Egyptian Journal of Aquatic Research (2014) 40, 225–233

HOSTED BY

ELSEVIER

National Institute of Oceanography and Fisheries

Egyptian Journal of Aquatic Research

http://ees.elsevier.com/ejar
www.sciencedirect.com

FULL LENGTH ARTICLE

Evaluation of surface water quality and heavy metal indices of Ismailia Canal, Nile River, Egypt

Mohamed E. Goher [a,*], Ali M. Hassan [b], Ibrahim A. Abdel-Moniem [b], Ayman H. Fahmy [b], Seliem M. El-sayed [a]

[a] *Chemistry Laboratory, Freshwater, Lakes Division, National Institute of Oceanography, Fisheries (NIOF), Cairo, Egypt*
[b] *Chemistry Department, Faculty of Science, Al-Azher University, Cairo, Egypt*

Received 10 June 2014; revised 15 September 2014; accepted 23 September 2014
Available online 26 November 2014

KEYWORDS

Water quality index;
Pollution index;
Metal index;
Ismailia Canal

Abstract Ismailia Canal is one of the most important branches of the Nile River in Egypt. It is the main source of drinking and irrigation water for many cities. Weighted arithmetic method of water quality index (WQI) was used to evaluate the water quality of Ismailia Canal according to drinking, irrigation and aquatic life water utilizations. The objective of the index is to transform complex water quality data into understandable and usable information by the public. The WQI values of Ismailia Canal are good to poor for drinking and aquatic life utilizations, and excellent for irrigation utilization. Metal index (MI) and pollution index (PI) were calculated to assess the contaminations of the canal water with the metals (Al^{+3}, Cd^{+2}. Cu^{+2}, Fe^{+2}, Mn^{+2}, Ni^{+2}, Pb^{+2} and Zn^{+2}). MI and PI values denote the dangerous pollution of the canal water, which is described as seriously at most sites along, in particular for drinking and fisheries utilizations. It may be attributed to the effluents of different industrial wastes arriving at the canal water. Law 48/1982 for the protection of the Nile River and its waterways against pollution must be enforced to prevent the obvious deterioration of the canal water and to improve its quality.

Introduction

Nile River is the main water source for Egypt, the traditional concern with securing sufficient water for Egypt's survival and economic development cannot be overemphasized. At the same time, uncontrolled wastewater discharges are causing immediate and long-term water quality health impacts on the users (Ibrahim et al., 2009). Ismailia Canal is one of the most important irrigation and drinking water resources in Egypt; it was constructed in 1862 to supply drinking water to the villages on the Suez Canal zones and to the workers during digging the Suez Canal Navigation Route (Geriesh et al., 2008). Today it's water is used for irrigation, domestic and industrial uses, it is the principle source of drinking water supply for a great number of Egyptian citizens (about 12 million inhabitants), including those living in the northern part of Great Cairo, Shubra El-Kheima, El Amira, Mattaria, Musturod, Abu-Zaabal, Inchas, Belbeis, Abbasa, Abu-Hammad, Zagazig and El-Tal El-Kabeer, before entering the Suez Canal area as well as industrial purposes (Geriesh et al., 2008).

* Corresponding author.
Peer review under responsibility of National Institute of Oceanography and Fisheries.

http://dx.doi.org/10.1016/j.ejar.2014.09.001
1687-4285

The canal is extending for about 128 km long, with about 30–70 m width and 1–3 m depth. In the final developing stage, the canal discharge is about 5,000,000 m^3/day of water for drinking and industrial purposes (El-Haddad, 2005). The canal has its inlet from the Nile at Cairo and runs directly to the east to Ismailia governorate passing Cairo – Kalioubeya – Sharkeya governorates, Ismailia (Stahl and Ramadan, 2008). At Ismailia town it bifurcates into two arms, one to the north (90 Km long) to supply Port Said governorate and the other to the south (about 80 Km long) to Suez governorate (Abdo, 1998) with total surround area of about 108,200 fedden (El-Haddad, 2005; Geriesh et al., 2008) indicating that the canal gains up to 24.06×10^6 m^3 of water from the surrounding low aquifer during the closing period of the High Dam gates, while during the rest of the year, the canal acts as an influent stream losing about 99.6×10^6 m^3 of its water account.

Pollution sources in Ismailia Canal

Owing to industrial and agricultural activities large amounts of untreated urban municipal, industrial wastewater and rural domestic wastes discharge into the Nile River, canals or agricultural drains which become an easy dumping site for all kinds of wastes (Stahl et al., 2009). Ismailia Canal represents the most distal downstream of the main Nile River. Thus its water contains all the proceeded pollutants discharged into the Nile. Ismailia Canal has many sources of pollution which, potentially affects and deteriorates the water quality of the canal (Geriesh et al., 2008). The first source is the upstream portion of the Ismailia Canal (from Cairo to Abu Zaabal, western side) including the largest industrial zones in the region (Shupra El-Kheima, Musturod, Abu Zaabal industrial zones), which include the activities of petroleum, petro gas, iron and steel, Abu Zaabal Fertilizers Company, Alum (Aluminum Sulfate) Company, detergent industries and electric power station. The second source is the water treatment plants which caused dramatic changes in its water quality by throwing waste water rich with Aluminum, Iron and Manganese. In addition to waste disposals seepage from the villages and septic tanks, distributed very close to the canal course and the agricultural effluents, are the major sources of contamination.

Mainly there are four main approaches that can be used to assess the water quality of a water body: (1) water quality index approach, (2) trophic status index approach, (3) statistical analysis approaches of the water quality data such as correlation analysis and (4) biological analysis approaches such as Genetic Algorithms method and other different biological indices (Elshemy and Meon, 2011).

Regular water quality monitoring of the water resources is absolutely necessary to assess the quality of water for ecosystem health and hygiene, industrial use, agricultural use and domestic use (Poonam et al., 2013). The water quality evaluation may be a complicated practice in compound parameters causing numerous anxieties in general quality of water (Bharti and Katyal, 2011).

Studies on heavy metals in rivers, lakes, fish and sediments have been a major environmental focus especially in the last decades (Ali and Fishar, 2005). Water pollution by trace metal ions is one of our most serious environmental problems. Effluents resulting from daily domestic and industrial activities may induce considerable changes in the physical and chemical properties of the Nile river and its Canal. These changes may greatly alter the environmental characteristics of river reaches (El-Sayed, 2011). Heavy metals are regard as serious pollution of aquatic ecosystem because of their environmental persistence and toxicity effects on living organisms (Khalil et al., 2007). In the aquatic environment, the trace elements are partitioned among various environmental components (water, suspended solids, sediments and biota) (Shakweer and Abbas, 2005). The toxicity tests are necessary in water pollution evaluation because chemical and physical measurements alone are not sufficient to assess the potential effects on aquatic biota (Abou El-Naga et al., 2005).

The water quality of Ismailia Canal and distributions of heavy metals were the topics of interested for many authors, (Abdo, 1998; Geriesh et al., 2004; El-Haddad, 2005; Tarek and Ali, 2007; Stahl and Ramadan, 2008; El-Sayed, 2008; Geriesh et al., 2008; Ibrahim et al., 2009; Abdo and El-nasharty, 2010; Abdo et al., 2010, 2012; Youssef et al., 2010; Abd El-Hady and Hussian, 2012; Nassif, 2012; Khalifa, 2014).

Materials and methods

Eleven subsurface water samples were collected seasonally (2013–2014) by a polyvinyl chloride Van Dorn bottle at eleven sites along the Ismailia Canal (Fig. 1). Details of surface water sampling location along with their longitude and latitude are presented in Table 1.

Field measurements

Water temperature, electrical conductivity and pH value were measured in situ, using Hydrolab, Model (Multi Set 430i WTW). The transparency was measured using Secchi-disk (diameter 30 cm).

Laboratory analysis

Water samples were kept in 2 l polyethylene bottles in ice box and analyzed in the laboratory. The methods of analyses are discussed in the American Public Health Association (APHA, 1998) except where noted. Total solids (TS) were measured by evaporating a known volume of well mixed sample at 105 °C. TDS was determined by filtrating a known volume of sample by (GF/C) and evaporating at 180 °C. TSS is direct obtained by subtraction of TS–TDS. Dissolved oxygen (DO) was measured by using the modified Winkler method. Biochemical oxygen demand (BOD) was determined by using the 5 day method. Chemical oxygen demand (COD) was carried out using the potassium permanganate method. Water alkalinity was determined immediately after sample collection using phenolphthalein and methyl orange as indicators. Chloride was measured using Mohr's method and sulfate by turbidimetric methods. Calcium and magnesium were determined by direct titration using EDTA solution, Na^+ and K+ were measured directly using the flame photometer Model "Jenway PFP, U.K.". Concentrations of NO_2-N, NO_3-N, NH_4-N, PO_4-P and SiO_4 were determined using colorimetric techniques with the formation of reddish purple azo-dye, Copper-Hydrazine sulfate reduction, phenate, ascorbic acid molybdate and molybdosilicate methods, respectively. Total phosphorus (TP) was measured as reactive

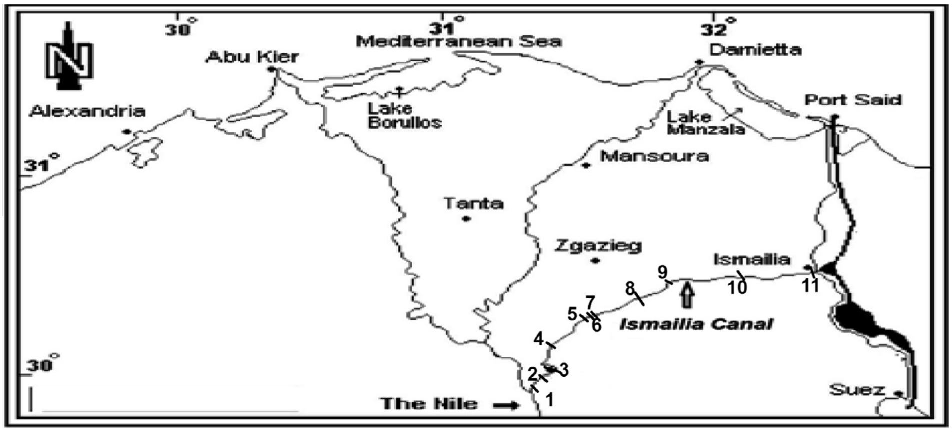

Figure 1 Sample locations at Ismailia Canal in Egypt.

Table 1 Details of surface water sampling location of Ismailia canal.

Station	Features of station	Latitude	Longitude
1	(El-Mazalat) Mouth of Ismailia Canal	30° 06\ 30\\	31° 15\ 10\\
2	In front of Al-Amiria drinking water purification station	30° 06\ 41\\	31° 16\ 22\\
3	Mostourd	30° 09\ 55\\	31° 17\ 36\\
4	Ring Road	30° 10\ 09\\	31° 18\ 20\\
5	In front of Abu Za'baal fertilizer Company	30° 16\ 28\\	31° 22\ 44\\
6	2 kilometer downstream Abu Zaable fertilizer Company	30° 16\ 46\\	31° 23\ 06\\
7	In front of Aluminum Sulfate Company	30° 16\ 49\\	31° 23\ 07\\
8	Bilbeis	30° 24\ 57\\	31° 34\ 33\\
9	Al Abbasa	30° 32\ 04\\	31° 42\ 35\\
10	El-Tal El-Kabeer	30° 32\ 47\\	31° 52\ 09\\
11	El-Ismailia (before bifurcation)	30° 34\ 05\\	32° 14\ 06\\

phosphate after persulfate digestion. Total Al^{+3}, Cd^{+2}. Cu^{+2}, Fe^{+2}, Mn^{+2}, Ni^{+2}, Pb^{+2} and Zn^{+2} were measured after digestion by conc. HNO_3 using an atomic absorption reader (SavantAA AAS with GF 5000 Graphite Furnace).

Water quality index

Water quality index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water (Al-Mohammed and Mutasher, 2013). WQI has been calculated to evaluate the suitability of water quality of Ismailia Canal using the Weighted arithmetic water quality index method, which classifies the water quality according to the degree of purity by using the most commonly measured water quality variables. The calculation method of WQI was developed by Brown et al. (1972), which has been widely used by many scientists (Tyagi1 et al., 2013; Chowdhury et al., 2012; Balan et al., 2012). The mathematical formula of this WQI method is given by:

$$\mathrm{WQI} = \sum_{i=1}^{n} Q_i W_i \Big/ \sum_{i=1}^{n} W_i$$

where Q_i is the sub quality index of ith parameter (or Q_i is the quality rating scale of each parameter). W = weight unit of each parameter, n = number of parameters.

Calculation of Q_i value

$$Q_i = [(V_i - V_o)/(S_i - V_o)]$$

V_i = measured value of ith parameter, S_i = standard permissible value of ith parameter, V_o = ideal value of ith parameter in pure water, V_o = zero for all parameters except for pH = 7.0 and DO = 14.6 mg/l (Tripaty and Sahu, 2005).

Calculation of W_i value

Calculation of unit weight (Wi) for various water quality parameters is inversely proportional to the recommended standards for the corresponding parameters.

$$\mathrm{Wi} \propto 1/\mathrm{Si} \quad \text{or} \quad \mathrm{Wi} = K/\mathrm{Si}$$

where K is the proportionality constant of the "Weights" for various water quality characteristics:

$$K = \frac{1}{\sum_{i=1}^{n} \frac{1}{\mathrm{Si}}}$$

WQI has been classified into 5 classes, the water quality is rated excellent, good, poor, very poor and unfit when the value of the index lies between 0–25, 26–50, 51–75, 76–100 and >100, respectively (Table 2).

Table 2 Water quality rating as per weight arithmetic water quality index method.

WQI value	Rating of water Quality	Grading
0–25	Excellent	A
26–50	Good	B
51–75	Poor	C
76–100	Very Poor	D
Above 100	Unsuitable for drinking purpose	E

Table 3 Categories of Water Pollution Index.

Class	PI value	Class
1	< 1	No effect
2	1–2	Slightly affected
3	2–3	Moderately affected
4	3–5	Strongly affected
5	> 5	Seriously affected

Metal quality index (MI)

Two different quality indices are used to determine the metal contamination of Ismailia Canal water.

(1) Pollution index (PI) is based on individual metal calculations and categorized into 6 classes (Table 3) according the following equation (Caerio et al., 2005).

$$PI = \frac{\sqrt{\left[\left(\frac{Ci}{Si}\right)^2_{max} + \left(\frac{Ci}{Si}\right)^2_{Min}\right]}}{2}$$

Ci: the concentration of each element; Si: metal level according to national water quality criteria.

(2) Metal index (MI) is based on a total trend evaluation of the present status. The higher the concentration of a metal compared to its respective MAC value, the worse the quality

Table 4 Mean, standard deviation and range of water parameters compared to guidelines used in WQI, PI and MI computations.

Parameter	Mean	SD	Range	Drinking water		Irrigation[c]	Aquatic live[d]
				Egypt[a]	WHO[b]		
Temp °C	24.04	±5.38	16–33				8–28
Transparency cm	74.32	±14.05	35–120				
EC µs/cm	423.4	±43.78	350–544	2000		3000	
TDS mg/l	281.8	±33.34	210–365	1000	500	2000	500
TSS mg/l	100.7	±26.23	39–176				+25
TS mg/l	382.5	±42.19	286–528				
pH	8.12	±0.18	7.09–8.46	6.5–8.5	8.5	8.5	6.5–9
DO mg/l	7.85	±0.62	5.78–9.98	6			5.5
BOD mg/l	3.77	±1.45	0.3–7.18	3			
COD mg/l	6.29	±1.17	3.68–15.08	10	10		7
T Alkalinity mg/l	128.09	±11.49	98.71–147.49		250		> 20
CO3 mg/l	8.85	±3.22	0.0–22.2			3	
HCO3 mg/l	138.27	±13.93	105.9–162.4			610	
Cl mg/l	22.32	±4.65	14.25–33.16	250	200	1063	120
SO_4 mg/l	25.47	±11.14	8.71–98.8	250	250	960	
T Hardness mg/l	112.11	±12.92	102–169.34	500	500		
Ca mg/l	29.09	±2.83	24.17–38.82	75	75	400	
Mg mg/l	14.05	±1.92	9.78–17.62	50	50	60	
Na mg/l	23.57	±5.25	15.14–39.7	200		919	
SAR	0.90	±0.17	0.57–1.44			15	
K mg/l	7.54	±0.87	5.77–8.89			2	
NO_3-N mg/l	0.239	±0.097	0.031–0.584	10	11	10	2.93
NO_2-N mg/l	0.01	±0.005	0.002–0.027	0.005	0.9		0.06
NH_3-N mg/l	0.130	±0.095	0.088–0.569	0.45	0.2	5	1.37
PO_4-P mg/l	0.068	±0.017	0.008–0.399			2	
TP mg/l 1	0.204	±0.087	0.038–0.480	1			
SiO_4 mg/l	5.00	±3.003	0.37–8.78				
Al mg/l	2.69	±2.22	0.055–45.4	0.2	0.2	5	0.1
Cd mg/l	$0.45*1^{0\text{-}3}$	$\pm 0.32*1^{0\text{-}3}$	0–0.003	0.003	0.003	0.010	0.001
Cu mg/l	0.007	±0.003	0.003–0.021	2	2	0.2	0.004
Fe mg/l	0.57	±0.37	0.109–2.239	0.3	0.3	5	0.3
Mn mg/l	0. 113	0.89	0.020–0.483	0.1	0.1	0.2	0.050
Ni mg/l	0.010	±0.005	0.0–0.025	0.020	0.070	0.2	0.025
Pb mg/l	0.018	±0.005	0.011–0.034	0.010	0.010	5	0.007
Zn mg/l	0.015	±0.011	0.002–0.127	3	0.5	2	0.050

[a] Egypt (2007).
[b] WHO (2011).
[c] FAO (1994).
[d] CCME, 2007.

of the water. MI value > 1 is a threshold of warning (Bakan et al., 2010). According to (Tamasi and Cini, 2004), the MI is calculated by using the following formula:

$$MI = \sum_{i=1}^{n} \frac{Ci}{(MAC)_i}$$

Ci: the concentration of each element, MAC: maximum allowable concentration.

Statistical analysis

Data were analyzed for spatial and temporal variations through Excel-Stat software using Multivariate Analysis; significance levels of tests were taken as $p < 0.05$ and highly significant as $p < 0.01$. The correlation coefficient (r) between the measured parameters was examined.

Results and discussion

The mean values, standard deviations and ranges of the obtained results are represented in Table 4. The results show relatively slight local variations in surface temperature except the areas exposed to a thermal pollution, as station (5) which recorded the maximum annual temperature of 33 °C in summer; this may be due to re-cooling water of Abu Zaabal Fertilizer Company. Temperature is positively correlated with EC, TS, TDS, Cl^{-1}, SO_4^{-2}, TP, PO_4^{-3}, NO_2^{-1}, NO_3^{-1} and Cu^{-2}, and is negatively correlated with pH and Pb^{-2}. Transparency was affected by domestic sewage and industrial effluents, it fluctuated between 35 and 120 cm. ANOVA results show highly spatial and temporal significant difference ($p < 0.01$) for transparency value, the remarkable decrease in transparency values was recorded at the discharging point of Alum (Aluminum sulfate) Company. Transparency is negatively correlated with EC, TS, TDS, TSS, most cations and anions. EC showed a highly spatial and temporal significant difference ($p < 0.01$). Abd El-Hady and Hussian (2012) showed that winter was the optimum season for water EC in Ismailia Canal. EC is positively correlated with TS, TSS, TDS, COD, major cations and major anions. TS, TDS and TSS were varied in the ranges of 286–528, 210–365 and 39–176 mg/l, respectively. According to Abdo (2005), salinity (TDS) shows a close trend as similar as major cations. ANOVA results show highly significant difference of solid contents between different seasons and locations.

pH values were in the alkaline side (7.09–8.46) with a highly significant difference between the sites ($p < 0.01$). There are high positive correlations ($n = 44$, $p < 0.05$) between pH/DO ($r = 0.63$), pH/CO_3^{-2} ($r = 0.86$) and pH/HCO_3^{-1} ($r = 0.63$). DO, BOD and COD were varied in the ranges of 5.78–9.98, 0.3–7.18 and 3.68–15.08 mg/l with remarkable seasonal and local variations ($p < 0.01$). The maximum value of COD recorded at station (7) during autumn, may be attributed to the discharge effluent from Alum (Aluminum Sulfate) Company, this result was found in good agreement with Raghuwansh and Pandey, 2013 for evaluating the pollution status of Parashari River. They pointed out that the highest values of COD are due to industrial pollution. CO_3^{-2} and HCO_3^{-1} concentrations were varied between complete depletion −22.2 and 105.91–162.37 mg/l, with a highly spatial significant difference ($p < 0.01$). Chloride and Sulfate have the same distribution pattern along Ismailia Canal, they were in the range of 14.25–33.16 and 8.71–98.8 mg/l, respectively. There are highly temporal significant differences ($p < 0.01$)

Table 5 WQI and its categorization of Ismailia Canal water for drinking, irrigation and aquatic life utilizations.

Station	Drinking water		Irrigation		Aquatic life	
1	43.68	Good	12.61	Excellent	48.25	Good
2	60.43	Poor	17.70	Excellent	45.97	Good
3	47.67	Good	15.23	Excellent	41.83	Good
4	44.23	Good	14.02	Excellent	42.68	Good
5	65.48	Poor	18.14	Excellent	48.02	Good
6	47.47	Good	13.07	Excellent	56.19	Poor
7	61.63	Poor	14.15	Excellent	52.65	Poor
8	49.67	Good	13.92	Excellent	51.25	Poor
9	44.47	Good	13.22	Excellent	47.90	Good
10	50.70	Poor	13.64	Excellent	57.42	Poor
11	45.82	Good	13.53	Excellent	48.84	Good

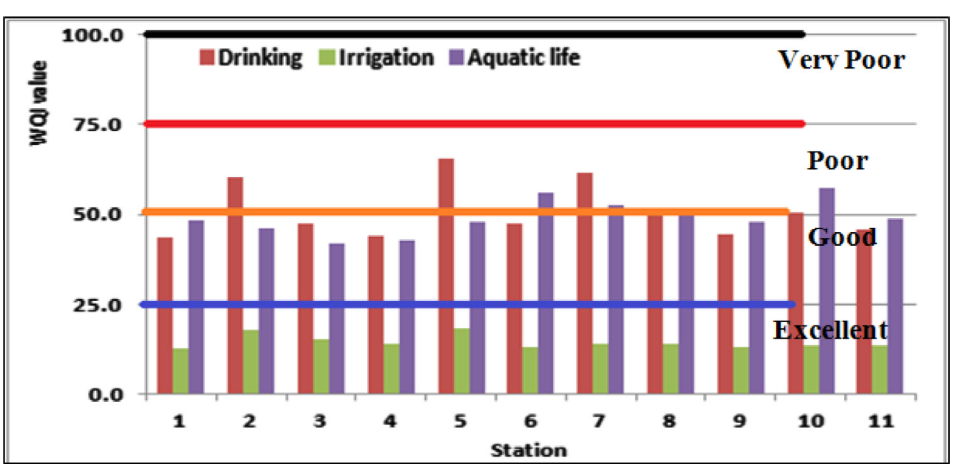

Figure 2 WQI of Ismailia Canal water for drinking, irrigation and aquatic life utilizations (Blue line at wqi 25 (Excellent), Orange line at wqi 50 (good), Red line at wqi 75 (poor) and Black line at wqi 100 (very poor)).

Table 6 Pollution index of the measured metals in Ismailia Canal water according to guideline levels of drinking, irrigation and aquatic life water.

Station	Drinking	Effect	Irrigation	Effect	Aquatic Life	Effect	Station	Drinking	Effect	Irrigation	Effect	Aquatic Life	Effect
Al^{+3}							Fe^{+2}						
1	4.37	Strongly	0.17	No	8.73	Seriously	1	0.17	No	0.09	No	1.44	Slightly
2	77.46	Seriously	3.10	Strongly	154.92	Seriously	2	3.10	Strongly	0.32	No	5.32	Seriously
3	3.89	Strongly	0.16	No	7.78	Seriously	3	0.16	No	0.11	No	1.84	Slightly
4	2.72	Moderately	0.11	No	5.45	Seriously	4	0.11	No	0.11	No	1.77	Slightly
5	10.53	Seriously	0.42	No	21.05	Seriously	5	0.42	No	0.28	No	4.74	Seriously
6	5.34	Seriously	0.21	No	10.68	Seriously	6	0.21	No	0.11	No	1.77	Slightly
7	160.66	Seriously	6.43	Seriously	321.31	Seriously	7	6.43	No	0.26	No	4.28	Strongly
8	8.72	Seriously	0.35	No	17.44	Seriously	8	0.35	No	0.19	No	3.17	Strongly
9	3.90	Strongly	0.16	No	7.80	Seriously	9	0.16	No	0.12	No	1.96	Slightly
10	5.62	Seriously	0.22	No	11.25	Seriously	10	0.22	No	0.16	No	2.71	Moderately
11	6.94	Seriously	0.28	No	13.87	Seriously	11	0.28	No	0.08	No	1.32	Slightly
Mn^{+2}							Zn^{+2}						
1	0.47	No	0.24	No	0.94	No	1	0.00	No	0.01	No	0.27	No
2	3.43	Strongly	1.71	Slightly	6.86	Seriously	2	0.01	No	0.02	No	0.67	No
3	2.08	Moderately	1.04	Slightly	4.16	Strongly	3	0.01	No	0.01	No	0.31	No
4	0.64	No	0.32	No	1.27	Slightly	4	0.00	No	0.00	No	0.16	No
5	2.33	Moderately	1.16	Slightly	4.65	Seriously	5	0.03	No	0.05	No	1.81	Slightly
6	0.80	No	0.40	No	1.61	Slightly	6	0.00	No	0.01	No	0.26	No
7	2.43	Moderately	1.22	Slightly	4.87	Strongly	7	0.01	No	0.01	No	0.50	No
8	2.28	Moderately	1.14	Slightly	4.56	Strongly	8	0.01	No	0.01	No	0.42	No
9	1.16	Slightly	0.58	No	2.31	Moderately	9	0.00	No	0.00	No	0.17	No
10	1.86	Slightly	0.93	No	3.73	Strongly	10	0.00	No	0.01	No	0.23	No
11	0.64	No	0.32	No	1.28	Slightly	11	0.00	No	0.00	No	0.18	No
Cu^{+2}							Ni^{+2}						
1	0.00	No	0.04	No	2.00	Moderately	1	0.04	No	0.04	No	0.36	No
2	0.01	No	0.06	No	3.03	Strongly	2	0.09	No	0.09	No	0.72	No
3	0.01	No	0.08	No	3.92	Strongly	3	0.06	No	0.06	No	0.48	No
4	0.00	No	0.03	No	1.49	Slightly	4	0.05	No	0.05	No	0.38	No
5	0.01	No	0.06	No	2.84	Moderately	5	0.05	No	0.05	No	0.44	No
6	0.00	No	0.03	No	1.38	Slightly	6	0.05	No	0.05	No	0.43	No
7	0.00	No	0.04	No	2.20	Moderately	7	0.07	No	0.07	No	0.54	No
8	0.00	No	0.03	No	1.57	Slightly	8	0.06	No	0.06	No	0.51	No
9	0.00	No	0.03	No	1.50	Slightly	9	0.07	No	0.07	No	0.56	No
10	0.00	No	0.03	No	1.48	Slightly	10	0.05	No	0.05	No	0.43	No
11	0.01	No	0.07	No	3.47	Strongly	11	0.04	No	0.04	No	0.33	No
Pb^{+2}							Cd^{+2}						
1	2.30	Moderately	0.00	No	3.28	Strongly	1	0.05	No	0.04	No	0.42	No
2	1.76	Slightly	0.00	No	2.52	Moderately	2	0.13	No	0.11	No	1.11	Slightly
3	1.79	Slightly	0.00	No	2.56	Moderately	3	0.10	No	0.08	No	0.83	No
4	2.56	Moderately	0.01	No	3.66	Strongly	4	0.13	No	0.11	No	1.11	Slightly
5	1.96	Slightly	0.00	No	2.80	Moderately	5	0.25	No	0.21	No	2.08	No
6	1.81	Slightly	0.00	No	2.58	Moderately	6	0.20	No	0.17	No	1.66	Slightly
7	1.89	Slightly	0.00	No	2.71	Moderately	7	0.15	No	0.12	No	1.25	Slightly
8	2.14	Moderately	0.00	No	3.06	Strongly	8	0.23	No	0.14	No	1.39	Slightly
9	1.86	Slightly	0.00	No	2.66	Moderately	9	0.26	No	0.11	No	1.11	Slightly
10	1.89	Slightly	0.00	No	2.70	Moderately	10	0.10	No	0.06	No	0.55	No
11	2.10	Moderately	0.00	No	2.99	Moderately	11	0.07	No	0.06	No	0.55	No

for chloride and sulfate distribution, with a remarkable increase during the drought period; this result is in agreement with the result obtained by Abdo et al. (2010). Chloride and sulfate are positively correlated with Ca^{+2} and Mg^{+2}. Calcium and Magnesium values ranged between 24.17–38.82 and 9.78–17.62 mg/l, respectively with highly seasonal variations ($p < 0.01$). The lowest concentrations of calcium and magnesium during the hot seasons may be due to the adsorption onto clay minerals and deposition to the bottom by temperature elevation as cited by El Bourie (2008) as well as the effect of the flood period. Sodium and potassium show a highly significant variation between sites and seasons ($p < 0.01$), with seasonal variations 15.14–39.7 and 5.77–8.89 mg/l, respectively.

Sodium adsorption ratio (SAR) is the measure of the suitability of water for use in agricultural irrigation. It quantifies the relative proportion of sodium to calcium and magnesium ions. In general, the higher the sodium adsorption ratio, the less suitable the water is for irrigation. Irrigation using water with high sodium adsorption ratio may require soil amendments to prevent long-term damage to the soil (Myers, 1991). SAR values reported during this study ranged from 0.57 to 1.44.

The basic nutrient salts show highly temporal significant differences ($p < 0.01$). They fluctuated between 2.31–26.66, 31.07–583.85, 88.12–569.44, 7.62–399.18, 38.26–480.81 μg/l and 0.37–8.76 mg/l for nitrite, nitrate, ammonia, orthophosphate, total phosphorus and silicate, respectively. Generally, station 5 recorded the maximum content of the nutrient salts due to the discharge effluents of Abu Zaabal Fertilizers Company.

The concentrations of the heavy metals were in the ranges of (55–45436.3), (0.0–2.94), (2–21.24), (109.2–2239), (20–483.4), (0.0–24.65), (10.55–34.01) and (1.4–127.9) μg/l for Al^{+3}, Cd^{+2}. Cu^{+2}, Fe^{+2}, Mn^{+2}, Ni^{+2}, Pb^{+2} and Zn^{+2}, respectively. The heavy metal concentrations increased at stations (2), (5) and (7) due to different effluents of drains. Iron, Manganese, Copper, Lead, Nickel and Cadmium showed a highly temporal significant difference ($p < 0.01$) with increas-

Table 7 Metal index in Ismailia Canal water for drinking, irrigation and aquatic life water utilizations.

Station	Drinking		Irrigation		Aquatic life	
1	7.59	threshold of warning	0.52		14.77	threshold of warning
2	39.02	threshold of warning	2.63	threshold of warning	76.25	threshold of warning
3	8.05	threshold of warning	0.94		17.02	threshold of warning
4	7.56	threshold of warning	0.61		13.80	threshold of warning
5	15.28	threshold of warning	1.36	threshold of warning	30.28	threshold of warning
6	7.86	threshold of warning	0.66		14.29	threshold of warning
7	83.49	threshold of warning	4.47	threshold of warning	165.37	threshold of warning
8	12.85	threshold of warning	1.47	threshold of warning	23.63	threshold of warning
9	8.71	threshold of warning	0.77		16.05	threshold of warning
10	9.46	threshold of warning	0.99		17.07	threshold of warning
11	8.80	threshold of warning	0.58		18.39	threshold of warning

ing during summer season that agrees with the results obtained by Bahnasawy et al. (2011), Nwabueze and Oghenevwairhe (2012) and Ibrahim and Omar (2013). According to Ibrahim and Omar (2013), the amount fluctuations of agricultural drainage water, sewage effluents and industrial wastes discharged into the canal, are the main reasons for the temporal difference of heavy metal content. On the other side, the increase of metal concentrations in the water during hot seasons (spring, summer) may be attributed to the liberation of heavy metals from the sediment to the overlying water under the effect of both high temperature and organic matter decomposition due to the fermentation process (Ali and Abdel-Satar, 2005).

Water quality index

Table 5 and Fig. 2 illustrate the values of the WQI of Ismailia Canal water. The WQI score for Drinking water was computed using guidelines of (Egyptian drinking water quality standards, 2007). Guidelines of (FAO, 1994) were used to compute the WQI value for irrigation water. Protection of aquatic life was computed using guidelines of (CCME, 2007). 14, 12 and 8 variables were used for the calculation of WQI according to Dinking, irrigation and aquatic life criteria, respectively. The selected parameters for drinking water include, TDS, pH, DO, BOD, COD, NH_3-N, NO_3^--N, TP, Cl^-, SO_4^{-2}, Na^+, Ca^{+2}, Mg^{+2} and total hardiness. While, TDS, pH, NH_3-N, NO_3^--N, PO_4^{-3}, HCO_3^-, Cl^-, SO_4^{-2}, Na^+, K^+, Ca^{+2} and Mg^{+2} were selected for irrigation. The selected variables for Aquatic life include TDS, pH, DO, COD, BOD, NH_3-N, NO_3-N and Cl^-.

The results show that WQI concentrations of Ismailia Canal range between 43.68–65.48, 12.61–18.14 and 42.83–57.42 with respect to drinking water, irrigation water and aquatic life protection according to the Egyptian drinking water quality standards, irrigation guidelines and protection of aquatic life guidelines respectively (Table 5). Our study indicates that the water quality fluctuation of Ismailia Canal could be classified from good to poor water for drinking and aquatic life and it is excellent for irrigation utilizations (Fig. 2).

Metal pollution Index

Eight metals (Al^{+3}, Cd^{+2}. Cu^{+2}, Fe^{+2}, Mn^{+2}, Ni^{+2}, Pb^+2, Zn^{+2}) are selected to assess the metal pollution of Ismailia Canal water, according to the pollution index (Table 6) which is based on individual metal calculations. The measured metals show a different degree of pollution in Ismailia Canal water for different utilizations. For irrigation utilization Mn^{+2} and Al^{+3} only exhibit a different degree of pollution at various locations, but Ismailia Canal suffers from obviously different contamination grades with the measured metals for drinking and aquatic life uses. Zn^{+2} shows only slight effect on aquatic life at station 5. Al^{+3} on the other hand, exhibits serious effect according to drinking and aquatic life criteria. Cd^{+2} shows slight pollution effect at some stations on aquatic life only. Cu^{+2} and Fe^{+2} exhibit different degrees of pollution for aquatic live uses. Pb^{+2} shows slight to strong pollution effects at all stations for drinking and aquatic life utilization, Mn^{+2} may causes slight to serious pollution at the most studied sites along the canal.

Metal index

Another index is used to estimate the metal pollution of Ismailia Canal water for different utilizations. Metal index denotes the trend evaluation of the present status by computing all measured metals (Table 7). According to metal index values, all selected stations along the canal are seriously threatened with metal pollution for drinking and aquatic usage (MI > 1), MI reaches to 83 and 165 at station 7 for drinking and aquatic utilization, respectively. Also, stations 2, 5, 7 and 8 suffer only from the same effect for irrigation usage.

Conclusion and recommendation

Ismailia Canal which is the main source of freshwater for several governorates, cities and villages is exposed to dramatic deterioration in its water quality due to different wastes that discharge into the water body. Although WQI results show that the water quality of the canal is excellent for irrigation usage and good to poor for drinking and aquatic life utilizations according to the selected parameters in the present study, but the canal is obviously polluted by metals for different utilizations along the canal especially at stations 2, 5, 7 and 8. Therefore the study recommends to tighten the control on the discharged waste into the canal, to compliance with the effluent concentration discharge standards set in Law 48/1982 for the protection of the Nile River and its waterways against pollution.

References

Abd El-Hady, H.H., Hussian, A.M., 2012. Regional and seasonal variation of phytoplankton assemblages and its biochemical analysis in Ismailia Canal, River Nile, Egypt. J. Appl. Sci. Res. 8 (7), 3433–3447.

Abdo, M.H., 1998. Some environmental studies on the River Nile, Ismailia Canal in front of the industrial area of Shoubra El-Kheima (M. Sc. Thesis). Fac. of Sci., Ain Shams Univ., Cairo, Egypt, p. 288.

Abdo, M.H., 2005. Physico-Chemical characteristics of Abu Za'baal ponds, Egypt. Egypt. J. Aquat. Res. 31 (2), 1–15.

Abdo, M.H., El-Nasharty, S.M., 2010. Physico-chemical evaluations and trace metals distribution in water-surficial sediment of Ismailia Canal, Egypt. J. Nat. Sci. 8 (5), 198–206.

Abdo, M.H., Sabae, S.Z., Haroon, B.M., Refaat, B.M., Mohammed, A.S., 2010. A physico-chemical characteristics, microbial assessment and antibiotic susceptibility of pathogenic bacteria of Ismailia Canal Water, River Nile, Egypt. J. Am. Sci. 6 (5), 234–250.

Abdo, M.H., Goher, M.E., Sayed, M.F., 2012. Environmental evaluation of Ismailia Canal water and sediment, Egypt. J. Egypt. Acad. Soc. Environ. Dev. 13 (2), 61–78.

Abou El-Naga, E.H., El-Moselhy, K.H.M., Hamed, M.A., 2005. Toxicity of cadmium and copper and their effect on some biochemical parameters of marine fish Mugil Seheli. Egypt. J. Aquat. Res. 31 (2), 60–71.

Ali, M., Abdel-Satar, A., 2005. Studies of some heavy metals in water, sediment, fish and fish diets in some fish farms in El-Fayoum province. Egypt J. Aquat. Res. 31 (2), 261–273.

Ali, M.H., Fishar, M.R., 2005. Accumulation of trace metals in some benthic invertebrate and fish species relevant to their concentration in water and sediment of lake Qarun, Egypt. Egypt. J. Aquat. Res. 31 (1), 289–301.

Al-Mohammed, F.M., Mutasher, A.A., 2013. Application of water quality index for evaluation of groundwater quality for drinking purpose in Dibdiba Aquifer, Kerbala City, Iraq. J. Babylon Univ./Eng. Sci. 21 (5), 1647–1660.

APHA, 1998. Standard methods for the examination of water and, waste water. In: Clesceri, L.S., Greenberg, A.E., Eaton, A.D. (Eds.). America Public Health Association, Washington, DC.

Ayers R.S., Westcot D.W., 1994. Food, Agriculture Organization of the United Nations (FAO), Water Quality for Agriculture, Irrigation and Drainage, Rome, Paper No. 29. Rev. 1, M-56. ISBN 92-5-102263-1.

Bahnasawy, M., Khidr, A., Dheina, N., 2011. Assessment of heavy metal concentrations in water, plankton and fish of Lake Manzala, Egypt. Turk. J. Zool. 35 (2), 271–280.

Bakan, G., Boke Ozkoc, H., Tulek, S., Cuce, H., 2010. Integrated environmental quality assessment of Kızılırmak River and its coastal environment. Turk. J. Fisheries Aquat. Sci. 10, 453–462.

Balan, I.N., Shivakumar, M., Kumar, P.D.M., 2012. An assessment of ground water quality using water quality index in Chennai Tamil Nadu, India. Chronicles Young Scient. 3 (2), 146–150.

Bharti, N., Katyal, D., 2011. Water quality indices used for surface water vulnerability assessment. Int. J. Environ. Sci. 2 (1), 154–173.

Brown, R.M., McCleiland, N.J., Deininger, R.A., O'Connor, M.F., 1972. A Water Quality Index – Crossing the Psychological Barrier. In: Jenkis, S.H. (Ed.), Proc. Int. Conf. on Water Poll. Res., Jerusalem, 6, 787–797.

Caerio, S., Costa, M.H., Ramos, T.B., Fernandes, F., Silveira, N., Coimbra, A., Mederios, G., Painho, M., 2005. Assessing heavy metal contamination in Sado Estuary sediment: an index analysis approach. Ecolog. Indicators 5, 151–169.

CCME (Canadian Council of Ministers of the Environment), 2007. For the protection of aquatic life 2007. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, 1999, Winnipeg.

Chowdhury, R.M., Muntasir, S.Y., Hossain, M.M., 2012. Water quality index of water bodies along Faridpur-Barisal road in Bangladesh. Glob. Eng. Tech. Rev. 2 (3), 1–8.

Egyptian drinking water quality standards, 2007. Ministry of Health, Population Decision number (458).

El Bourie, M.M.Y., 2008. Evaluation of organic pollutants in Rosetta branch water-River Nile (M.SC. Thesis). Fac., of Sci., Tanta Univ., Egypt.

El-Haddad, E.S.M., 2005. Some environmental studies on water and sediment of Ismailia Canal from El-Mazallat to Anshas Region (M. Sci. Thesis). Fac. of Sci., Al-Azhar Univ. Egypt, p. 218.

El-Sayed, S.A., 2008. Microbiological studies on Ismailia Canal, River Nile, Egypt (M. Sci. Thesis). Fac. of Sci. Al-Azhar Univ. Egypt, p. 198.

El-Sayed, S.M.M., 2011. Physicochemical studies on the impact of pollution up on the River Nile branches, Egypt (M.Sc. Thesis). Faculty of Science, Benha University, Egypt, p. 248.

Elshemy, M., Meon, G., 2011. Climate Change Impacts On Water Quality Indices of the Southern Part of Aswan High Dam Reservoir, Lake Nubia. Fifteenth International Water Technology Conference, IWTC-15 2011, Alexandria, Egypt, p. 17.

Geriesh, M.H., Stueben, D. Berner, Z., 2004. Deficiencies of Simple Technologies in Surface Water Purification: A Case Study of Surface Water Treatment for Drinking Purposes at Suez City, Egypt. In: The 7th International Conference of Geology of Arab World (GAW 7), Cairo, Egypt, 429–437.

Geriesh, M.H., Balke, K., El-Bayes, A., 2008. Problems of drinking water treatment along Ismailia Canal Province, Egypt. J. Zhejiang Univ. Sci. B. 9 (3), 232–242.

Guidelines for Drinking-water Quality, 2011, fourth ed. World Health (WHO) Organization.

Ibrahim, A.T.A., Omar, H.M., 2013. Seasonal variation of heavy metals accumulation in muscles of the African Catfish Clarias gariepinus, River Nile water and sediments at Assiut Governorate, Egypt. J. Biol. Earth Sci. 3 (2), 236–248.

Ibrahim, H.S., Ibrahim, M.A., Samhan, F.A., 2009. Distribution and bacterial bioavailability of selected metals in sediments of Ismailia Canal, Egypt. J. Hazard. Mater. 168, 1012–1016.

Khalifa, N., 2014. Population dynamics of Rotifera in Ismailia Canal, Egypt. J. Biodivers. Environ. Sci. (JBES) 4 (2), 58–67.

Khalil, M.K.H., Radwan, A.M., El-Moselhy, K.H.M., 2007. Distribution of phosphorus fractions and some of heavy metals in surface sediments of Burullus lagoon and adjacent Mediterranean Sea. Egypt. J. Aquat. Res. 33 (1), 277–289.

Myers, D.E., 1991. Interpolation and estimation with spatially located data. Chemom. Intell. Lab. Syst. 11, 209–228.

Nassif, M.G., 2012. Ecological studies on aquatic invertebrates of Ismailia Canal, Egypt (M Sc Thesis). Faculty of Science, Ain Shams University, Egypt.

Nwabueze, A., Oghenevwairhe, E., 2012. Heavy metal concentrations in the west African clam, Egeria radiata (Lammark, 1 804) from mciver market, warri, Nigeria. Int. J. Sci. Nat. 3 (2), 309–315.

Poonam, T., Tanushree, B., Sukalyan, C., 2013. Water quality indices-important tools for water quality assessment: a review. Int. J. Adv. Chem. (IJAC) 1 (1), 15–28.

Raghuwansh, J., Pandey, S.C., 2013. Water Quality Status of Parashari River in Ganj Basoda Town, Vidisha, (M.P.). J. Chem. Biol. Phys. Sci. 3 (1), 456–646.

Shakweer, L.M., Abbas, M.M., 2005. Effect of ecological and biological factors on the uptake and concentration of trace elements by aquatic organisms at Edku lake. Egypt. J. Aquat. Res. 31 (1), 271–288.

Stahl, R., Ramadan A.B., 2008. Environmental Studies on Water Quality of the Ismailia Canal, Egypt. Scientific Report, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft Wissenschaftliche Berichte FZKA 7427, p. 58.

Stahl, R., Ramadan, A.B., Pimpl, M., 2009. Bahr El-Baqar Drain System/Egypt Environmental Studies on Water Quality Part I: Bilbeis Drain/Bahr El-Baqar Drain. Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft Wissenschaftliche Berichte FZKA 7505, p. 72.

Tamasi, G., Cini, R., 2004. Heavy metals in drinking waters from Mount Amiata. Possible risks from arsenic for public health in the province of Siena. Sci. Total Environ. 327, 41–51.

Tarek, S.J., Ali, A.O., 2007. The effect of industrial waste of oil companies on the distribution of organic pollution in Ismailia Canal water. Bull. Natl. Res. Center, Egypt 32 (6), 647–659.

Tripaty, J.K., Sahu, K.C., 2005. Seasonal hydrochemistry of groundwater in the Barrier Spit system of the Chilika Lagoon, India. J. Environ. Hydrol. 13, 1–9.

Tyagi1, S., Sharma, B., Singh, P., Dobhal, R., 2013. Water Quality Assessment in Terms of water quality index. Am. J. Water Res. 1 (3), 34–38.

Youssef, M., El-Taweel, G.E., El-Naggar, M., El-Hawary, S.E., El-Meleigy, M.A., Ahmed, S.A., 2010. Hydrocarbon degrading bacteria as indicator of petroleum pollution in Ismailia Canal, Egypt. World Appl. Sci. J. 8 (10), 1226–1233.