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Recent environmental changes and water quality index of Abu Za'baal lakes, Egypt

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ABSTRACT

Abu Za'baal Lakes are three newly formed wetlands, lying in the north of El-Qalubiya Governorate. Physical parameters (air and water temperatures, electrical conductivity, TS, TDS and TSS) and chemical parameters (salinity, pH, DO, BOD, COD, CO_3^{-2}, HCO_3^-, Cl^-, SO_4^{--}, Ca^{2+}, Mg^{2+}, Na^+, K^+, NO_2^-, NO_3^-, NH_3, PO_4^{3-}, TP and SiO_2^-) were determined in lakes water during four successive seasons in the period from April 2008 to February 2009, to identify the recent environmental changes in Abu Za'baal Lakes water quality. The present results revealed that the values of most physical and chemical parameters were increasing during summer, winter, autumn and decreasing during spring, and also, were higher than that recorded by Abdo (2005) in the same lakes. Average Water Quality Index (AWQI) was calculated for 12 parameters in the present study and was found to be 287.80 (very bad) over 200. However, (AWQI) during 2005 for the same parameters was 180.87 (bad), that indicates the increasing of pollution loading of Abu Za'baal Lakes water.

1. INTRODUCTION

Abu Za'baal Lakes (three) were formed during the last century. The 1st and 2nd lakes were formed between 1950's and 1980's while, the 3rd one was formed in the ninth decade and there is a small depression still in the filling phase now. The highest water storage was 3840.464×10^3 m^3 in the 1st lake, while the lowest water storage was 465.516×10^3 m^3 in the 3rd lake. The water storage in 2nd lake was 928.095×10^3 m^3. Therefore, the total water storage 5234.075×10^3 m^3 (Abd-Ellah, 2003). The 1st lake is the widest (61.81 % of total water surface area) and deepest (73.38 % of the total water storage) basin. The 3rd lake is the narrower (13.22 % of the total water surface area), shallower and smaller (8.89 % of the total water storage) (Abd-Ellah, 2003).

Abdo (2005) concluded that Abu Za'baal Lakes are unique ecosystems and they considered as an oligotrophic, brackish water lakes, and he recommended continuous monitoring and studies on these lakes to arrive to the favorite conditions for fish aquaculture.

Rabeh and Azab (2006) studied the physico-chemical and bacteriological analysis of the lakes water. The results revealed that the recorded pH values were on alkaline side. High total bacterial count (Saprophytic and Parasitic) and high bacterial indicators of sewage pollution (total and fecal coliforms as well as fecal streptococci) were recorded in summer.

El-Shabrawy *et al.* (2007) revealed that Abu Za'baal Lakes have a unique ecosystem and they considered as mesotrophic and oligohaline.

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These three man-made brackish water have created a variety of new habitats and added considerably to the beauty and serenity of the area.

Shaloof and Khalifa (2009) reported that the major food of *O. niloticus* in Abu Za'baal Lakes were detritus, diatoms, green algae, animal derivatives, sand particles and rotifers. This ability to feed at different trophic levels, coupled with potential for fast growth. Ibrahim *et al.* (2008) mentioned that this species is a promising candidate for incorporation into local operated poly culture system. Also, the presence of several species in these lakes indicates that, despite the initial failure to raise fishes in pens, aquaculture could become possibility here. However, this may not be compatible with other uses requiring higher water quality (El-Bassat and Jaylor, 2008).

In pond ecosystem, eutrophic producers convert elementary nutrient (C, N, P) into food nutrients (energy, protein,…etc.), where production capacity is determined by the quality of incident radiation, turbidity and water temperature (Osman *et al.*, 2010). Pollution of the environment by inorganic and organic chemicals is a major factor posing serious threats to the survival of aquatic organisms including fish (Saeed and Shaker, 2008). Liminological investigations on water bodies aimed to assess the deterioration of water quality due to pollution (Mondal *et al.*, 2001).

The water quality index (WQI) is considered as one of the simplest method used in assessing the overall water quality. It defined as rating reflecting the composite effects of a number of parameters on the overall water quality (Donia, 2011). In fact WQI has been used for assessment of water quality of many water bodies around the world (Bordalo *et al.*, 2006; Abrahao *et al.*, 2007; Simoes *et al.*, 2008; Ramakrishnaiah *et al.*, 2009; Abdul Hameed *et al.*, 2010).

The present study is conduct to infer the present physical and chemical status of Abu Za'baal Lakes water and the recent environmental changes of the water quality. In addition, to calculate the average water quality index (AWQI) and (WQI) for 12 parameters to evaluate the pollution loading in Abu Za'baal Lakes water.

2. MATERIALS AND METHODS

2.1. Lakes Description:

Abu Za'baal Lakes are three newly formed ecosystem, probably due to fracture and extraction of basalt rocks and gradually filled by ground water and seepage (Abdo, 2005). Abu Za'baal Lakes are occupy at the area between latitudes 30^0 16.62' and 30^0 17.58' N and longitude 31^0 20.90' and 31^0 21.69' E, (Fig. 1). The water depth in 1st lake was sharply increased northward (0.6 – 20.0 m with average 10.219 m). The 2nd lake varied between (2.9 – 7.6 m) with an average of 6.12 m. The 3rd lake varied between (0.8 – 7.1 m) with an average of 5.791 m (Abd-Ellah, 2003).

2.2. Sampling and Analysis:

Subsurface water samples were collected from the three lakes during four sampling campaigns at five sites in the 1st lake, two sites in the 2nd lake and one site in the 3rd lake in the period from April 2008 to February 2009. These water sampling sites are represented in Fig. (1).

2.3. Field Measurements:

The electrical conductivity (EC) of water samples (µS/cm), temperatures (^{0}C), salinity (‰) and pH values were measured in the field using Hydrolab, Model "Multi 340I/SET". Alkalinity CO_3^{2-} and HCO_3^- were measured titrimetrically on the spot, where samples were titrated against standard H_2SO_4 (0.025 N) using phenolphthalein and methyl orange indicators. Also, Dissolved Oxygen (DO) content was determined by azide modification method as specified in APHA (2005).

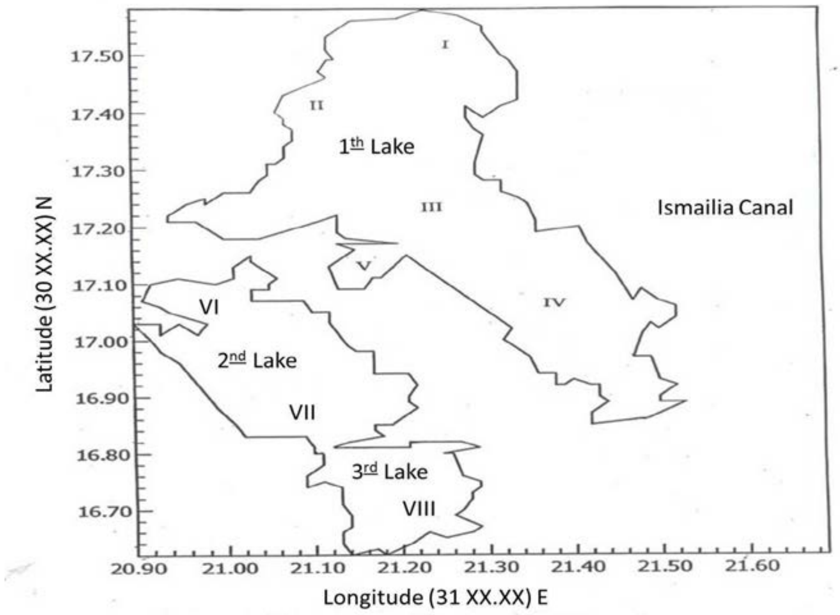

Fig.1: Diagrammatic map showing the sampling sites in Abu Za'baal Lakes.

2.4. Laboratory Analysis:

Water samples were analyzed for all selected variables according to procedures specified in the standard methods of American Public Health Association APHA (2005). Total solid (TS) were measured by evaporating a known volume of well mixed samples at 105 ^{0}C. TDS by filtrating a known volume of sample with glass micro-fiber filter (GF/C) and a known volume of filtrate was evaporated at 180^{0}C. TSS = TS – TDS. Chemical Oxygen Demand (COD) was performed by potassium permanganate oxidation and Biochemical Oxygen Demand (BOD) by 5 days incubation method. Cl^- was determined by argenometric and SO_4^{2-} by turbidity method. Na^+ and K^+ were measured directly using the flame photometer Model "Jenway PFP, UK". Ca^{2+} and Mg^{2+} were determined by EDTA titrimetric method. Concentrations of NO_2^-, NO_3^-, NH_3, orthophosphate (Orth-P) and reactive silicate in water were determined using the colorimetric techniques with formations of reddish purple azo-dye, Cd reduction, phenate, stannous chlorite reduction and molybdosilicate methods, respectively. Total phosphorus (Total-P) was measured as reactive phosphate after Ammonium persulphat digestion technique.

2.5. Statistical Analysis:

The relationship among the different studied physico-chemical variables in water assigned by computing the correlation coefficients (r).

3. RESULTS AND DISCUSSION

The water quality is largely affected by natural processes (weathering and soil erosion) as well as anthropogenic inputs (municipal and industrial wastewater discharge). The anthropogenic discharges represent a constant polluting source, whereas surface runoff is a seasonal phenomenon, largely affected by climatic conditions (Najafpour *et al.,* 2008).

3.1. Physical Variables:

3.1.1. Air and Water Temperatures:

The surface water temperature is one of the most significant parameter which control in born physical water qualities and it plays a vital role in the chemical and biological activities of water body (Sinha and Biswas, 2011).

The surface water temperature temperatures of Abu Za'baal Lakes were found to be 20-29, 29-34, 29-31, 25-30, 22-28, 28- 32, 27 – 29 and 22 – 28 ^{0}C during spring, summer, autumn and winter seasons respectively. There is a little variance between the sites of the three lakes and showed clear seasonal variations. However, the water and air temperatures results (Table 1) showed significant seasonal difference ($P < 0.05$) ($r = 1.0$, 0.9 and 1.0) during spring, summer and winter seasons respectively. According to USEPA (1999), the surface water temperatures is influenced by latitude, altitude, season, time of day, air circulation, could cover, flow and depth of the water body.

3.1.2. TS, TDS and TSS:

The total solids (TS), total dissolved solids (TDS) and total suspended solids (TSS) contents in the Abu Za'baal Lakes water are obviously affected by various factors, the most important of which are the continuous discharge of drainage water and the weathering of Abu Za'baal Lakes area, in addition to the increasing in salinity of water lakes up to 8.6 ‰. The ranges of TS, TDS and TSS were found to be 6331 – 13300, 6297 – 13192 and 22 – 190 mg/l respectively, during different seasons. However these values on the same studied area (Abdo, 2005) were found to be 3468 – 5664, 3412 – 5600 and 40 – 212 mg/l lower than that of the present study. This reflects the increasing in pollution loading and dissolution of different rocks in Abu Za'baal Lakes water. According to Desjardins, (1989).

Abu Za'baal Lakes water lies in the moderately brackish water category. The correlation coefficient statics indicated that TS, TDS and TSS were positively correlated ($n = 10$, $P < 0.05$), TS with TDS ($r = 1.0$ and 0.9) and TDS with TSS ($r = 1.0$ and 0.9). Also, TDS with many variables, like Cl^- ($r = 0.9$), SO_4^{--} ($r = 1.0$), Na^+ ($r = 1.0$), K^+ ($r = 1.0$), Ca^{2+} ($r = 0.9$) and Mg^{2+} ($r = 1.0$), which constitute the major anions and cations in Abu Za'baal Lakes water.

3.1.3. Electrical Conductivity:

In the same trend of TS and TDS, the EC values of Abu Za'baal Lakes water were different during various seasons and ranged between 6100 – 11580, 9700 – 14000, 9330 – 14320 and 9310 – 14910 µmohs/cm during spring, summer, autumn and winter seasons respectively. These values were higher than that obtained by Abdo (2005) on the same lakes (4000 – 8090µmohs/cm) that reflects the increasing in the dissolution of different salts and pollutants discharged into the lakes water. According to Talling and Talling (1965) the EC of fresh water varies between 50 to 1500 µmohs/cm but some polluted water reached to 10000 µmohs/cm, while in seawater reached to 35000 µmohs/cm. therefore, the EC values of Abu Za'baal Lakes water lies in polluted water category. EC showed significant positive correlations ($n = 10$, $P < 0.05$) among different variables e.g. Cl^- ($r = 0.7$, 1.0 and 1.0), SO_4^{2-} ($r = 0.8$, 0.8 and 0.9), Na^+ ($r = 0.4$, 1.0 and 1.0), K^+ ($r = 0.8$, 1.0 and 1.0), Ca^{2+} ($r = 0.5$, 0.5 and 0.4) and Mg^{2+} ($r = 0.7$, 0.9 and 0.9), which considered as the component of the major anions and cations in the Abu Za'baal Lakes water.

3.2. Chemical Variables:

3.2.1. Salinity:

Salinity is among the most important factors and exerts various effects on the vitality of marine organisms. The salinity of Abu Za'baal Lakes water increased from the first lake: 5.1 – 5.6 ‰, second lake: 6.6 – 7.2 ‰ then third lake: 8.2 – 8.6 ‰. However, recorded different values of salinity in the same lakes ranged between 2.80 – 4.30 ‰ measured by Abdo (2005). This is mainly attributed to the increase in the evaporation rate, where the temperature influences the rate of rock weathering and precipitation process (Wetzel, 1983). This documented through the positive correlation between air and water temperatures with salinity (at $n = 10$, $P < 0.05$), ($r = 0.9$, 0.8, 0.9 & 0.9, 0.6 and 0.80) respectively during different seasons. The above mentioned values of TS, EC and salinity were found approximately in the same ranges of Manzala Lake water (4346 mg/l, 6320 µmohs/cm and 4.25 ‰) respectively (Abdel-Satar, 2008) which classified under brackish water lake.

3.2.2. Hydrogen Ion Concentration:

The pH values of Abu Za'baal Lakes water were ranged between 8.18 – 8.47 during hot seasons and 7.32 – 8.36 during cold seasons. The minimum value of pH (5.1) was recorded at station VIII in the third lake, where sulpher rock fragments is discharged in this lake during winter. These values were in the same ranges reported by Abdo (2005) at the same lakes (8.02 – 8.57) that indicates they are in the alkaline side (pH > 7.0), as reported by Goldman and Horne (1983).

3.2.3. Dissolved Oxygen:

Dissolved oxygen is one of the most important water quality indicators. It showed clear slightly local variation and some degree of seasonality. The highest values of DO were recorded in both spring (8 – 12 mg/l) and winter (10 – 12 mg/l). This may be due to the flourishing of phytoplankton (Anon, 2007) and the fall in water temperature during winter. The sharp decreases in DO concentration were recorded at all stations in the first lake during winter (Table 3). This may be attributed to the sewage and domestic wastes discharged into the lake during this season, where organic wastes and some inorganic material exert, upon decomposition, an oxygen demand, while deplete the dissolved oxygen below levels required by aquatic life (Abdel-Satar, 2008). Generally, the DO values at most selected sites of Abu Za'baal lakes water during different seasons, except for autumn, were within the guideline values cited by USEPA (1999) for the protection of aquatic life (for warm water biota: early life stages = 6 mg/l, other life stage = 5.5 mg/l; for cold water biota: early life stage = 9.5 mg/l, other life stage = 6.5 mg/l).

3.2.4. Biochemical and Chemical Oxygen Demands:

The present results of BOD in Tables (1 – 4) revealed that the lower values were recorded during autumn (2.0 – 4.8 mg/l). On the other side, the higher values of BOD were recorded during spring (2.8 – 5.2 mg/l). This may be due to the photosynthetic activity and phytoplankton abundance during spring (Abdo, 2004). The maximum values of COD were recorded during summer (11.6 – 16.0 mg/l) is mainly attributed to the raises in air and water temperatures that facilitate the decomposition and oxidation of organic matter (Abdo, 2004). The present results showed significant positive correlation between BOD and COD during autumn (n = 10, P < 0.05, r = 0.8). The DO, BOD and COD values were found in the same ranges of Abdo (2005).

3.2.5. Major Anions:

Table 1: Physico-chemical variables of Abu-Za’baal Lakes during spring 2008

Sites / Parameters	Units	1st					2nd		3rd
		I	II	III	IV	V	VI	VII	VIII
Air Temp	^0C	20	21	20	22	20	22	29	29
Water Temp	^0C	22	22	22	24	22	24	28	28
Depth	m	10	25	28	4	3	6	6	4
TS	mg/l	6332	6331	6332	6421	6384	8522	8532	11296
TDS	mg/l	6297	6297	6298	6298	6362	8488	8486	11196
TSS	mg/l	35	33	33	29	22	34	46	100
EC	µmhos/cm	6100	6100	6070	7000	6980	6980	7960	11580
Salinity	‰	5.1	5.1	5.1	5.1	5.1	6.7	6.7	8.4
pH		8.38	8.34	8.31	8.33	8.32	8.18	8.18	8.40
DO	mg/l	12	12	12	12	12	10	8	10
BOD	mg/l	3.2	4	4	4	4.8	5.2	4	2.8
COD	mg/l	6	6	6	7	7	8	8	9
CO_3^{--}	mg/l	22.5	22.5	15	15	15	22.5	22.5	25
HCO_3^-	mg/l	194.4	186.3	275.4	275.4	275.5	332.1	291.6	364.4
Cl^-	mg/l	1843.4	1730	1702	1702	1702	2411	2340	2553
SO_4^{--}	mg/l	326.84	326.8	326.7	322.8	320.8	344.42	341.70	354.70
Na^+	mg/l	608	644.7	647.3	662.4	662.4	771.52	782.8	884.4
K^+	mg/l	15.13	15.52	15.83	17.1	15.83	22.35	22.35	24.83
Ca^{2+}	mg/l	201	209	241	200	200	241	241	242
Mg^{2+}	mg/l	171	181	195	171	195	230	230	235
NO_2^-	µg/l	2.6	2.4	3.05	3.92	21.13	4.14	7.62	5.44
NO_3^-	µg/l	7.44	14.67	11.0	5.11	34.1	12.92	121.0	10.12
NH_4^+	µg/l	159	200	190	185	285	165	189	144
PO_4^{3-}	µg/l	40.90	54.16	45.0	48.0	142.0	58.24	73.6	73.6
TP	µg/l	158.38	269.7	230.0	172.7	246.25	439.4	308.6	187.0
SiO_3^-	mg/l	13.62	13.57	13.43	13.51	13.74	11.8	11.85	4.11

i- CO_3^{2-} and HCO_3^- Alkalinity:

The results of CO_3^{2-} and HCO_3^- alkalinity are present in Tables (1 – 4). It is declare that the CO_3^{2-} values were increased during hot seasons (spring/summer); 15 – 22.5 mg/l, decreased during autumn (5 – 20 mg/l) and not detected at most sites during winter. This is explained as the flourishing of phytoplankton and the increase in photosynthetic process leading to liberation of CO_2 which is converted into CO_3^{2-} according to the following equation:

$CO_2(g) == CO_2\ (eq) + H_2O == H_2CO_3 == H^+ + HCO_3^- = 2H^+ + CO_3^{--}$ (Abdo, 2005).

On the other side, the lower values of CO_3^{2-} during autumn and depletion during winter, may be related to the decomposition of phytoplankton and liberation of CO_2 dissolves in water and formation of HCO_3^- according to the following equation:

$CO_2 + CO_3^- + H_2O \rightarrow 2HCO_3^-$ (Abdo, 2004).

However, HCO_3^- values were found increased during could seasons (324 – 445 mg/l), and decreased during hot seasons (186.3 – 369.36 mg/l). CO_3^{2-} and HCO_3^- were positive correlation during autumn (r = 0.6) and negative correlation (r = - 0.6) during summer (n = 10, P < 0.05).

ii- Cl^- and SO_4^{--} :

Both of Cl^- and SO_4^{--} distribution in Abu Za'baal Lakes had the same behavior; the maximum values of Cl^- and SO_4^{--} were recorded during summer (Table 2). While, during spring, autumn and winter seasons, they varied among different sites at the three lakes (Tables 1, 3 and 4). Also, the concentration values of Cl^- & SO_4^{2-} during 2003 were ranged between 1595.25 – 1843.4, 780 – 1276.2, 886.25 – 1240.75 and 322.63 – 546.0, 355.32 – 643.78 and 322.51 – 664.83 mg/l for the three lakes respectively as reported by Abdo (2005).

Table 2: Physico-chemical variables of Abu-Za'baal Lakes during summer 2008.

Sites / Parameters	Units	1st					2nd		3rd
		I	II	III	IV	V	VI	VII	VIII
Air Temp	^0C	31	29	29	30	31	32	30	34
Water Temp	^0C	29	28	29	29	30	30	28	32
Depth	m	10	28	27	25	2	7	6	10
TS	mg/l	6912	6914	6974	6918	6908	8956	8934	10688
TDS	mg/l	6882	6880	6924	6895	6870	8882	8886	10610
TSS	mg/l	30	34	50	23	38	74	48	78
EC	µmhos/cm	9700	9740	9750	9770	9750	12220	12320	14000
Salinity	‰	5.6	5.6	5.6	5.6	5.6	7.1	7.2	8.2
pH		8.47	8.45	8.52	8.47	8.42	8.32	8.18	8.18
DO	mg/l	6.8	7.2	7.2	7.5	6.0	6.8	5.6	5.2
BOD	mg/l	3.2	4.0	4.0	3.6	2.0	2.8	2.8	3.2
COD	mg/l	12.8	16.0	11.6	12.8	12.8	16.0	15.6	14.0
CO_3^{--}	mg/l	22	20	20	22	22	16	16	8
HCO_3^-	mg/l	239.8	233.3	226.8	226.8	230.7	369.36	369.36	298.08
Cl^-	mg/l	1999.4	1999.4	1999.4	1999.4	1999.4	2649	2599	2599.2
SO_4^{--}	mg/l	1010.7	1114.7	1492.4	1686.23	1628.9	1960.0	1763.0	2230.8
Na^+	mg/l	554.33	549.37	556.0	552.6	547.7	618.87	618.87	662.9
K^+	mg/l	18.87	16.43	16.9	17.37	16.9	23.48	23.48	24.42
Ca^{2+}	mg/l	200.4	193	193	193	193	233	249	300.64
Mg^{2+}	mg/l	224.5	220	224.5	224.5	239.12	288	288	317.2
NO_2^-	µg/l	2.93	4.98	4.10	5.56	4.98	7.61	7.91	35.45
NO_3^-	µg/l	6.27	5.20	5.10	6.00	5.20	8.80	10.1	83.35
NH_4^+	µg/l	74	52	121	68	57	92	244	254
PO_4^{3-}	µg/l	47.04	29.12	33.6	26.88	35.84	44.8	47.04	30.24
TP	µg/l	103.04	169.12	169.12	127.68	115.36	148.96	159.04	140.0
SiO_3^-	mg/l	13.21	12.87	12.89	13.08	12.82	12.19	12.09	5.25

These values were double increased in the present study which ranged between 1702-1994, 2340-2694, 2553-3048, 320.8-1686.23, 341.7-1960 and 354.7 – 2230.8 mg/l respectively. These results declare that the increase in salinity of Abu Za'baal Lakes water.

The chloride and sulphate concentrations possessed a good positive relationship (n = 10, P < 0.05) during different seasons with SO_4^{--} (r = 1.0, 0.8, 0.6 and 0.9), Na^+ (r= 0.9, 0.9, 1.0), K^+ (r = 0.7, 1.0, 1.0 and 1.0), Ca^{2+} (r = 0.7, 0.8, 0.9 and 0.9) and Mg^{2+} (r = 0.9, 0.8, 0.8 and 0.7). This reflects the strong relationship between major cations and anions in Abu Za'baal Lakes water.

3.2.6. Major Cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+):

The concentration levels of divalent (Ca^{2+} & Mg^{2+}) and monovalent (Na^+ & K^+) were high in the three lakes water. The most predominate cation in lake water (Na^+) showed high variations during different seasons at different sites of the three lakes, while the cations (K^+, Ca^{2+} and Mg^{2+}) showed slight variations. The distribution of (Ca^{2+}, Mg^{2+}, Na^+ and K^+) were found decreased during winter followed by autumn, while the highest values were recorded during summer followed by spring as shown in Tables (1 – 4). The order of abundance on a mass basis was Na^+ (53.4 %) > Ca^{2+} (23.5 %) > Mg^{2+} (21.43 %) > K^+ (1.7 %). The two elements (Na^+ & K^+) fulfilled a significant positive relationship during different seasons (r = 1.0, 1.0, 0.9 and 1.0, n = 10, P < 0.05). Also, the divalent elements (Ca^{2+} & Mg^{2+}) were possessed a good positive relationship (r = 0.8, 0.8 and 0.9).

Generally, the distribution of major anions and cations in lakes water were governed mainly by the rate of evaporation and the intrusion of drainage water. This interpretation coincident with that reported by Abdel-Satar and Sayed (2010) on Qarun Lake water.

3.2.7. Nutrient Salts:

Nitrogen and phosphorus limit the growth of terrestrial plants, phytoplankton, macro algae and vascular plants in freshwater and marine ecosystem, and silicon additionally limits the growth of diatoms (Rabalais, 2005). Nitrogen typically occurs in concentrations much higher than that of phosphorus and despite that the demand by primary producer for nitrogen is higher than those of phosphorus (Søndergaard, 2007).

i- Nitrite, Nitrate and Ammonia:

The obtained results revealed that the ammonia accounted for the major proportion of total soluble inorganic nitrogen, NH_4^+ ranged between 52 – 450 µg/l during different seasons. Nitrite showed low levels than the corresponding values of nitrate due to the fast conversion of NO_2^- to NO_3^- ions by nitrifying bacteria (Abdo, 2005). The ranges of NO_2^- and NO_3^- were found to be 2.40 – 35.45 and 6.00 – 83.85 µg/l at the three lakes during different seasons, respectively. The ranges of NH_4^+, NO_2^- and NO_3^- were found to be 234 – 489, 2.4 – 189.74 and 8.41 – 571.66 µg/l respectively (Abdo, 2005) in the same lakes during 2003. This reflects the decrease in nutrient salts (NO_2^- & NO_3^-) concentrations in Abu Za'baal Lakes water in the present time. This may be due to the pollutants discharging into the lakes water. NO_2^-, NO_3^- and $^+NH_4$ have good positive correlations with each other (n = 10, P < 0.05), NO_2^- and NO_3^- (r = 1.0 and 0.9), NO_2^- and $^+NH_4$ (r = 0.8 and 0.7) during different seasons. These explain the dependence and inter conversion of the three nitrogen forms to each other.

ii- Ortho-and Total Phosphorus:-

Phosphorus that enters the system through anthropogenic sources, such as fertilizer-runoff, potentially could be incorporated into either inorganic or organic fractions (Mainstone *et al.*, 2008). The orth- and total phosphates at the three lakes were increased during different seasons. However, the ranges of PO_4^{3-} and (TP) in the three lakes are (23.50 – 142.00), (41 – 73.6), (30.24 – 73.6) and (80 – 246.25), (159.04 – 439.4), (140 – 232) µg/l, respectively. The high seasonal variations and irregular distributions of the PO_4^{3-} and TP at different sites of the three lakes, reflecting the effect of drainage water discharging into lakes. These results are coincident with that reported by Abdel-Satar and Sayed (2010) on Qarun Lake. The weak and negative correlation between inorganic phosphorus

PO_4^{3-} and TP (r = 0.1, 0.2, 0.4 and 0.2) suggest that the large amount of TP in lake water is organic phosphorus.

iii- Reactive Silicate:

The present results declared that, silicate showed a gradual decrease at different sites during autumn and relative increase during hot seasons (spring/summer), then winter (Tables 1 – 4). The high values of SiO_3^- were recorded in the first lake during different seasons which ranged between 11.7 – 15.40 mg/l, and the lower values were recorded during autumn (Table 3). This can explain the abundance of diatoms in the first lake, which is typically bloom water low-temperature condition during autumn. This agrees with that found by Abdel-Satar (2008) and Abdel-star and Sayed (2010) in Manzala and Quarn Lakes respectively.

Table 3: Physico-chemical variables of Abu-Za'baal Lakes during autumn 2008.

Sites / Parameters	Units	1st					2nd		3rd
		I	II	III	IV	V	VI	VII	VIII
Air Temp	^0C	31	30	31	33	29	31	31	31
Water Temp	^0C	28	27	29	28	28	29	29	28
Depth	m	11	10	15	10	8	7	6	10
TS	mg/l	8800	9900	9000	9100	8400	10600	11900	13300
TDS	mg/l	8630	8710	8910	9000	8254	10482	10774	13192
TSS	mg/l	170	190	90	100	146	118	126	108
EC	µmhos/cm	9330	9360	9330	9320	9330	11970	11970	14320
Salinity	‰	5.3	5.2	5.3	5.2	5.3	6.8	6.9	8.3
pH		8.27	7.98	7.98	8.02	8.02	8.02	8.16	7.97
DO	mg/l	4	4	4	4	4	12	10	10
BOD	mg/l	3.6	2.0	2.4	2.4	2.4	4.8	4.0	4.4
COD	mg/l	6.0	7.2	5.2	6.4	5.2	12.0	9.6	9.2
CO_3^{--}	mg/l	12.5	5.0	5.0	5.0	12.5	20.0	35.0	Nil
HCO_3^-	mg/l	381	413	397	397	405	421	421	283
Cl^-	mg/l	1914	1914	1843	1843	1843	2481	2481	2623
SO_4^{--}	mg/l	348.3	348.3	350.0	348.0	348.0	357.0	357.0	690.0
Na^+	mg/l	432	418	418	418	473	514	514	576
K^+	mg/l	16.0	16.0	15.5	14.6	14.6	20.6	20.4	23.6
Ca^{2+}	mg/l	247	247	205	189	224	200	178	349
Mg^{2+}	mg/l	191	183	200	180	217	255	310	300
NO_2^-	µg/l	5.7	4.8	4.8	5.0	7.2	10.0	9.15	19.4
NO_3^-	µg/l	12	6	8	9	9	11	11	23
NH_4^+	µg/l	250	250	260	450	440	250	260	270
PO_4^{3-}	µg/l	34.0	23.5	45.0	46.0	42.0	55.2	41.0	55.2
TP	µg/l	80	186	90	166	180	192	164	232
SiO_3^-	mg/l	11.7	12.4	11.7	12.22	12.0	7.52	7.82	3.69

3.3. N/P ratio (Eutrophication):

Eutrophication of lakes is due to enrichment of water with high amount of nutrient, mainly phosphorus and nitrogen. The N/P ratio has been calculated from the lake data for nitrogen as DIN ($^+NH_4$, NO_2^- and NO_3^-) and phosphorus as orthophosphates (PO_4^{3-}) (Mcpherson *et al.*, 1982). The most conservation ratio suggests that N/P ratio is lying betweens (5 – 10) in most lakes. If the values are less than 5, indicates that nitrogen is limiting for plant growth and if more than 5, indicates that phosphorus is limiting (Smith, 1983; Thomann and Multer, 1987).

The calculation of N/P ration of Abu Za'baal Lakes water was found to be 7.8, 8.7, 18.29 and 4.9 during spring, summer, autumn and winter seasons respectively. Therefore, the phosphorus is limiting nutrient factor (N/P > 5) in the lakes during spring, summer and autumn but during winter (N/P < 5), nitrogen is limiting nutrient factor for plant growth. Smith (1983) reported that the low N/P ratio appears to favor green algae dominance in nature lakes in the temperate zone.

3.4. Water Quality Index "WQI":

WQI is a mathematical way of summarizing multiple properties into a single value. Typically, WQI ranges between 0 –

100, with higher numbers indicating lower quality water. QWI is useful for comparing differences in water quality across a region, or for monitoring changes in water quality over time. In the present study WQI was calculated using the equation developed by Tiwari and Manzoor (1988). The quality rating q_i, for the i^{th} water quality parameter can be obtained by the following relation:-

$$q_i = 100\ [V_i / S_i] \qquad (1)$$

Where V_i = observed value of the i^{th} parameter at a given sampling site and S_i = stream water quality standard. Equation (1) ensures that q_i = 100 if the observed value is just equal to its standard value. Thus, the larger value of q_i the more polluted the water. To calculate WQI, the quality rating q_i corresponding to parameter can be determined using the equation (1). The overall WQI was calculated by aggregating this quality rating linearly as follows:-

$$WQI = \sum_{i=1}^{n} q_i \qquad (2)$$

Where n = number of parameters, the average water quality index (AWQI) for n parameters was calculated using the following equation:-

$$AWQI = \frac{\sum_{i=1}^{n} q_i}{n} \qquad (3)$$

where n = number of parameters. AWQI was classified into 4 categories: (good) 0.0 – 100, (medium) 100 – 150, (bad) 150 – 200 and (very bad) over 200.

Table 4: Physico-chemical variables of Abu-Za'baal Lakes during winter 2009.

Sites / Parameters	Units	1st					2nd		3rd
		I	II	III	IV	V	VI	VII	VIII
Air Temp	^0C	25	25	26	26	26	30	30	30
Water Temp	^0C	22	22	24	24	24	28	28	28
Depth	cm	10	7	10	6	4	6	7	7
TS	mg/l	6580	6610	6620	6620	6680	8390	8120	11840
TDS	mg/l	6500	6510	6480	6518	6580	8300	8300	11600
TSS	mg/l	80	100	90	102	100	90	120	240
EC	µmhos/cm	9310	9340	9300	9320	9340	11570	11610	14910
Salinity	‰	5.2	5.2	5.2	5.2	5.2	6.6	6.6	8.6
pH		8.30	7.88	7.78	7.76	7.76	8.36	7.32	5.1
DO	mg/l	10	10	10	12	10	10	10.4	10.8
BOD	mg/l	5	5	5	5	5	5	5	5
COD	mg/l	7.2	8.8	7.2	6.4	6.8	8.8	9.2	6.0
CO_3^{--}	mg/l	12.5	ND	ND	ND	ND	12.5	ND	ND
HCO_3^-	mg/l	324	324	324	445	445	405	429	162
Cl^-	mg/l	1915	1985	1985	1985	1985	2481	2694	3048
SO_4^{--}	mg/l	337	346	344	344	344	348	347	367
Na^+	mg/l	424	426	428	428	430	485	489	562
K^+	mg/l	12.54	12.40	12.54	12.40	12.54	17.24	17.55	20.00
Ca^{2+}	mg/l	281	281	241	321	241	321	321	441
Mg^{2+}	mg/l	198	195	190	195	195	195	196	293
NO_2^-	µg/l	9.15	9.37	10.23	9.80	10.50	6.10	4.60	15.00
NO_3^-	µg/l	13.00	24.26	13.86	22.83	25.14	30.55	33.00	26.70
NH_4^+	µg/l	71	58	68	63	63	150	100	170
PO_4^{3-}	µg/l	41	48	56	48	58	54	57	62
TP	µg/l	112	184	235	205	154	250	184	143
SiO_3^-	mg/l	15.10	15.40	15.40	15.30	15.10	9.10	9.15	4.93

The present values of WQI and AWQI in (Table 5) were calculated according to Egyptian Standard (EEAA, 1994). It shows that AWQI of Abu Za'baal Lakes water during (2003 and 2009) was found to be 176.86 and 286.70 respectively. This means that the Abu Za'baal Lakes water is classified under bad water quality during (2003) and very bad water during 2009 (present study). Also, the results indicate of increasing in the pollution levels of Abu Za'baal Lakes water which are essential coved by untreated domestic and sewage water, industrial waste water, in addition to drainage water.

Table 5: Comparison between WQI & AWQI of Abu-Za'baal Lakes water during 2003 and 2009.

Parameters	2003			2009		
	V_i	S_i	$q_i = 100[V_i/S_i]$	V_i	S_i	$q_i = 100[V_i/S_i]$
pH	8.43	6.5 – 8.5	112.40	7.57	6.5 – 8.5	101.00
EC µmhos/cm	5960	1200	496.66	10271.66	1200	855.97
TDS mg/l	4616.66	1200	384.72	9853.16	1200	821.09
T. alkalinity mg/l	322.38	120	268.60	324.71	120	270.60
Cl^- mg/l	1270.30	500	254.06	2389.4	500	477.88
SO_4^{--} mg/l	475.84	400	118.96	1149.00	400	287.25
Ca^{2+} mg/l	120.90	200	60.45	247.43	200	123.71
Mg^{2+} mg/l	144.30	150	96.20	244.5	150	163.00
T. hardness mg/l	265.2	500	53.06	491.93	500	98.38
NO_3^- mg/l	0.2593	10	2.593	0.0437	10	0.437
DO mg/l	9	5	180	8.26	5	165.33
BOD mg/l	4.7	5	94.66	3.8	5	76
$WQI = \sum_{i=1}^{n} q_i$			2122.36	$WQI = \sum_{i=1}^{n} q_i$		3440.647
$AWQI = \sum_{i=1}^{n} q_i/n$			176.86	$AWQI = \sum_{i=1}^{n} q_i/n$		286.70

4. CONCLUSION AND RECOMMENDATIONS

Abu Za'baal Lakes water quality parameters showed a wide variation due to the discharge of drainage water from different pollutants sources during different times. The lakes still has very bad water quality (high AWQI), and its aquatic life has been threatened to a devastating point and in dire need of more human intervention. Also, the N/P ratio of Abu Za'baal Lakes water lying between (5– 10) revealed that the lakes are eutrophic. So, it is recommended a continuous monitoring program for management of Abu Za'baal Lakes as fish aquaculture, fishing and source of fishery foods.

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