Impact of Water Level Fluctuation on Water Quality and Trophic State of Lake Nasser and its Khors, Egypt.

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ABSTRACT

The morophometric configuration of lakes or reservoirs plays an important role in their water quality variations. The morophometry of Lake Nasser is characterized by the presence of many dendritic side extensions known as side channels or Khors. The surface area, depth and shape of these Khors depend upon the water level upstream the Aswan High Dam (AHD). In the last decade, the water level upstream the Dam fluctuated from about 181m ASL during year 2001 to about 174 m ASL during year 2005.This Fluctuation of water level from year to year affects water quality status of the Lake and its Khors due to the change of their morophometric configuration. To study the effect of water level fluctuation, four main important Khors characterized by gentle slope and sandy bottom with different size were selected. These Khors are Kalabsha, El-Alaki, Toushka, and Sara at Km, 41, 91, 247, and 325 from AHD respectively. The main goal for the present study is to assess the quality of water in the main Khors of Lake Nasser and its main channel during periods of low and high water levels (years 2001 and 2005 respectively). This assessment explores the potential pollution hazards coming from these Khors to the whole Lake. To achieve this goal water quality data generated from the analysis of water samples collected from the Khors and main channel during high and low water levels were used to calculate the water quality and trophic state indices as well as determination of the limiting nutrient factor of the lake. The abundances of Phytoplankton were also considered. The results of the water quality index (WQI) calculations during this study showed that the drop in Lake water levels led to a decline in the water quality of the Lake and Khors from the order of good to medium. Also, the trophic state index (TSI) values revealed that the productivity of the Lake changed from mesotrophic during high water level to eutrophic during low water level. These results are consistent with high phytoplankton counts recorded during low water level period. The values of N/P ratios indicated that phosphorus controls the phytoplankton growth during high water level, while during low water level either phosphorus (P) or nitrogen (N) could be limiting phytoplankton growth. Based on the obtained results of the present study, it could be concluded that the drop in water level upstream the dam may have negative impact on the water Quality of the Khors. This impact may in turn influence the whole Lake due to water rebounce from the Khors to the main channel. Therefore, it is further concluded that khors could be considered as potential pollution sources during low water levels of the lake.

Key Words: Lake Nasser, Khors, water levels, water quality, Phytoplankton.

INTRODUCTION

Lake Nasser lies between 22º 00` N and 23º 58` N in Egypt, and extends southward into the Sudan to 20º 27 N` as Lake Nubia (Fig. 1). Lake Nasser had been gradually formed behind the Aswan High Dam (AHD) and completed in 1968. The reservoir is designed to have a maximum water level of 183 m above sea level (ASL) and a total capacity of $162x10^9$ m^3. At this level, the reservoir has a length close to 500 km, an average width of 12km and surface area of 6,540 km^2. The lake shoreline is very irregular, with numerous side channels known as khors. There are about 85 longer khors, 48 of which are on the east side and 37 on the west side. The mean length of the khors increases downstream from south to north and all are U- shaped in cross section. Their surface area covers about 4900 km^2, i.e. 79% of total Lake Surface, while their volume is 86.4 km^3, i.e. 55% of total Lake Volume (Entz, 1973). The water levels in the lake vary from year to year, according to the coming flood, and from month to another, according to the discharge from the lake across the High Dam. In the last decade, the water level upstream the Dam fluctuated from about 181m ASL during year 2001 to about 174 m ASL during year 2005. This Fluctuation of water level from year to year affects water quality status of the Lake and its Khors due to the change of their morophometric configuration. To study the effect of water level fluctuation on these khors, four main important Khors characterized by gentle slope and sandy bottom with different sizes were selected. These Khors are Kalabsha, El-Alaki, Toushka, and Sara at Km, 41, 91, 247, and 325 from AHD respectively. The selection of these khors was based on previous studies (Nader, 2004) which found that the drop in the lake water level from 181m ASL to 174 m ASL leads to reduction of the surface areas of these Khors with 40%, 16%, 20% and 55% respectively. Therefore the main goal for the present study is to assess the quality of water in the main channel of Lake Nasser and its main Khors during periods of high and low water levels (during year 2001 and 2005 respectively).

MATERIAL AND METHODS

Sampling:

The water samples were collected from nine stations along the open water of the main channel in Lake Nasser (Egypt) and from four main important Khors. These Khors are Kalabsha, El-Alaki, Toushka, and Sara at Km, 41, 91, 247, and 325 from AHD respectively. Each khor is represented by three sampling sites. Sampling was performed during periods of low and high water level (December 2001 and 2005 respectively). During that time the lake water becomes completely mixed (turnover period) and the flood season was also completely finished.

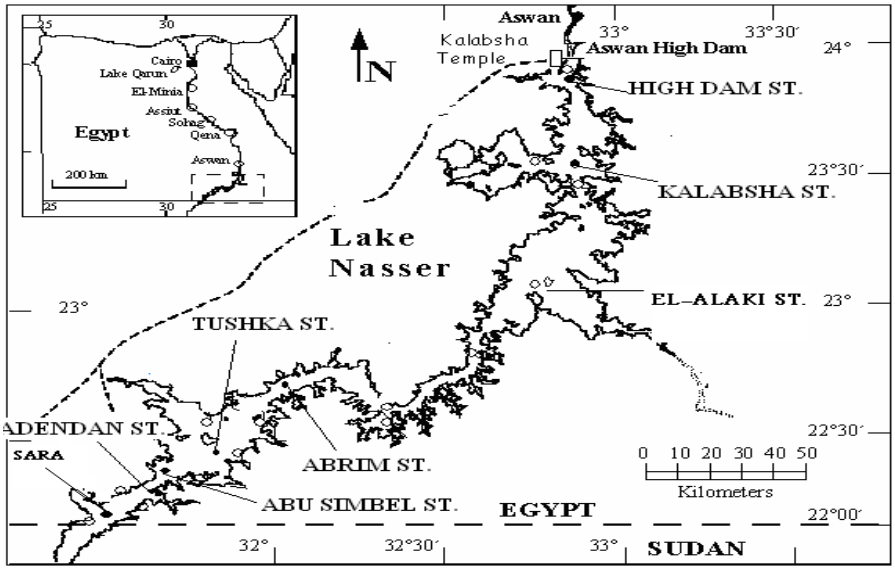


Fig. (1): Map of Lake Nasser showing stations of study

Physico-Chemical and Biological Analysis:

For analysis of water quality parameters, temperature, pH, oxygen, turbidity, conductivity, and secchi disc were measured immediately in situ. The chemical measurements were performed within few hours of collection. The parameters which are necessary for water quality index calculations were analyzed. The following are these parameters and their analytical methods according to APHA (1995): dissolved oxygen (4500-O C), nitrates (4500-NO_3-D), pH (4500-H^+ B), phosphorus (4500-P), solids total (2540-B), temperature (2550-B), fecal coliforms (9221-C), turbidity (2130-B), 5-day biological oxygen demand (BOD-5), (5220 A).

For phytoplankton, 1 L of lake water was taken from 0.5 m deep, preserved immediately in 4 % formalin. The preserved samples were transferred in a clean graduated cylinder of 1000 ml capacity and few drops of Lugol's Iodine solution were added. The phytoplankton cells were allowed to settle, for 5 days. The supernatant was carefully siphoned off with a small plastic tube ending with a fine net of 20 µm mesh diameter, until the samples were concentrated to 50 ml. The drop method was applied for counting and identification of different algal species as in APHA (1995), the phytoplankton species were calculated as number per liter. Chlorophyll *a* was measured by filtering of 10ml water sample immediately after collection from 0.5 m deep onto GF/F paper. The filters were folded with aluminum foil and kept in deep freezer then extracted with hot methanol and measured by Spectrophotometer as µg/l.

Data analysis:

Water Quality Index (WQI) Calculations:

Geometrical Water Quality Index (WQI_g) which was proposed by Ott, (1987) was used to evaluate the Lake water quality during low and high water levels conditions. This index depends on nine parameters in its calculation. These parameters are dissolved oxygen, fecal coliform, pH, BOD_5, nitrate, total phosphate, temperature deviation from 20°C, turbidity and total solids. Each parameter has known weight and functional curve according to its importance and significance.

The geometrical water quality index was shown by the following equation:

$$WQIg = \prod_{i=1}^{n} IiWi$$

Where I_i is the water quality rating (sub index) corresponding to the value of the parameter from the functional curve, W_i is the parameter′s weight.

The quality values produced from applying this index are classified into five categories as follows: 0-25 (very poor), 26-50 (poor), 51-70 (medium), 71-90 (good) and 91-100 (excellent).

Trophic State Index (TSI) Calculations:

Carlson's (1997)Trophic State Index (TSI) was used to combine measures of Secchi disc readings (SD), chlorophyll *a* (CHL), and total phosphorous (TP) in a common numeric scale. The TSI values are calculated according to the following equations:

TSI (SD) = 60- 14.41ln SD (meters)

TSI(CHLA) = 9.81 ln CHLA (µg/l) +30.6

TSI (TP) = 14.42 ln TP (µg/l) +4.15

The index ranges from 0 to 100 with higher values indicating more eutrophic conditions. Values below 40 are associated with oligotrophy (low productivity).The range between 40 and 50 is usually associated with mesotrophy (moderate productivity) and values above 50 are associated with eutrophy (high productivity).

Limiting Nutrient measurement:

Calculating the N/P ratios from the data for nitrogen as nitrate and phosphorus as phosphate was suggested by (Forsberg and Ryding, 1980). The most conservative ratio suggest that when N/P is more than 10, phosphorus is the limiting nutrient, if N/P ratio is between 5 and 10, either nutrient could be limiting and if less than 5, nitrogen is the limiting for plant growth.

RESULTS

The data of water quality variables, WQI, TSI, N/p ratio and phytoplankton counts were presented in Tables (1&2) and Figures (2, 3, 4 & 5).

Table (1) Average values of water quality variables along Lake Nasser main channel during high and low water level (2001- 2005)

Sites Name	Km from HAD	Temperature		pH value		DO (mg/l)		Turbidity (NTU)		Total-P (mg/l)		NO_2 (mg/l)		BOD (mg/l)		TDS (mg/l)		FC (cfu/100 ml)	
		2001	2005	2001	2005	2001	2005	2001	2005	2001	2005	2001	2005	2001	2005	2001	2005	2001	2005
High Dam	2	19.8	22	8.01	8.79	8.37	7.67	0.24	1.3	0.075	0.2	0.4	0.2	1.2	3.3	176	164	140	600
Kalabsha	41	19.7	22.7	8.11	8.64	8.42	7.38	0.25	1.34	0.11	0.16	0.65	0.28	1	3.6	168	160	110	560
El Alaki	91	19.7	22.7	8.36	8.55	8.59	7.43	0.39	1.35	0.071	0.14	0.8	0.22	1.77	3.3	160	156	120	560
Ebreem	228	19.8	22.5	8.29	8.65	8.87	7.85	3.99	4.21	0.045	0.15	1.1	0.2	1.54	3	159	150	120	500
Toushka	247	18.4	22.4	8.1	8.55	8.47	7.65	7.67	8.5	0.15	0.23	1.2	0.4	2.1	3.22	157	150	120	750
Abu Simble	281	18.8	22.7	8.29	8.75	8.54	7.86	6.83	9.4	0.145	0.26	1.3	0.4	1.92	3.89	150	146	130	800
Adendan	307	18.3	22.5	8.26	8.71	8.8	7.84	8.31	11.6	0.16	0.3	1.3	0.5	1.8	3.82	148	145	130	560
Sara	325	18.5	22.5	7.98	8.47	8.63	7.93	10.8	13.75	0.14	0.3	1.4	0.49	1.88	3.77	145	140	130	450
Arkeen	333	18	22.6	8.27	8.5	8.98	7.85	13.7	15.5	0.145	0.29	1.5	0.6	1.8	3.66	145	140	140	400

Table (2) Average values of water quality variables along Lake Nasser Khors during high and low water level (2001- 2005)

Khors Name	Km from HAD	Temperature		pH value		DO (mg/l)		Turbidity (NTU)		Total-P (mg/l)		NO_2 (mg/l)		BOD (mg/l)		TDS (mg/l)		FC (cfu/100 ml)	
		2001	2005	2001	2005	2001	2005	2001	2005	2001	2005	2001	2005	2001	2005	2001	2005	2001	2005
Kalabsha	41*	19.2	22.5	8.24	8.74	8.3	7.11	0.45	1.94	0.12	0.18	0.7	0.3	1.02	3.8	149	138	120	900
El Alaki	91*	19.8	22.7	8.46	8.83	8.28	73	0.86	1.7	0.075	0.17	0.9	0.3	1.89	3.58	141	136	120	750
Toushka	247*	18.6	23	8.28	8.75	8.29	7.2	8.17	9.44	0.1	0.22	1.2	0.45	2.25	3.66	130	146	130	800
Sara	325*	19	22.5	8.01	8.42	8.25	7.5	13.1	14.5	0.08	0.23	0.75	0.35	1.9	3.8	140	135	135	500

1- Water Quality Variables

1-1 Water temperature:

The period of this study was selected in winter season during both high and low water levels. At this period, mixing in water column was completed. The data showed that during high water levels the temperature of water along the main channel ranged from 18 to 19.8 ^{o}C and from 18.6 to 19.8 ^{o}C at different khors, while during low water levels it ranged from 22 to 22.7 ^{o}C and from 22.5 to 23 ^{o}C at the main channel and khors respectively.

1-2 Hydrogen ion concentration (pH):

The pH values in the main channel of the Lake ranged from 7.98 to 8.36 and from 8.47 to 8.79 during high and low water levels (2001- 2005) respectively. The pH values in the Khors ranged from 8.01 to 8.46 and from 8.62 to 8.83 during high and low water levels respectively.

1-3 Dissolved oxygen (DO):

Generally the DO concentration recorded higher values in the main channel and khors during high water level. Its values in the main channel ranged from 8.37 to 8.98 mg/l and from 7.38 to 7.93 mg/l during high and low water levels respectively, while, its concentration in the khors ranged from 8.25 to 8.3mg/l and from 7.11 to 7.5 mg/l during high and low water levels respectively.

1-4 Biological oxygen demand (BOD):

The organic matters concentrations along the Lake and its khors as indicated by BOD that recorded higher values during low water levels than that during high water levels. These values ranged from 1 to 1.92 mg/l and from 3.0 to 3.89 mg/l in the main channel during high and low water level respectively, while in the khors, its values ranged from 1.02 to 2.25 mg/l and from 3.58 to 3.8 mg/l during high and low water levels respectively.

1-5 Total dissolved salts (TDS):

The concentrations of TDS along the main channel of the Lake and its khors showed little variations between high and low water levels period. Their concentrations in the main channel ranged from 145 to 176 mg/l and from 140 to 164 mg/l during high and low water level respectively. Their values in the khors ranged from 140 to 169 mg/l and from 135 to 158 mg/l during high and low water levels respectively.

1-6 Nitrates (NO_3):

The nitrate concentration in the main channel of the Lake ranged from 0.4 to 1.5 mg/l and from 0.2 to 0.6 mg/l during high and low water level respectively, while in the khors, the nitrate concentrations ranged from 0.7 to 1.2 mg/l and from 0.30 to 0.55 mg/l during high and low water levels respectively.

1-7 Turbidity:

The results of turbidity showed that its values in the main channel of the Lake increases from North to south during both high and low water level where its values ranged from 0.24 to 13.7 NTU and from 1.3 to 15.5 NTU during high and low water level respectively. The same trend of turbidity values was observed at khors, where it ranged from 0.45 to 13.1 NTU and from 1.7 to 14.5 NTU during high and low water levels respectively.

1-8 Total phosphorus (TP):

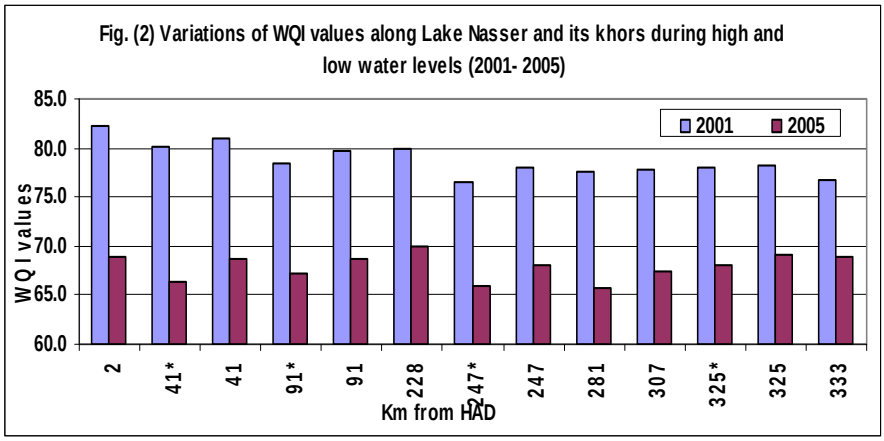
Generally TP concentrations during high and low water levels recorded higher values at the southern sites of the Lake than that sites located in its northern part. Its values in the main channel ranged from 0.05 to 0.16 mg/l and from 0.14 to 0.30 mg/l during high and low water levels respectively, while its values in the khors ranged from 0.08 to 0.12 mg/l and from 0.17 to 0.23 mg/l during high and low water levels respectively.

1-9 Fecal Coliform (FC):

The results of FC counts showed that the highest counts observed during low water levels in the main channel and the khors of the lake. During high water levels, the FC values ranged from 110 to 140 cfu/100 ml and from 120 to 135 cfu/100 ml at the main channel and khors respectively, while during low water levels, their counts ranged from 400 to 800 cfu/100 ml and from 500 to 900 cfu/100 ml in the main channel and the khors respectively.

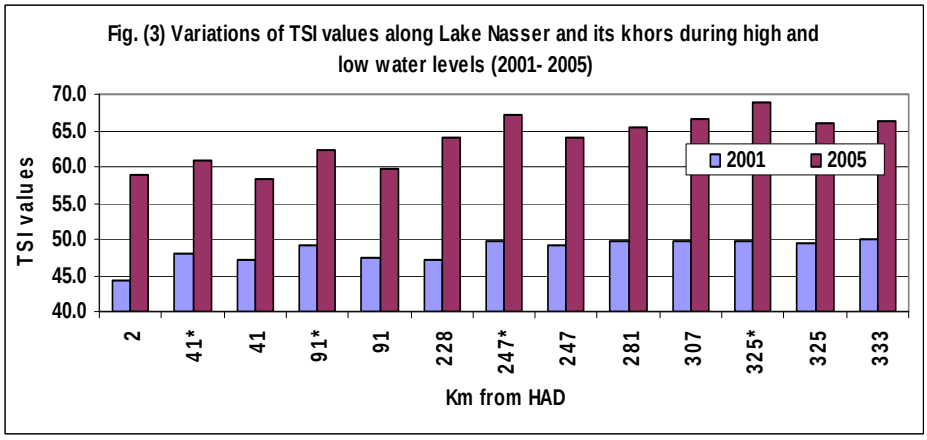
2- Water quality index (WQI):

The values obtained from calculations of water quality index (Fig. 2) along the main channel and khors during high water levels ranged from 76.7 to 82.2 and from 76.5 to 80.2 respectively. These values indicated good water quality level, while during low water levels along the main channel and khors they ranged from 65.7 to 69.9 and from 65.9 to 68.0 respectively. These values indicated medium quality level.



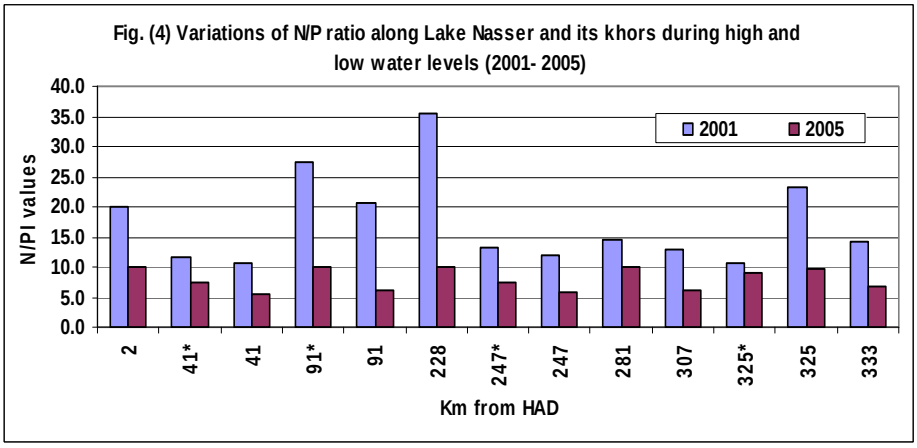
3- Trophic State index (TSI):

The average TSI calculation (Fig. 3) showed that its values during high water levels in the main channel and khors ranged from 44.3 to 49.9 and from 48.0 to 49.7 respectively. These values represent mesotrophic condition in the Lake. In contrast, the productivity of the main channel and khors increased during low water levels periods, where its values ranged from 58.2 to 66.7 and from 60.9 to 68.9 respectively. The Lake during these period could be described as eutrophic.



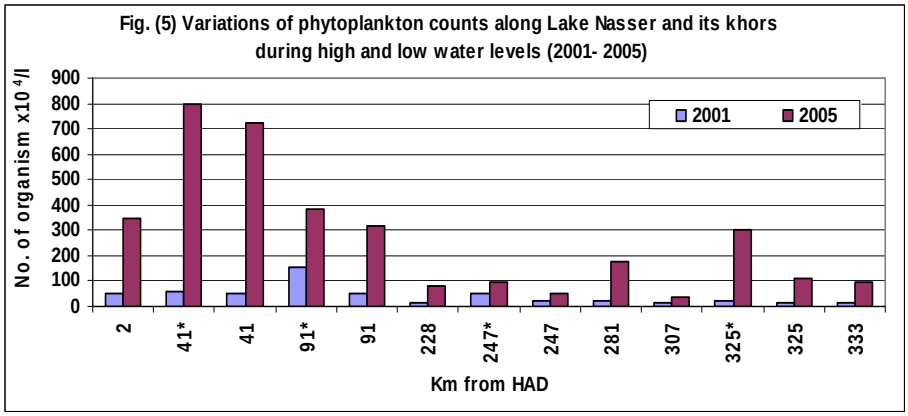
4- Limiting nutrient factor (N/P) ratio:

Calculating the N/P ratios from the data for nitrogen as nitrate and phosphorus as phosphate (Fig. 4) revealed that their values in the main channel and khors during high water levels ranged from 10.7 to 35.5, indicating that phosphorus is the limiting nutrient factor, while during low water levels, these values ranged from 5.6 to 10, indicating that both phosphorus and nitrogen could be a limiting nutrient factor.



5- Total phytoplankton standing crop:

During low water levels, phytoplankton standing crop in the main channel of the Lake (Fig. 5) reached its maximum value (720 x 10^4 org./l) at Kalabsha site, while the lowest value (40x10^4org./l) was recorded at Adendan site. During high water levels, the maximum value (55x10^4org./l) was recorded at High Dam site, while the minimum value (12x10^4org./l) was recorded at Ebreem site. In the khors, the phytoplankton counts ranged from 98 x 10^4 to 800 x10^4 org./l during low water levels, while their number ranged from 25 x 10^4 to 152 x 10^4 org./l during high water levels.



DISCUSSIONS

It is clear from the above mentioned results that there is a remarkable change in water quality variables and phytoplanktonic abundance in the main channel and its main Khors of Lake Nasser during low water level periods. During these periods, the values of some variables such as pH, BOD, FC, and total phosphate increased, while the values of other variables such as dissolved oxygen, orthophosphate, nitrate and water transparency showed lower values. These changes have led to decline in the water quality of the lake during low water level periods as indicated by the results obtained from WQI and TSI calculations. The above results showed that the temperature variation between high and low water level periods was limited because the water samples were collected during winter season (turnover period) to avoid the stratification effect which is more pronounced at the deep locations only. Moreover, during this period the pollutants are equally distributed throughout the water column (Abdel Rehim *et al.,* 2002). The present study revealed that the pH values were higher during low water levels. This could be attributed to the increase in the photosynthetic activity of phytoplankton as indicated by high phytoplankton counts and lake productivity as indicated by TSI values. This means that the pH value could be used as an indicator of algal growth and eutrophication of the Lake waters (Forsberg and Ryding, 1980). Moreover, Touliabah (1996) found that highly alkaline water is more productive than the acidic water. The decrease in the water transparency at the main channel and khors during low water levels may be also related to the phytoplankton growth, which flourished during this period. The lowest concentrations of dissolved oxygen during low water level are mainly due to the decomposition of detritus planktons and organic matters, whereby oxygen becomes consumed and carbon dioxide is produced (Golterman, 1975). Generally, the low concentrations of BOD along Lake Nasser are due to the high capacity of its water to assimilate the organic material in presence of high levels of oxygen. However, the BOD values were higher during low water levels due to the decomposition of detritus planktons which flourished during this period. Increases of bacterial counts during low water levels and their inverse proportion to the oxygen concentrations are consistent with Allan (2001), who found that bacteria consume considerable quantities of DO in their biological oxidation processes. TDS concentrations were found directly proportional with the water level of the lake. Its concentration decreases during low water level period due to their consumption by the flourished algae. Nitrogen and phosphorus compound are considered essential nutrients for living organisms (Ravindra *et al*., 2003)**.** The decrease in orthophosphate and nitrate values during low water level periods is mainly due to flourishing of phytoplankton that consumes these nutrients (Becher, *et al*., 2000). The values of N/P ratios obtained in the present study indicated that phosphorus controls the phytoplankton growth during high water levels, while during low water level either phosphorus (P) or nitrogen (N) could be limiting the phytoplankton

growth. The Water quality index is one of the simplest methods used in assessing the overall water quality status. It allows the reduction of vast amount of data on a range of parameters to a single number in a simple reproducible manner **(**Chapman, 1992).The results of the water quality index (WQI) calculations during this study showed that the drop in Lake water levels led to a decline in the water quality of the Lake and Khors from the order of good to medium. The trophic state index (TSI) values revealed that the productivity of the Lake changed from mesotrophic during high water level to eutrophic during low water level. These results are consistent with high phytoplankton counts recorded during low water level periods. Finally the drop in water level upstream the Dam from about 181m ASL in 2001 to about 174 m ASL in 2005 affected the water quality status of the Lake and its Khors due to the change of their morophometric configuration. In this respect, Nader (2004) found that this drop in the lake water levels had led to a reduction in the surface areas of the Khors (selected during the present study) with a ratio ranged from 16% to 55%. According to Entz (1973) the khors of Lake Nasser covers about 79% of the total Lake Surface, while their volume represents 55% of the total Lake Volume. Therefore, the drop in lake water levels leads to a continual rebounce of large quantities of water from the khors to the main channel of the lake. This rebounce water is characterized by its poor quality level as indicated by the results obtained during the study. So, the rebounce of khor`s water to the main channel may have a negative impact on the whole lake. Accordingly, the khors could be considered as potential pollution sources.

CONCLUSIONS

Based on the present results, it could be concluded that the drop in water levels upstream the dam may have negative impacts on the water quality of the Khors. This impact may in turn influence the whole Lake due to water rebounce from the Khors to the main channel. Therefore, it is further concluded that khors could be considered as potential pollution sources during low water levels.

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