., 1989; Goher and Ali, 2009), still little informations on bacteriological properties of Lake Nasser are available (Rabeh *et al*., 1999; Rabeh, 2001, 2003). Bacteriological analysis is very important to evaluate the quality of water, e.g., higher level of bacterial indicators of faecal pollution is directly propositional to faecal contamination and raise the risk of water borne diseases (Shridhar, 2012). Besides, faecal coliform counts were used in water quality index calculations (Ott, 1987), which classified water quality to five categories (very poor, poor, medium, good and excellent). As well as, some physico-chemical parameters with chlorophyll a were used in trophic state index calculations (Carlson, 1977), which gives information about productivity (low, moderate and high productivity). Moreover, in aquatic environments, the biological nitrogen fixation (biochemical process) occurred by free-living N_2 fixing bacteria (cyanobacteria, Azotobacter and Clostridium) is necessary for availability of nitrogenous compounds for other living organisms, where diazotrophic bacteria release growth factors (Fukami *et al*., 1997), beneficial for fauna and flora in aquatic environments and thus increase water productivity and consequently increase the production of fish. Also, diazotroph used successfully as probiotic for fish (Ali *et al*., 2011) and used as waste bioremediators (Ali, 2014; Ali *et al*., 2012). Therefore, diazotrophs protect aquatic environments from pollution and generate value-added products.

The main aim of this present study is to estimate the microbial loads of water (surface and bottom water layers) in the northern Lake Nasser khors (El-Ramla, Kalabsha, Wadi Abyad and Rahma) and to estimate autochthonous and diazotroph microbial loads in sediments and plants collected from these khors.

MATERIALS AND METHODS

Study area: Four khors in the northern part of Lake Nasser were selected, El-Ramla and Kalabsha located in the western side of Lake Nasser and Rahma and Wadi Abyad located in the eastern side (Fig. 1 and Table 1). For each khor, three sites were selected, in the entrance of khor, in the beginning of khor and its end.

Sampling

Water samples: Water samples were collected representing surface and bottom water layers using 500 mL sterile bottles for bacteriological analyses. Water samples were collected during winter (January) and spring (May), 2015 to monitor microbiological characteristics of waters.

Sediment samples: Sediment samples were collected using Ekman grab from each khors during winter and spring, 2015 to estimate microbial content, autochthonous (total and spore-forming bacteria) and diazotrophs (total and spore-formers).

Plant samples: Plant samples were collected manually from each khors during winter and spring to enumerate total and spore-forming bacteria as well as total and spore-forming diazotrophs. *Myriophyllum spicatum* represents the aquatic plant collected.

Analyses

***In situ* measurements:**

- Transparency was measured by a black-white Secchi-disc
- Electrical conductivity, total dissolved solids and hydrogen ion concentration were measured *in situ* using Martini instruments Mi 805
- Dissolved Oxygen (DO) and temperature were measured by Trans Instruments HD 3030 (APHA., 1995)

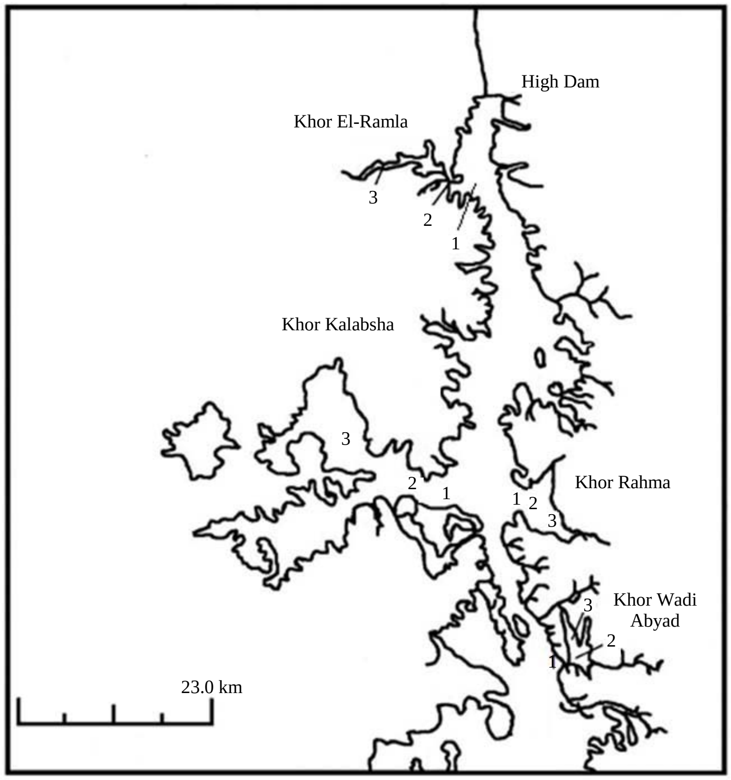

Fig. 1: Location map of the Northern khors of Lake Nasser, 1: Entrance of khor, 2: Beginning of khor and 3: Ending of khor

Table 1: Description of the sampling station and GPS data of Nortnern khors of Lake Nasser

Khor name	Distance from H.D (km)	Direction position	Surface area km^2 at 180 m level	Sample station	GPS data Latitude	Longitude
El-Ramla	10	West side	101.2	S1	23°52'9.66"N	32°50'59.26"E
				S2	23°52'43.43"N	32°49'24.87"E
				S3	23°54'4.03"N	32°46'48.03"E
Kalabsha	50	West side	620.0	S1	23°32'40.20"N	32°50'48.23"E
				S2	23°33'25.79"N	32°46'21.75"E
				S3	23°37'2.57"N	32°41'2.31"E
Rahma	55	East side	95.2	S1	23°31'56.04"N	32°54'8.00"E
				S2	23°31'45.58"N	32°56'14.33"E
				S3	23°30'33.78"N	32°56'41.34"E
Wadi Abyad	70	East side	48.7	S1	23°21'56.30"N	32°57'50.96"E
				S2	23°22'37.13"N	32°59'14.03"E
				S3	23°23'49.02"N	32°58'29.31"E

S1: Entrance of khor, S2: Beginning of khor, S3: Ending of khor

Laboratory measurements

Bacteriological analyses:

- Autochthonous and allochthonous bacteria: The pour plate technique and the plate count agar (APHA., 1995) were used for the enumeration of total bacterial counts at both 22 and 37°C incubation temperatures (autochthonous and allochthonous, respectively)
- Total thermophilic bacteria: Agar plates of total thermophilic bacteria were incubated at 55°C (APHA., 1995)
- Total spore-forming bacteria: Water samples and successive dilutions were pasteurized, for 15 min at 80°C, prior to plating using plate count agar and incubation at 30°C (APHA., 1995)
- Bacterial indicators of pollution: Bacterial indicators of pollution included counting of total and faecal coliforms

using MacConkey broth and faecal streptococci using azide-dextrose broth media (Eaton and Franson, 2005)

- Total diazotrophs were counted using the surface inoculated plate method and N-deficient combined carbon sources agar medium, CCM (Hegazi *et al*., 1998)
- Spore-forming diazotrophs: Water samples and successive dilutions were pasteurized, for 15 min at 80°C, prior to plating using CCM agar medium and incubation at 30°C (Hegazi *et al*., 1998)

Statistical analysis: Data obtained were statistically analyzed using STATISTICA 10 (StatSoft, Inc., Tulsa, USA). Analysis of variance (ANOVA) was used to examine the independent effects as well as possible interactions.

RESULTS

Water physico-chemical analyses: Physico-chemical results for surface and bottom water samples during winter and spring seasons are presented in Table 2 and 3, respectively.

Water temperature showed a noticeable variation during winter and spring, where lowest values were recorded during winter (means of 20.6°C) while highest values were recorded during spring (means of 28.8°C). In addition, there were no higher differences between khors temperature during the same season. El-Ramla khor recorded the highest temperature especially during spring (means of 31.17°C), entrance khors recorded lower temperatures than inside Khors.

Electrical Conductivity (EC) ranged from 267-289 µS cm^{-1} during winter and from 223-271 µS cm^{-1} during spring (Table 2 and 3). Kalabsha khor recorded higher EC estimates during winter season (means of 277 µS cm^{-1}), while El-Ramla khor recorded higher EC during spring season (256 µS cm^{-1}).

Total Dissolved Solids (TDS) fluctuated between 173-186 mg L^{-1} during winter, while during spring the range was 146-193 mg L^{-1} (Table 1 and 3). In general, highest TDS values were recorded at winter (means of 178 mg L^{-1}) compared to spring (159 mg L^{-1}). Among khors, El-Ramla khor recorded the highest TDS (means of 180 and 168 mg L^{-1} at winter and spring, respectively). In general, bottom layers recorded higher TDS in all khors studied except El-Ramla khor.

Highest values for transparency were recorded in khor Kalabsha (5.7 and 3.3 m at winter and spring, respectively). In general, highest values were recorded during winter (means of 4.1 m), while low values were detected during spring (means of 2.9 m) (Table 2 and 3).

The pH ranged between 7.9-9.0, in the alkaline side (Table 2 and 3). The result of pH values showed no higher differences among khors (means of 8.3, 8.4, 8.6 and 8.4 for El-Ramla, Kalabsha, Rahma and Wadi Abyad, respectively) and among seasons (means of 8.3 and 8.5 at winter and spring, respectively). In general, Rahma khor recorded the highest values in spring season (8.9).

High levels of DO were recorded during winter (7.3-10.4 mg L^{-1}), while less values were scored during spring (4.0-8.9 mg L^{-1}). Among khors, Kalabsha khor recorded the highest DO (means of 9.1 and 7.5 mg L^{-1} at winter and spring, respectively). The minimum DO values were observed near bottom sites of khors, particulate during spring season (means of 6.2 mg L^{-1}).

Water bacteriological analyses: The results of bacteriological analyses for surface and bottom water samples during winter and spring seasons are illustrated in Fig. 2, 3 and 4 and varied depending on the seasons, the sites and the level of samples (surface or bottom water layers).

Total bacterial counts either growing at 22 or 37°C (autochthonous or allochthonous, respectively) ranged from 10^2-10^6 CFU mL^{-1}. In addition, the ratio of total bacteria counts at 22 to 37°C ranged from 0.01-6.2. Among khors, Wadi Abyad khor recorded the highest populations either for autochthonous or allochthonous (means 3.3 or 2.3×10^4 CFU mL^{-1}, respectively). While Rahma khor recorded the lowest populations (means of 1.3 and 1.0×10^4 CFU mL^{-1} for autochthonous and allochthonous, respectively) (Table 4). In spite of decreased water temperature at winter season, samples recorded the highest microbial load compared to spring season (means of 35.4 and 2.3×10^3 CFU mL^{-1}, respectively for autochthonous and 21.3 and 7.3×10^3 CFU mL^{-1}, respectively for allochthonous) (Table 5). Irrespective of khors, seasons and water layers, the means for entrance and ending of khor sites were 2.5, 2.0 and 1.1×10^4 CFU mL^{-1}, respectively for autochthonous and 1.8, 1.5 and 1.0×10^4 CFU mL^{-1}, respectively for allochthonous. Bottom water layers were higher than surface water layers (means 3.4×10^4 and 3.9×10^3 CFU mL^{-1}, respectively for autochthonous and means 2.2×10^4 and 6.9×10^3 CFU mL^{-1}, respectively for allochthonous) (Table 5). The highest populations were recorded in the entrance of khor and gradually decreased in the beginning khor and at the khor end either for surface or bottom samples for autochthonous and allochthonous (Table 5).

As expected, higher thermophilic bacteria were recorded in the spring season compared to winter season (means of 2.5×10^2 and 1 CFU mL^{-1}, respectively) (Table 5). Among khors, Wadi Abyad khor recorded the highest thermophilic bacterial populations either in surface water

Table 2: Physico-chemical determinations of water samples of northern khors of Lake Nasser during winter, 2015

Khor name, sites and depth: El-Ramla

	S1		S2		S3			
Parameters	S	B	S	B	S	B	Mean	SD
Temp. (°C)	21.2	18.2	23.5	19.7	23.2	19.6	20.90	2.12
Trans. (m)	4.50		3.90		3.70		4.03	0.42
E.C (µs cm^{-1})	276	276	278	277	269	278	275	3.39
TDS (mg L^{-1})	179	179	181	179	176	186	180	3.35
pH	8.22	8.25	8.54	8.0	8.51	8.30	8.30	0.20
D.O (mg L^{-1})	9.70	7.29	10.00	7.72	8.80	7.60	8.52	1.15

Khor name, sites and depth: Kalabsha

	S1		S2		S3			
Parameters	S	B	S	B	S	B	Mean	SD
Temp. (°C)	21.1	19.9	21.2	19.4	21.0	18.9	20.25	0.99
Trans. (m)	5.5		5.8		5.8		5.7	0.17
E.C (µs cm^{-1})	274	271	289	274	274	280	277	6.57
TDS (mg L^{-1})	178	177	178	179	179	179	178	0.82
pH	8.40	8.37	8.13	8.22	8.35	8.36	8.31	0.11
D.O (mg L^{-1})	10.35	8.56	9.96	8.24	8.96	8.68	9.13	0.84

Khor name, sites and depth: Wadi Abyad

	S1		S2		S3			
Parameters	S	B	S	B	S	B	Mean	SD
Temp. (°C)	21.5	19.4	22.0	19.7	23.2	19.0	20.80	1.68
Trans. (m)	2.80		2.80		2.50		2.70	0.17
E.C (µs cm^{-1})	267	268	267	268	271	268	268	1.47
TDS (mg L^{-1})	176	173	176	173	177	176	175	1.72
pH	8.56	8.08	8.56	8.08	8.44	8.23	8.33	0.22
D.O (mg L^{-1})	9.61	7.57	9.64	7.72	8.64	7.44	8.44	1.01

Khor name, sites and depth: Rahma

	S1		S2		S3			
Parameters	S	B	S	B	S	B	Mean	SD
Temp. (°C)	22.9	19.2	20.2	18.9	21.5	19.1	20.30	1.60
Trans. (m)	3.80		3.80		4.40		4.00	0.35
E.C (µs cm^{-1})	275	275	275	275	270	278	274	2.58
TDS (mg L^{-1})	180	179	180	179	178	180	179	0.82
pH	8.58	8.28	8.58	8.28	8.20	8.02	8.32	0.22
D.O (mg L^{-1})	10.01	7.84	8.72	7.88	9.92	8.96	8.89	0.95

S1: Entrance of khor, S2: Beginning of khor, S3: Ending of khor, S: Surface, B: Bottom, SD: Standard deviation, Temp: Temperature, Trans: Transparency, E.C: Electrical conductivity, TDS: Total dissolved solids and DO: Dissolved oxygen

Table 3: Physico-chemical determinations of water samples of northern khors of Lake Nasser during spring, 2015

Khor name, sites and depth: El-Ramla

	S1		S2		S3			
Parameters	S	B	S	B	S	B	Mean	SD
Temp. (°C)	34.5	26.5	34.8	31.5	33.7	26.0	31.17	3.98
Transp. (m)	2.90		2.90		2.80		2.87	0.06
E.C (µs cm^{-1})	271	260	247	248	252	261	256	9.2
TDS (mg L^{-1})	193	168	161	161	167	162	168	12.3
pH	8.36	7.90	8.47	8.56	8.55	8.16	8.33	0.26
D.O (mg L^{-1})	7.52	4.14	7.53	8.85	7.80	4.73	6.76	1.88

Khor name, sites and depth: Kalabsha

	S1		S2		S3			
Parameters	S	B	S	B	S	B	Mean	SD
Temp. (°C)	32.0	25.0	28.5	27.2	27.3	25.7	27.6	2.5
Transp. (m)	3.20		3.20		3.50		3.30	0.17
E.C (µs cm^{-1})	230	255	232	223	228	245	235.5	12.05
TDS (mg L^{-1})	151	167	150	146	151	160	154	7.78
pH	8.76	7.92	8.50	8.80	8.30	8.33	8.44	0.33
D.O (mg L^{-1})	8.8	4.0	8.80	8.52	8.80	6.10	7.50	2.02

Khor name, sites and depth: Wadi Abyad

	S1		S2		S3			
Parameters	S	B	S	B	S	B	Mean	SD
Temp. (°C)	28.5	25.7	29.0	27.4	31.0	26.0	27.93	1.99
Transp. (m)	2.60		2.70		2.90		2.73	0.15
E.C (µs cm^{-1})	234	245	237	235	243	251	241	6.65
TDS (mg L^{-1})	153	160	154	156	160	165	158	4.52
pH	8.68	8.33	8.60	8.50	8.30	8.30	8.45	0.17
D.O (mg L^{-1})	8.61	5.2	8.45	8.50	7.70	4.80	7.21	1.75

Khor name, sites and depth: Rahma

	S1		S2		S3			
Parameters	S	B	S	B	S	B	Mean	SD
Temp. (°C)	29.5	26.4	33.0	25.0	29.5	27.6	28.5	2.82
Transp. (m)	2.50		2.60		2.90		2.67	0.21
E.C (µs cm^{-1})	235	250	235	250	234	245	242	7.71
TDS (mg L^{-1})	154	160	153	162	152	160	157	4.31
pH	8.97	9.00	8.95	8.53	9.01	8.90	8.89	0.18
D.O (mg L^{-1})	8.5	8.0	7.08	4.70	8.30	6.80	7.23	1.41

S1: Entrance of khor, S2: Beginning of khor, S3: Ending of khor, S: Surface, B: Bottom, SD: Standard deviation, Temp: Temperature, Trans: Transparency, EC: Electrical conductivity, TDS: Total dissolved solids and DO: Dissolved oxygen

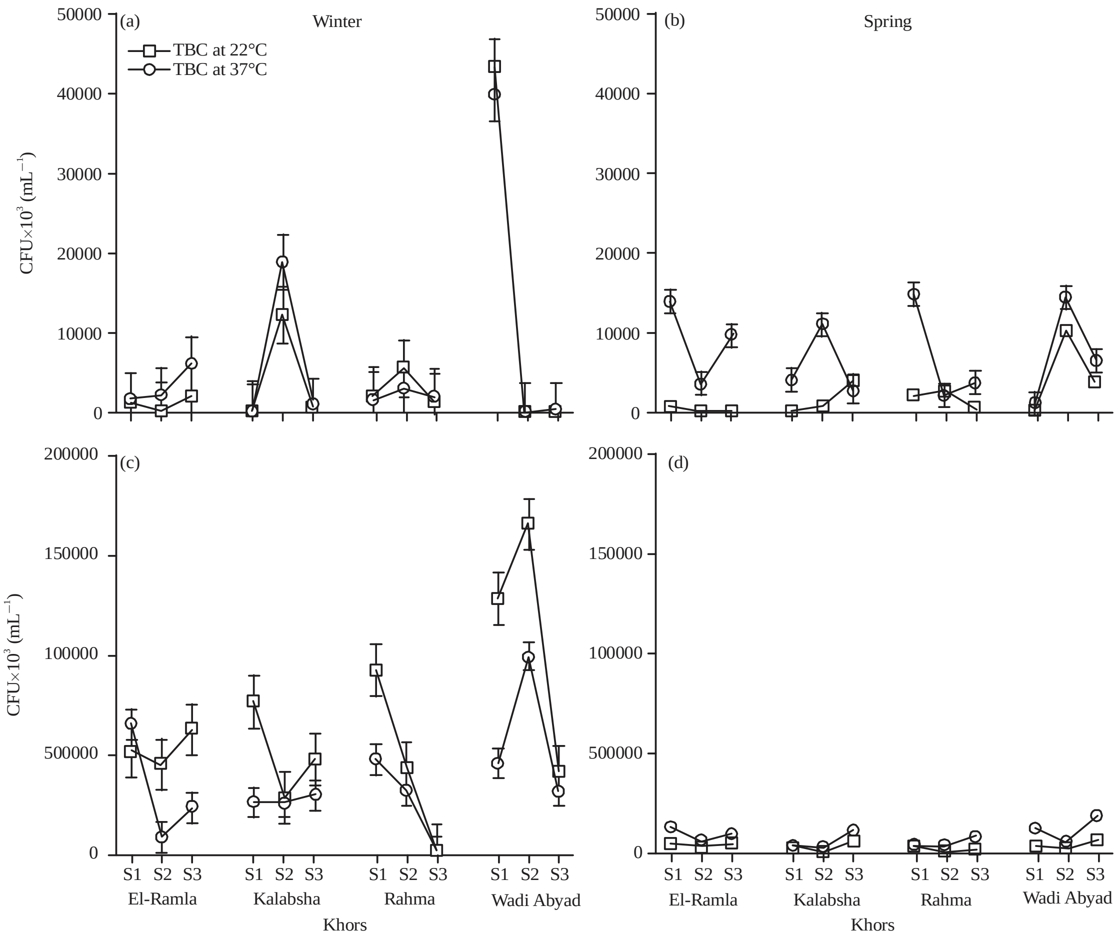

Fig. 2(a-d): Microbial loads (a, b) For surface and (c, d) Bottom water samples in Northern Lake Nasser khors at winter and spring seasons, S1: Entrance of khor, S2: Beginning of khor, S3: Ending of khor and bar whiskers represent SE (Standard error)

Table 4: Statistical analysis (ANOVA analysis) of the bacteria population (CFU mL^{-1}) of khors water samples as affected by seasons, sites and depth

Khors name	TBC22	TBC37	TThB	TSFB	TC	FC	FS
El-Ramla	14349^{b}	13386^{b}	123^{b}	30^{c}	312^{a}	45^{a}	3^{c}
Kalabsha	14742^{b}	11249^{c}	106^{b}	38^{c}	217^{c}	16^{c}	4^{a}
Rahma	12898^{b}	10035^{d}	55^{c}	76^{b}	256^{b}	34^{b}	4^{ab}
Wadi abyad	33466^{a}	22600^{a}	224^{a}	111^{a}	48^{d}	11^{d}	4^{b}

Means followed by the same letter are not significantly different (p>0.05), TBC22: Total bacterial counts at 22°C, TBC37: Total bacterial counts at 37°C, TthB: Total thermophilic bacteria, TSFB: Total spore forming bacteria, TC: Total califorms, FC: Faecal coliforms, FS: Faecal streptococci

layers (means of 188 CFU mL^{-1}) or in bottom water layers (260 CFU mL^{-1}) (Table 5). Irrespective of khors, seasons and water layers, beginning of khor recorded highest thermophilic bacteria count either in surface and bottom water layers (means 123 and 180 CFU mL^{-1}, respectively) (Table 5).

Numbers of spore-forming bacteria were minimal compared to thermophilic bacteria. In general, the highest spore-forming bacterial number was recorded in Eastern khors (Wadi Abyad and Rahma) compared to Western khors (Kalabsha and El-Ramla) (means of 111 and 76, respectively for Eastern khors and 38 and 30 for western khors, respectively) (Table 4). Spore-forming bacteria were higher in surface water layers compared to bottom water layers in the Western khors, while the contrary observations were in the eastern khors (means of 52 and 24, respectively for Kalabsha, means 45 and 14, respectively for El-Ramla, means 53 and 168, respectively for Wadi Abyad and means 55 and 96, respectively for Rahma khor) (Table 5).

Bacterial indicators of pollution (total coliforms, faecal coliforms and faecal streptococci) did present with perceived population (Fig. 4). In general, the indicators of pollution did present with population ranged from >0-1800, >0-350 and >0-15 MPN/100 mL of total coliforms, faecal coliforms and faecal streptococci, respectively. In addition, faecal streptococci was lowest than faecal coliforms; where the ratio of faecal coliforms to faecal streptococci ranged from 0-22 in winter and 0-55 in spring. In general, total and faecal coliforms followed the order: El-Ramla> Rahma>Kalabsha>

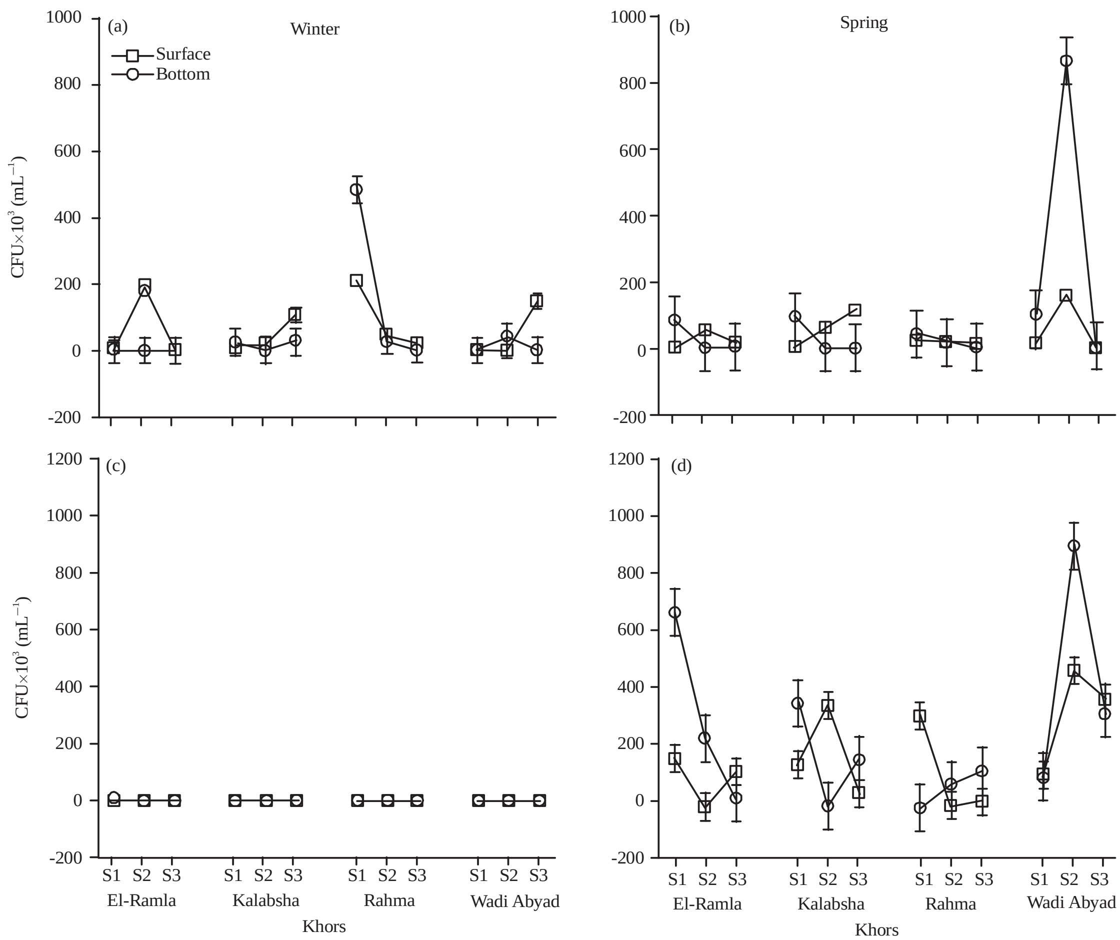

Fig. 3(a-d): (a, b) Spore-forming and (c, d) Thermo-philic bacteria for surface and bottom water samples in Northern Lake Nasser khors at winter and spring seasons, S1: Entrance of khor, S2: Beginning of khor, S3: Ending of khor and bar whiskers represent SE (Standard error)

Wadi Abyad (means of 312, 256, 217 and 48 MPN/100 mL, respectively for total coliforms and 45, 34, 16 and 11 MPN/100 mL, respectively for faecal coliforms (Table 4). Spring season recorded higher total coliforms than winter for all khors studied (Table 5). Faecal coliform numbers were higher in spring seasons in El-Ramla and Rahma khors and higher in winter seasons in Kalabsha and Wadi Abyad khors (Table 5). Bottom water samples recorded higher total coliforms than surface water in all khors studied except Wadi Abyad khor (Table 5). Among khors, Wadi Abyad khor recorded higher total coliforms in the entrance of khor; while other khors recorded higher total coliforms in the ending of khor sites (Fig. 4), where, the means of total coliforms in the entrance, beginning and ending khor sites were 22, 448, 465; 16, 109, 527; 116, 19, 633 and 75, 32, 38 MPN/100 mL for El-Ramla, Kalabsha, Rahma and Wadi Abyad khors, respectively.

Results of sediment bacteriological analyses: Bacterial load (total and sporeforming bacteria as well as total and sporeforming diazotrophs) of sediments obtained from Northern khors in winter and spring seasons are illustrated in Fig. 5.

Total bacterial counts of khors sediment ranged from 5.1×10^7 to 3.7×10^9 CFU g^{-1}, with the higher counts recorded in Rahma khor (mean of 1.8×10^9 CFU g^{-1}) in winter season, also Rahma and El-Ramla khor (means of 7.4 and 6.0×10^8 CFU g^{-1}, respectively) in spring season. While the lowest counts were recorded in El-Ramla khor (means of 6.1×10^7 CFU g^{-1}) during winter season and Kalabsha Khor in spring season (means of 2.1×10^8 CFU g^{-1}).

Total sporeforming bacteria ranged from <1-1.7×10^7 CFU g^{-1} sediment. Higher numbers of sporforming bacteria were recorded in Rahma khor in winter and spring (means of 9.7×10^6 and 2.2×10^4 CFU g^{-1}, respectively).

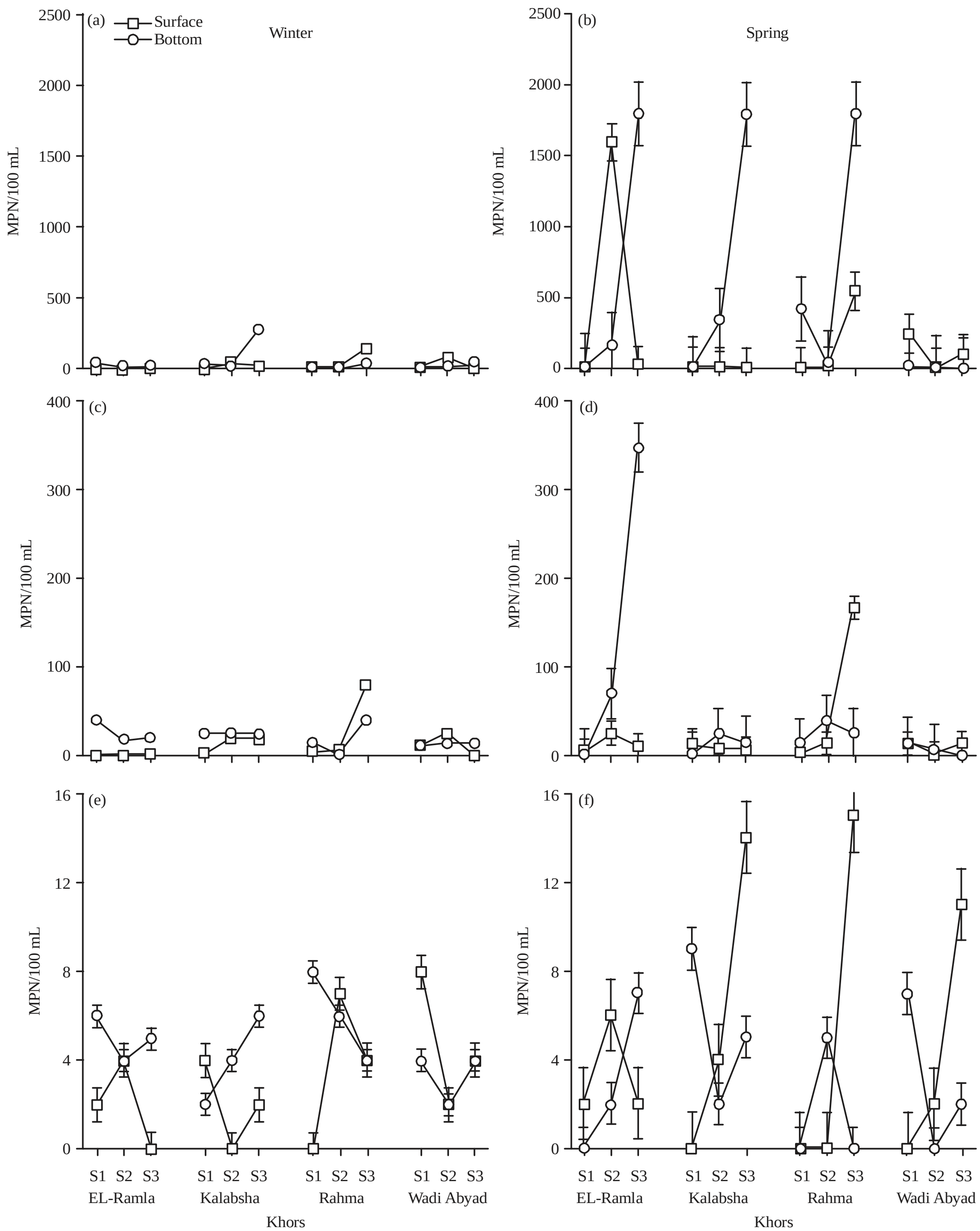

Fig. 4(a-f): Bacterial indicators of pollution (a, b) Total coliform bacteria, (c, d) Faecal coliform and (e, f) Faecal streptococci counts for surface and bottom water samples in northern Lake Nasser khors at winter and spring seasons, S1: Entrance of khor, S2: Beginning of khor, S3: Ending of khor, bar whiskers represent SE (Standard error)

Total diazotrophs count were found in the range of 6.2×10^{6}-1.9×10^{9} CFU g^{-1} sediment, while sporforming diazotrophs ranging from <1-2.7×10^{7} CFU g^{-1} sediment. In general, spring season samples showed higher diazotrophs than winter ones in all khors studied. The highest diazotrophic bacteria were recorded in Kalabsha khor (means of 2.2×10^{8} CFU g^{-1}) in winter season and El-Ramla Khor (1.0×10^{9} CFU g^{-1}) in spring season.

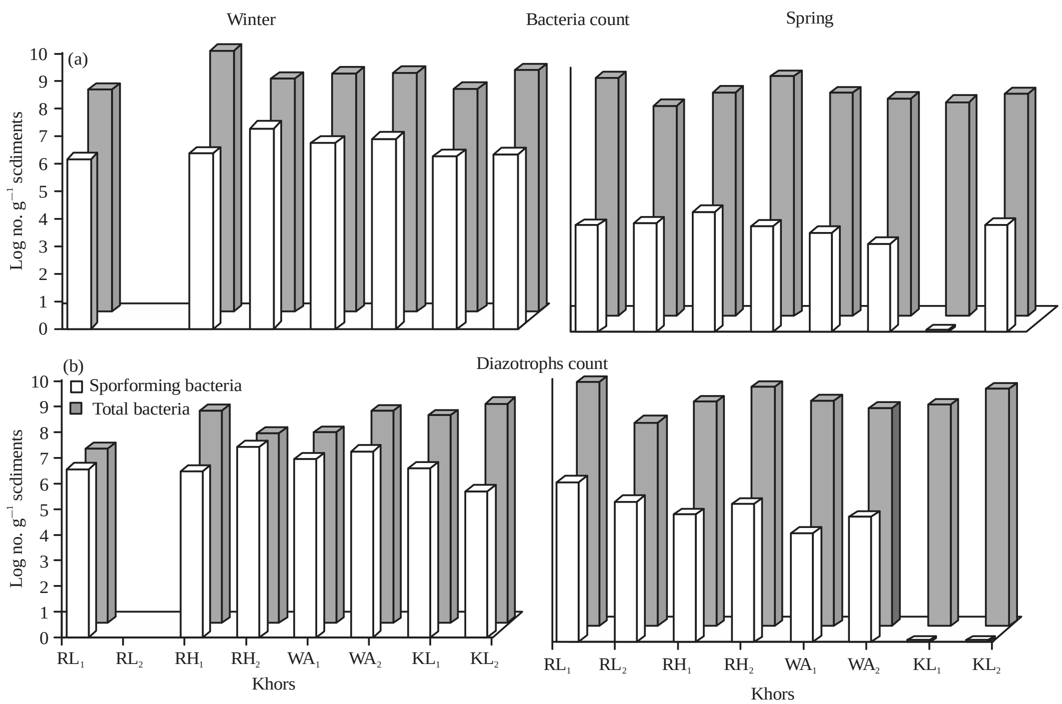

Fig. 5(a-b): Populations of total and sporforming (a) Bacteria and (b) Diazotrophs in sediments for Northern khors of Lake Nasser during winter and spring, 2015, RL_1: El-Ramla in the beginning of khor, RL_2: El-Ramla in the ending of khor, RH_1: Rahma in the beginning of khor, RH_2: Rahma in the ending of khor, WA_1: Wadi Abyad in the beginning of khor, WA_2: Wadi Abyad in the ending of khor, KL_1: Kalabsha in the beginning of khor and KL_2: Kalabsha in the ending of Khor

As expected, winter season recorded higher sporforming bacteria for either total or diazotrophs. Sporeforming bacteria represented >40-85 and >48-101% of total bacteria and diazotrophs, respectively.

Results of plants bacteriological analyses: Counts of total and sporeforming bacteria as well as total and sporeforming diazotrophs of *Myriophyllum spicatum* obtained from Northern khors during winter and spring seasons are illustrated in Fig. 6.

The bacteriological analyses reported total bacterial counts of 3.0×10^2-4.4×10^7 CFU g^{-1}, spore formers of 1.3×10^2-7.1×10^4 CFU g^{-1}, total diazotrophs of 2.9×10^5-7.7×10^7CFU g^{-1} and spore forming diazotrophs of <1-6.1×10^4 CFU g^{-1}. In general, spring season recorded higher bacterial and diazotroph loads than winter season in all khors studied except Kalabsha khor. Wadi Abyad khor recorded higher total bacterial and diazotrophs (means of 4.3 and 4.5×10^7 CFU g^{-1}, respectively) in spring season. Also, Wadi Abyad khor recorded lower spore formers either for total or diazotroph bacteria (means of 3.4 and 5.8×10^2 CFU g^{-1}, respectively) in winter season. Rahma khor recorded lower total bacteria counts (means of 1.1×10^6 CFU g^{-1}) in winter season.

DISCUSSION

Nowadays with increasing human activities and lessening fresh water resources, the environmental monitoring and control of water pollution should be carefully considered to environmental protection. In Egypt, Lake Nasser considered the main source of fresh water and fresh water fish. Therefore, this study illustrated physico-chemical and bacteriological quality of water, sediments and plants for Northern khors of Lake Nasser.

The results of water analysis revealed that, although the variation in temperatures affect the survival of aquatic organisms; the highest microbial load was recorded in the winter season this may be due to presence of high nutrient level at winter that rises microbial load, this copes with increased Total Dissolved Solids (TDS) and Electric Conductivity (EC) values in the winter season. There are positive correlation between TDS and TBC at 22°C, TBC at 37°C (0.33 and 0.29, respectively, n = 48); as well as between EC and TBC at 22°C, TBC at 37°C (0.37 and 0.32, respectively, n = 48). In addition, increasing Dissolved Oxygen (DO) during winter increased the biological activity. Moreover, the results demonstrated minimum dissolved oxygen values in the near bottom sites of khors, particulate during spring season;

Table 5: Statistical analysis (ANOVA analysis) of the bacterial populations at the khors as affected by seasons, winter and spring, 2015 and depth, surface and bottom as well as sites, entrance of khor, beginning of khor and ending of khor with surface and bottom

	TBC22	TBC37	TTHB	TSFB	TC	FC	FS
	(CFU mL^{-1})				(MPN/100 mL)		
Seasons effect, Rao R (21,258) = 95.89, p<0.000							
El-Ramla							
Winter	26896	17823	1	33	15	13	4
Spring	1803	8949	244	27	608	77	3
Kalabsha							
Winter	27492	16968	0	31	66	20	3
Spring	1992	5530	212	45	369	12	6
Rahma							
Winter	24247	14495	1	131	36	24	5
Spring	1549	5576	108	20	475	45	3
Wadi abyad							
Winter	62905	36017	0	32	27	13	4
Spring	4027	9183	448	190	69	9	4
Depth effect, Rao R (21,258) = 65.39, p<0.000							
El-Ramla							
Surface	722	6175	59	45	276	7	3
Bottom	27977	20597	187	14	347	83	4
Kalabsha							
Surface	3013	6309	108	52	19	12	4
Bottom	26471	16189	104	24	416	20	5
Rahma							
Surface	2398	4589	69	55	124	46	4
Bottom	23398	15482	40	96	387	23	4
Wadi Abyad							
Surface	9655	10428	188	53	79	11	5
Bottom	57277	34773	260	168	17	10	3
Site effects in surface and bottom, Rao R (14,180) = 70.70, p<0.000							
S1 (entrance of khor)							
Surface	6302	9662	110	33	41	7	2
Bottom	44667	26673	169	103	74	15	5
S2 (beginning of khor)							
Surface	4015	6951	123	68	223	13	3
Bottom	35593	22530	180	119	80	25	3
S3 (ending of khor)							
Surface	1524	4012	84	52	110	38	7
Bottom	21082	16077	95	5	721	61	4

TBC22: Total bacterial counts at 22°C, TBC37: Total bacterial counts at 37°C, TthB: Total thermophilic bacteria, TSFB: Total spore forming bacteria, TC: Total califorms, FC: Faecal coliforms, FS: Faecal streptococci

this may due to that oxygen content is affected by decomposition of organic matter. These explains the higher microbial load as well as total and faecal coliform bacteria in the bottom water samples compared to surface water samples (Awadallah *et al*., 1991). In general, differential temperature ratio test between total bacterial counts on 22 and on 37°C (authochthonous and allochthonous bacteria, respectively) ranged from 0.01-6.2, compared to the permissible standard of 10:1 according to Ministry of Health (1939), this reflects the pollution of the khors. The similar low ratios were previously recorded for the main channel of Lake Nasser (Elewa and Azazy, 1986; Rabeh, 2001, 2003). In addition, the ratio between faecal coliforms and faecal streptococci ranged from 0-50, this indicates animal and human sources of pollution (Geldreich, 1970). The highest microbial load and counts of indicator bacteria were recorded during winter, this may be due to tourism between the high Dam and Abu-Simble was increased in winter season, the same observation were recorded with Rabeh (2001, 2003). Among khors, El-Ramla khor recorded the highest total and faecal coliform bacteria compared to other khors this may be due to increased fisheries activities in El-Ramla khor; where, it is the nearest one to the High Dam at Aswan city. In the other hand, the highest bacterial population was recorded in the entrance of lake and gradually decreased in the khor beginning and in the khors end either for surface or bottom samples this may be due to the sedimentation effects and the effects of water level and flood (Mageed and Heikal, 2006).

The results of sediments and plants analysis revealed that, Wadi Abyad khor recorded higher microbial load in tested water and plants samples, where bacteria can sense and

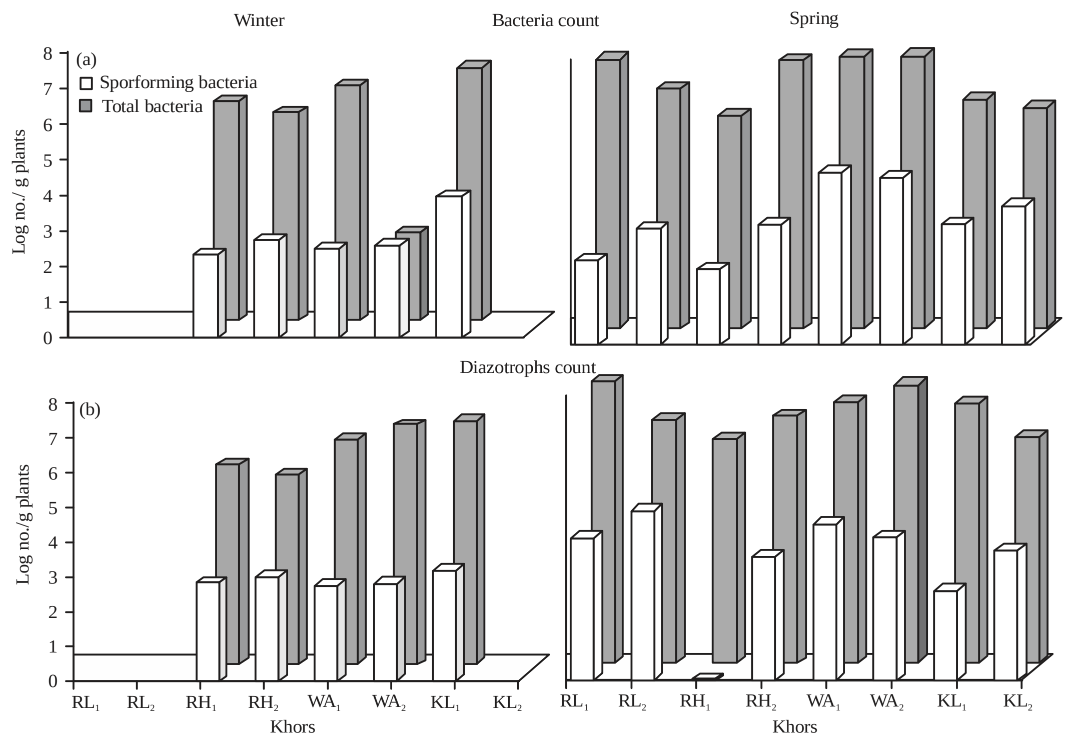

Fig. 6(a-b): Populations of total and sporforming (a) Bacteria and (b) Diazotrophs of plants for northern khors of Lake Nasser during winter and spring 2015, RL_1: El-Ramla in the beginning of khor, RL_2: El-Ramla in the ending of khor, RH_1: Rahma in the beginning of khor, RH_2: Rahma in the ending of khor, WA_1: Wadi abyad in the beginning of khor, WA_2: Wadi Abyad in the ending of khor, KL_1: Kalabsha in the beginning of khor, KL_2: Kalabsha in the ending of khor

Table 6: Relating the analyses of the Northern khors of Lake Nasser to the international permissible limits

		Permissible limits	
Parameters	Range	Irrigation water	Drinking water
pH	7-8	6.5-8.5	6.5-8.5
Conductivity (d S mL^{-1})	0.22-0.29	<0.7–<3	0.4^{EC}
Total count 22°C (CFU mL^{-1}) (authochthonous)	3×10^1-2×10^5	NA	100^{EC}
Total count 37°C (CFU mL^{-1}) allochthonous	2×10^2-1×10^5	NA	10^{EC}
Differential temperature ratio	0.01-6.2	NA	$10:1^{APHA}$
Total coliforms (MPN/100 mL)	0 -1100	NA	0, 10^{WHO}
Faecal coliforms (MPN/100 mL)	0 -75	Unrestricted irrigation($\leq$or 10^3)^{WHO}	0

Permissible limits are those provided by FAO for irrigation water (Ayers and Westcot, 1985) and WHO (2006) for drinking water, Superscripted values: EC (1998), ECA1, Level A1 simple physical treatment and disinfection, APHA (1995) and NA: Not available

respond to phytohormones from plants. Also, the plants and sediments results showed that, spring season recorded higher bacterial and diazotroph loads than winter season, especially for plant samples. While winter season recorded higher sporeformers either for total or diazotroph bacteria. Moreover, in some samples counts of sporeforming bacteria represented >70% of total bacteria, this indicates unsuitable environmental conditions, such as, lower temperature in winter or poorer nitrogenous compounds and nutrients. In addition, total diazotrophs were found in high numbers and in some samples comparable with counts of total bacteria. This is may be reflect suitable environmental condition for growth of diazotrophs, where, high organic load and low nitrogen components prompt growth of N_2-fixing bacteria. Indeed, diazotrophic bacteria play an important role in aquatic environments, such as, increased the aquatic productivity by increased nitrogenous compounds (nitrogen fixation), release growth factors (Fukami *et al*., 1997), increased fish probiotic (Ali *et al*., 2011) and safe disposal of pollutants (Ali *et al*., 2012; Ali, 2014). In conclusion, the results of physico-chemical and bacteriological analyses for Northern khors of Lake Nasser summarized in Table 6 indicate that, water quality of the Northern khors of Lake Nasser are acceptable from physico-chemical parameters not point of view bacteriological parameters and it is acceptable for irrigation water not for drinking water.

CONCLUSION

In conclusion, the Lake Nasser khors is exposed to pollution, mainly from fisheries and touristic activities. In addition, water quality is respect to physic-chemical but not microbiological parameters. Consequently, the control of water pollution and environmental protection should be carefully considered to avoid any defect at an appropriate time, especially Lake Nasser (main source of fresh water and fresh water fish) and especially nowadays with lessening fresh water resources.

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