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Application of Nile Chemical Pollution Index to evaluate the quality of water for drinking and agricultural purposes on Bahr Yusuf Branch, River Nile, Egypt

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ABSTRACT

Bahr Yusuf is one of the most important branches of the River Nile in Egypt, being the main source of drinking and irrigation waters for many cities. Nile Chemical Pollution Index (NCPI) was estimated to assess the quality of such waters. Water samples were collected from 6 locations along the canal in El-Minia and El-Fayoum Governorates. Seven chemical parameters were determined including dissolved oxygen (DO), biological oxygen demand (BOD), ammonia (NH_3), total dissolved solids (TDS), total suspended solids (TSS), nitrate (NO_3^-) and ortho-phosphorus (PO_4^{-3}). Results indicated that all the tested parameters were within the permissible limits of both the Egyptian and WHO standards for drinking water and FAO standards for irrigation water. The NCPI records ranged from 13-19 indicating clean (less than 15) to slightly polluted (16-20) waters. Classification of water based on electrical conductivity illustrates that the canal water belongs to medium salinity class (C2). The total hardness concentrations were belonging to medium hard to hard category except one very hard category. The SAR estimates were excellent (S1), PI were class II category, RSC were safe/good to marginal/doubtful and Na% were good (20 – 40) to permissible (40 - 60), PS were classified as "excellent to good" (<5 meq/l) to "good to injurious" category (5-10 meq/l). In addition, the balance error % were less than the allowed error, KR were < 1.0. So, all the samples are acceptable, indicating their suitability for drinking and irrigation purposes.

INTRODUCTION

Egypt is an arid country which depends almost entirely on the River Nile for its water supply. It is estimated that the Nile River provides about 97% of the country's fresh renewable water supply, agriculture is almost totally dependent on this source. It is estimated that 85 percent of the water released from the High Dam at Aswan is using for irrigation and the remaining 15 percent for other purposes, i.e., industry, domestic water supply, navigation, hydropower, fisheries, recreation and tourism (Nile Basin Initiative, 2005).

Water pollution is one of the most dangerous hazards affecting Egypt. Pollution in the Nile River System (main stream Nile, drains and canals) has increased in the past few decades as a result of increasing the population, several new irrigated agriculture projects, industrial development and other activities along the Nile. Pollution sources encompass: 1) industrial wastewater pollution; 2) domestic wastewater pollution; 3) agricultural pollution; and 4) Pollution originating from dumping of solid waste (Nile Basin Initiative, 2005). Water quality characteristics of aquatic environment arise from a multitude of physical, chemical and biological interactions. A regular monitoring of water bodies with required number of parameters in relation to water quality prevents the outbreak of diseases and occurrence of hazards.

Water quality monitoring is an important exercise, helps in evaluating the nature and extent of pollution as well as effectiveness of pollution control measures. It also helps in determining the water quality trends and prioritizing pollution control effort (Sultana and Kala, 2012). The Egyptian government has built over 30,300 km of small and large canals in Egypt (El Gamal, 1999).

The aim of the present study was to monitor the water quality of Bahr Yusuf canal at El-Minia and El-Fayuom governorates, by using Nile Chemical Pollution Index (NCPI), in comparison with the international standard ECS, WHO and FAO guidelines in an attempt to test the suitability of the surface water from this canal for drinking and irrigation purposes.

MATERIALS AND METHODS

Water samples collection:

The samples were collected from six locations at Bahr Yusuf canal in El-Minia (earmarked as El-Minia 1 (M1), El-Minia 2 (M2), and El-Minia 3 (M3)) and El-Fayuom (assigned as El-Fayuom 1 (F1), El-Fayuom 2 (F2) and El-Fayuom 3 (F3)). Selected locations are exposed to direct and indirect industrial wastewater and agricultural drainage disposals (Fig. 1), and each sample was analyzed twice for the period of November (autumn 2016) and February (winter 2017) for El-Minia Governorate, while El-Fayuom samples were for November (autumn 2016), May during two consecutive years (spring 2017 and 2018).

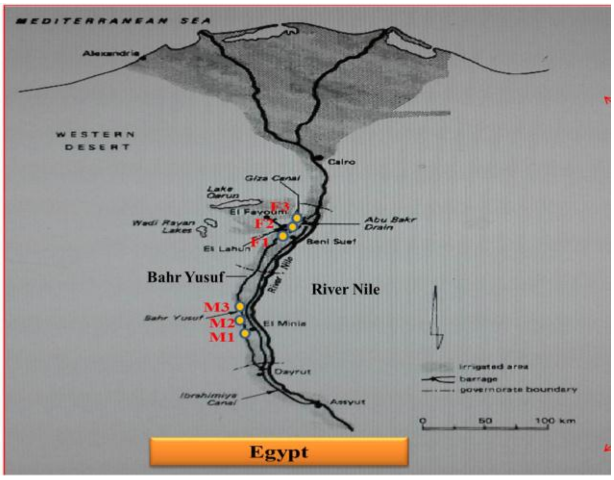

Fig. 1: A map showing sampling sites on Bahr Yusuf canal of the River Nile.

In situ measurements:

Water temperature, electrical conductivity and pH values were measured in situ, using Hydrolab, Model (Multi Set 430i WTW).

Laboratory analyses:

Water samples were collected at 60 cm depth from different sites (3samples/season); using polyvinyl chloride Van Dorn plastic bottles in ice box. The methods of analyses are those of the American Public Health Association **(APHA, 2005).** Total solids (TS) were measured by evaporating a known volume of well mixed sample at 105 ^{0}C. TDS was determined by filtrating a known volume of sample by GF/C and evaporation at 180 ^{0}C. TSS is obtained by subtraction of TS to 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 turbidmetric methods. Calcium and magnesium were determined by titration using EDTA solution, Na^+ and K^+ were measured using the flame photometer Model ''Jenway PFP, U.K.''. Concentrations of NO_2-N, NO_3-N, NH_4-N, SiO_4, SO_4^{-2} and PO_4-P were determined using colorimetric techniques, Copper-Hydrazine sulfate reduction, phenate molybdosilicate, turbidimetric and ascorbic acid molybdate methods, respectively. Total phosphorus (TP) was measured as orthophosphate (ascorbic acid molybdate methods).

Data analysis by using Nile Chemical Pollution Index (NCPI):

The NCPI score was calculated for each site. The NCPI determines the pollution level of the Nile water by given a distinct number (NCPI score) for each selected chemical parameter for each station. There are two score types, primary significance was given to DO, BOD and NH_3 each has a maximum score in the index of (10), where 10 was equated with gross pollution and 1 with clean water. NO_3^-, PO_4^{-3}, TDS and TSS gave secondary status in the index with a maximum of (5) indicating highly significant inputs and one equal to background levels in clean water.

Table 1a and b shows the value boundaries for each score for the seven chemical variables. The scoring categories have been selected on the basis of known levels in clean and grossly polluted sites from the literature (Stiff, 1980, Armitage *et al*., 1983, Chapman, 1992, Fishar and Williams 2008 and Fishar *et al.,* 2015).

Table 1: Pollution categories for the Nile Chemical Pollution Index
(a): Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO) and Ammonia (NH_3)

Description	Chem. Index	BOD mg/l	DO mg/l	NH_3 mg/l
Excellent	1	0 < 1	+7	0 < 0.25
Very Good	2	1 < 2	6 < 7	0.25 < 0.5
Good	3	2 < 4	5 < 6	0.5 < 1
Fair	5	4 < 6	3 < 5	1 < 2.5
Poor	7	6 < 10	1 < 3	2.5 < 5
Very Poor	9	10 < 15	0 < 1	5 < 10
Bad	10	+15	0	+10

(b): Nitrate (NO_3), Orthophosphate (O-PO_4), Total Dissolved Solids (TDS), Total Suspended Solids (TSS)

Description	Chem. Index	NO_3 mg/l	PO_4 mg/l	TDS mg/l	TSS mg/l
Excellent	1	0 < 0.1	0 < 0.1	0 < 200	0 < 30
Good	2	0.1 < 0.5	0.1 < 1.5	200 < 300	30 < 50
Fair	3	0.5 < 1.0	0.5 < 1.0	300 < 500	50 < 100
Poor	4	1.0 < 1.5	1.0 < 2.0	500 < 800	100 < 300
Bad	5	+1.5	+2.0	+800	+300

The NCPI scoring system (Table (2)) means that a grossly polluted station could theoretically have a score of 50 while a pristine (very clean) stations a score of

7. Sites scoring over 36 - 50 are designated as grossly polluted, 26 - 35 heavily polluted, 21 – 25 moderately polluted, 16 – 20 slightly polluted, less than15 clean.

Table 2: The NCPI scoring system.

Class	Scoring system	NCPI value
1	Grossly polluted	36 – 50
2	Heavily polluted	26 – 35
3	Moderately polluted	21 – 25
4	Slightly polluted	16 – 20
5	Clean	Less than 15
6	A pristine (very clean)	7

RESULTS AND DISCUSSION

The minimum, maximum, mean and standard division (SD) analytical results for each parameter for each period of analyses for both El-Minia and El-Fayuom governorates are summarized in Table (3). The annual average value and ranges of water parameters compared to different guidelines used are summarized in Table (4).

Table 3: Chemical profile of Bahr Yusuf canal water at El-Minia and El-Fayuom governorate

Parameters	El-Minia				El-Fayuom			
	Min	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
Water temp. ^{0}C	19.10	22.60	20.79	1.77	21.10	29.60	25.89	3.52
TS (mg/l)	230	735	382	271.16	230	367	299.83	71.11
TDS (mg/l)	188.00	351.00	272.08	84.90	325.00	443.00	390.67	46.79
TSS (mg/l)	11.50	52.00	27.75	15.34	24.00	64.00	46.00	13.55
EC (µS/cm)	371.00	440.00	405.17	25.42	609.00	692.00	644.67	25.15
pH	7.43	8.37	7.92	0.37	6.83	7.75	7.40	0.36
CO_3^{--} (mg/l)	0.00	5.00	1.25	2.09	0.00	9.50	4.11	3.66
HCO_3^- (mg/l)	195.00	240.00	214.58	19.39	160.00	180.00	170.00	6.12
T-Alkalinity (mg/l)	200.00	240.00	215.83	18.00	160.00	187.50	174.94	9.70
DO (mg/l)	7.95	9.42	8.57	0.61	7.60	8.40	8.03	0.29
BOD (mg/l)	1.86	3.10	2.55	0.50	2.40	4.20	3.50	0.77
COD (mg/l)	5.60	9.80	7.38	1.65	2.80	6.30	4.73	1.32
NO_2^--N (mg/l)	0.01	0.06	0.03	0.03	0.01	0.05	0.03	0.02
NO_3^--N (mg/l)	0.03	0.17	0.09	0.06	0.03	0.06	0.05	0.01
NH_3-N (mg/l)	0.11	0.79	0.45	0.32	0.09	0.94	0.41	0.37
SO_4^{2-} (mg/l)	49.78	66.25	58.06	6.02	40.85	64.80	55.97	10.80
SiO_2^- (mg/l)	2.89	3.44	3.10	0.21	2.70	3.75	3.36	0.45
PO_4^{3-} (mg/l)	0.02	0.02	0.02	0.00	0.06	0.96	0.57	0.39
TP (mg/l)	0.14	0.17	0.16	0.01	0.15	1.28	0.77	0.47
Cl^- (mg/l)	135.00	190.00	164.83	17.90	100.00	150.00	124.78	16.58
Ca^{2+} (mg/l)	41.68	59.32	49.84	7.34	32.06	49.70	41.74	6.43
Mg^{2+} (mg/l)	35.99	56.62	47.12	8.10	31.79	44.65	38.08	3.74
T-Hardness (mg/l)	296.22	352.27	318.41	21.99	234.90	305.09	260.93	24.69
Na^+ (mg/l)	22.73	85.63	53.96	33.13	55.60	62.01	60.10	1.99
K^+ (mg/l)	11.95	16.94	14.10	1.68	5.14	8.19	7.27	1.04
SAR (meq/l)	1.53	2.11	1.81	0.29	1.39	1.76	1.62	0.11
RSC (meq/l)	0.00	1.66	0.84	0.68	0.06	1.19	0.61	0.41
Na ‰	33.36	44.06	38.93	4.26	27.55	39.72	34.05	3.92
Potential Salinity (PS)	4.50	6.01	5.25	0.49	3.47	4.66	4.10	0.37
Permeability index (PI)	48.17	57.97	53.05	4.09	47.97	58.36	54.86	3.60
% Balance error (BE %)	0.27	6.84	2.92	2.73	0.81	6.03	3.47	2.08
KR meq/l	0.42	0.61	0.51	0.09	0.40	0.57	0.51	0.06

Table 4: Range and mean of physicochemical parameters of the Bahr Yusuf canal compared to guidelines used.

Parameters	Range	Mean	Drinking water		Irrigation (FAO, 1994)
			Egyptian, (ECS, 2007)	(WHO, 2011)	
Water Temp. ^{0}C	19.10-29.60	23.44			
TS mg/l	230-475	368.25			
TDS mg/l	188-443	331.38	1000	1000	2000
TSS mg/l	11.5-64	36.88			
EC µS/cm	371-692	548.87	2000		3000
pH	6.83-8.37	7.61	6-9	6.5-8.5	8.5
DO mg/l	7.60-9.42	8.25	6		
BOD mg/l	1.86-4.20	3.12	3		
COD mg/l	2.80-9.80	5.79	10	10	
CO_3^{2-} mg/l	0.00-9.50	2.97			3
HCO_3^- mg/l	160-240	187.83			610
T-Alkalinity mg/l	160-240	191.30		250	
Cl^- mg/l	100-190	140.80	400	250	1063
Ca^{2+} mg/l	32.06-59.12	46.56	75	200	400
Mg^{2+} mg/l	31.79-56.62	41.70	200	150	250
T-Hardness mg/l	240.19-352.27	283.92	500	500	
Na^+ mg/l	22.73-85.63	65.64	200	200	919
SAR meq/l	1.39-2.11	1.70			0-15
K^+ mg/l	5.14-16.94	10.00			2
NO_2^--N mg/l	0.008-0.062	0.034	0.005	0.90	
NO_3^- -N mg/l	0.026-0.169	0.066	0.60	1.0	10
NH_4 -N mg/l	0.089-0.937	0.423	0.45	0.20	5
PO_4^{3-} mg/l	0.017-0.961	0.353	0.10	0.30	2
TP mg/l	0.140-1.280	0.523	1.5		
SO_4^{-2} mg/l	40.85-66.25	56.80			
SiO_2^- mg/l	2.70-3.75	3.26			

Water temperature (^{o}C) plays an important role on bacterial activity, decomposition of organic matter, and the solubility of dissolved oxygen. The range of water temperature was 19.10 - 29.60^o C and the general average was 23.44^o C, which indicates a good degree for irrigation purpose. Total solids TS are defined as the matter residues after the evaporation of well-mixed sample in drying oven at a defined temperature (105^o C). The range of TS was 230 - 475 mg/l and the general average was 368.2 mg/l. Total dissolved solids (TDS) mainly consists of inorganic salts such as carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, sodium, potassium, iron etc. and small amount of organic matter.

The range of TDS was 188 - 443 mg/l and the general average was 331.38 mg/l. TDS values of the Bahr Yusuf canal waters at El-Minia and El-Fayoum governorates were below the permissible limit of irrigation water of 2000 mg/l and 500 – 1000 mg/l for drinking water. The range of TSS was 16.5 - 64 mg/l and the general annual average was 36.88 mg/l. Peaks in TSS were observed in the canal waters. The highest levels of TSS are probably a result of high evaporation and increased use of water producing turbidity.

pH values were 6.83 - 8.37 and the general annual average is 7.61. Data indicated that, the canal water was slightly alkaline. The pH of water samples was within the range of both the permissible limits for drinking and irrigation water standard (6.5 – 8.5), reflecting its suitability for irrigation, aquatic life and for all types of water uses.

EC values were 371 - 692 µS/cm and the general annual average was 548.87 µS/cm. These results are within the permissible limits (2000 µS/cm) for drinking water and as well within the permissible limit of 3,000 µS/cm for irrigation. Classification of water based on EC (Table 5), illustrates that El-Minia and El-Fayoum canal water belongs to medium salinity class (C2).

Table 5: Classification of samples of Bahr Yusuf canal waters according to standards specified for different water quality parameters.

Parameters	Range	Class	El-Minia	El-Fayuom
TDS (mg/l)	< 1000	Non-saline	446.83	329.67
	1000-3000	Slightly Saline		
	3000-10000	Moderately saline		
	>10000	Very saline		
EC WHO, (2008)	< 250	C1 Excellent for irrigation		
	250-750	C2 Good for irrigation	405.17	618.00
	750-2000	C3 Permissible for irrigation		
	2000-3000	C4 Doubtful for irrigation		
	> 3000	Unsafe for irrigation		
TH (WHO, 2004)	<75	Soft		
	75-150	Moderate		
	150-300	Hard		240.38
	>300	Very hard	318.41	
Cl^- meq/l	Below 2.03	Generally safe for all plants		
	2.03 – 4.06	Sensitive plants show injury		3.51
	4.07-10.15	Moderately tolerant plants injury	4.64	
	Above 10.15	Can cause severe problems		
$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$	0-10	Excellent	1.81	1.62
	10-18	Good		
Richards, (1954)	18-26	Fair		
	above 26	Poor		
$\% Na = \frac{Na^+}{(Na^+ + K^+ + Ca^{+2} + Mg^{+2})} \times 100$	<20	Excellent		
	20-40	Good	38.93	34.05
	40-60	Permissible		
Wilcox, (1995)	60-80	Doubtful		
	>80	Unsafe		
RSC = (Alkalinity × 0.0333) – (Ca^{+2}_{meq} + Mg^{+2}_{meq})	< 1.25	Safe	0.84	0.61
	1.25-250	Marginally suitable		
	>2.50	Unsuitable		
$PS = Cl^- + \frac{1}{2} SO_4^{2-}$	200	Suitable	193.86	152.76
	>200	Unsuitable		
$PI = \frac{Na^+ + \sqrt{HCO_3}}{(Na^+ + Ca^{+2} + Mg^{+2})} \times 100$	< 80	Good	53.05	54.86
	80-100	Moderate		
	100-120	Poor		
$KR = \frac{Na^+}{Ca^{+2} + Mg^{+2}}$	<1.0	Suitable	0.51	0.51
Ramesh and Elango, (2012)	>1.0	Unsuitable		

DO regulate the distribution of aquatic flora and fauna. It is an important parameter which is essential to the metabolism of all aquatic organisms that possess aerobic respiration. DO concentrations was 7.60 - 9.42 mg/l and the general annual average was 8.25 mg/l. DO is the amount of oxygen dissolved in water, while the BOD is the amount of oxygen used by the biological organisms during biodegradation. The range of BOD was 1.86 - 4.20 mg/l and the general annual average was 3.12 mg/l. According to WHO drinking water standard, BOD should not exceed 6 mg/l (De, 2003). It is evident from the results that BOD values of El-Minia canal water are below the standard limit of 3 mg/l, the BOD was decreased with increasing of DO content, these results agreed with that reported by Islam *et al.*, (2012). COD concentrations were ranged from 2.80 to 9.80 mg/l and the general annual average was 5.79 mg/l. The concentrations of COD in El-Minia and El-Fayuom canal water were below the permissible limit of 10 mg/l (ECS, 2007; WHO, 2011).

Major ion chemistry (MIC):

The predominant cations trend in El-Minia and El-Fayoum canal water, were in the descending order of $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ with sodium being dominant cation. As well as, the predominant anions were in the descending order of $HCO_3^- > Cl^- > SO_4^{2-} > CO_3^{-2}$, with bicarbonate being the dominant anion (Fig. 2).

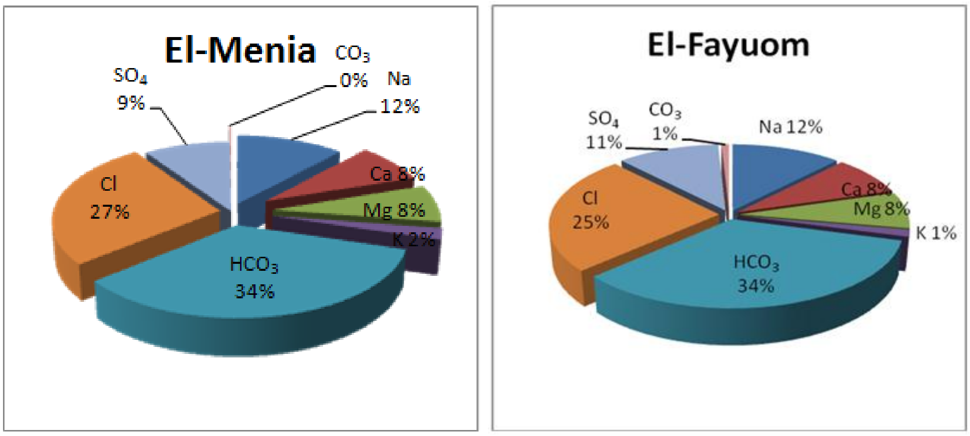

Fig. 2: Schoeller diagrams illustrating major ionic dominance in the surface canal water.

Cations load:

Na^+, K^+, Ca^{2+} and Mg^{2+} are considered as important elements that are utilized in the growth of phytoplankton, plants and other aquatic animals. The main source of cations in surface water of Bahr Yusuf comes from irrigation and ground water. The range of Na^+ and K^+ were 22.73-85.63 and 5.14-16.94 mg/l and the general annual average were 65.64 and 10.0 mg/l, respectively.

From the result of the investigation, the levels of Na^+ and K^+ concentrations peaked with a similar reduction in their levels afterwards. Na^+ concentrations of El-Minia and El-Fayuom canal water are within the permissible limits 200 mg/l for (ECS, 2007) and (WHO, 2011), while 919 for (FAO, 1994). K^+ concentrations in canal water were above the permissible limits of 2 mg/l according to (FAO, 1994), Table (4). The elevated levels of Na^+ and K^+ concentrations are probably due to carbonate precipitation and subsequent prevalence of Na^+ and K^+ ions. The lower reduction in the levels of K^+ relative to Na^+ is probably attributed to water discharges containing K^+ fertilizers from the adjacent agricultural lands. While the range of Ca^{+2} and Mg^{+2} were 32.06-59.12 and 31.79-56.62 mg/l and the general annual average were 46.56 and 41.70 mg/l, respectively. The results revealed that, the concentrations of both Ca^{+2} and Mg^{+2} hardness were well below the permissible limit of 75 and 400 mg/l for Ca^{+2}, 50 and 60 mg/l for Mg^{+2} according to drinking water and irrigation, respectively. The surface water is suitable for irrigation use, because the water is within good range of FAO irrigation water quality guidelines.

Total hardness (TH) of water is not a pollution indicator parameter but indicates water quality mainly in terms of $Ca^{2+}$and Mg^{2+}. The Total Hardness was determined by the following equation according to El-Aassy *et al.*, (2015).

$$TH = 2.497\ Ca^{2+} + 4.115\ Mg^{2+}$$

where Ca^{2+} and Mg^{2+} concentrations are expressed in mg/L.

The range of TH was 240.19 - 352.27 mg/l and the general annual average was 283.92 mg/l. Total hardness values in Bahr Yusuf canal water were below the permissible limit of 500 mg/l for drinking waters (ECS, 2007 and WHO, 2011). The degree of hardness of drinking water has been classified (WHO, 2004) in terms of its equivalent $CaCO_3$ concentration (Table 5) and accordingly, belong from medium hard to hard category except one very hard (Sawyer and McCarthy, 1967).

Anions load:

The levels of CO_3^{2-} and HCO_3^- concentrations peaked with a similar reduction in their levels afterwards. In canal water, the level of CO_3^{2-} and HCO_3^- were 0.00-9.50 and 160-240 mg/l and the general annual average were 2.97 and 187.83 mg/l, respectively. El-Minia canal water found the carbonate (CO_3^{2-}) levels well below the permissible limit of 3 mg/l for irrigation but above in El-Fayuom, while HCO_3^- levels well below the permissible limit of 610 mg/l for irrigation, and its values were within the permissible limit of 250 mg/l for drinking water according to WHO, (2011).

Chloride is one of the most important parameter in assessing the quality of water. The ranges of Cl^- were 100 - 190 mg/l and the general annual averages were 140.80 mg/l. The water canal were within the permissible limits 400 mg/l for (ECS, 2007), 250 mg/l (WHO, 2011) and 1063 mg/l for (FAO, 1994), Tables (3 and 4).

Nitrite is an intermediate product of the aerobic nitrification bacterial process, produced by the autotrophic Nitrosomonas bacteria combining oxygen and ammonia. The range of NO_2^--N was 0.008 - 0.062 mg/l and the general annual average was 0.034 mg/l. The canal water of NO_2^--N was above the permissible limits (0.005 mg/l) for Egyptian standard while were well below the permissible limits (0.9 mg/l) for drinking water according WHO, (2011). The peaks of NO_2^--N may be attributed to the oxidation of nitrite into nitrate due to the high contents of dissolved oxygen, which recorded the mean value of DO (8.27 mg/l). In general, the denitrification and deammonification are the processes, which added nitrite to the water but under control of dissolved oxygen content (EPA, 1976) has set 0.1 mg/l as a maximum admissible limit for nitrite in natural water, which revealed that the canal water did not reach the alarm case of nitrite toxicity.

Nitrate (NO_3^--N) can get into water directly as the result of runoff of fertilizers containing nitrate, and also be formed in water bodies through the oxidation of other, more reduced forms of nitrogen, including nitrite, ammonia, and organic nitrogen compounds such as amino acids (Kidd, 2011). The range of NO_3^--N was 0.026 - 0.169 mg/l and the general annual average was 0.066 mg/l. The canal water of NO_3^--N was below the permissible limits (10 and 11 mg/l) for drinking water and 10 mg/l for irrigation, Table (4). The peaks of NO_3^--N may be related to the denitrification of NO_3^--N into NO_2^--N and NH_3-N by denitrifying bacteria (Merck, 1980).

The range of NH_4-N was 0.089 - 0.937 mg/l and the general annual average was 0.423 mg/l. The canal water of NH_4-N was above the permissible limits (0.45 and 0.2 mg/l) for drinking water and below 5 mg/l for irrigation. Ammonia in excess of 1 mg/l is an indicator of organic pollution and can be toxic to aquatic species in concentration over 2.5 mg/l (Reid, 1961).

Sulphate ion is soluble, and therefore it's absorbed by plants, thus entering the cellular metabolism (Delince, 1992). The range of SO_4^{2-} and SiO_2^- were 40.85-66.25 and 2.70-3.75 mg/l and the general annual average were 56.80 and 3.26 mg/l, respectively. Both El-Minia and El-Fayuom canal water showed sulphate values below the permissible limit of 250 mg/l for drinking water (ECS, 2007and WHO, 2011) and 960 mg/l for irrigation (FAO, 1994). The concentrations of silicate in freshwater of temperate regions, in different parts of the world, are less than 10 mg/l (Lund, 1965). So, the obtained results for SiO_2^- at Bahr Yusuf canal water at El-Minia canal water and El-Fayuom are within the recommended range according to Lund, (1965).

The range of PO_4^{3-} was 0.017 - 0.961 mg/l and the general annual average was 0.353 mg/l. The canal water of PO_4^{-3} was below the permissible limits 2 mg/l for irrigation. The depletion of orthophosphate is related to its adsorption on hydrous FeO, Fe_2O_3, or Al_2O_3, and its consumption by algae, bacteria or other aquatic plant. There is no national or international limits for orthophosphate in drinking water, but (FAO, 1994), mentioned a 2 mg/l of orthophosphate as allowable level for irrigation water. The range of TP was 0.140 to 1.280 mg/l and the general annual average was 0.523 mg/l. The canal water of TP was below the permissible limits (1 mg/l) for Egyptian standard drinking water except one site was above, and there are not national or international limits for TP for irrigation water. Above TP of permissible limits (1 mg/l) may be attributed to the release of the phosphorus from sediments under favorable conditions by either desorption or resuspension processes, these results agree with that reported by Al-Afify, (2011).

Irrigation quality parameters (Irrigation suitability):

To evaluate the suitability of the water quality for agricultural purposes, the parameters such as residual sodium carbonate (RSC), percentage of sodium (%Na), permeability index (PI), potential salinity (PS), sodium adsorption ratio (SAR), % balance error and Kelly's ratio (KR) of the Bahr Yusuf canal waters were also calculated. Table (5) illustrated the summary classification of samples according to standards specified for different water quality parameters. Sodium adsorption ratio (SAR), if the SAR ratio of the water samples in the study area is less than 10, it is excellent for irrigation purposes and low values are always desirable (Raihan and Alam, 2008) because it influence infiltration rate of water. The SAR values varied from 1.39 to 2.11 meq/l with an average value of 1.70 meq/l and have been classified as suitable for irrigation. The results of SAR indicated that El-Minia and El-Fayoum canal waters are excellent (S1) for irrigation (Table 5). For sodium percentage (% Na), the canal water showed mean of % Na value varied from 27.55 to 44.06 meq/l with an average value of 36.00 meq/l, illustrating that these waters are good (20 – 40) to permissible (40 - 60) for irrigation.

Permeability index (PI), the PI values are varying from 47.97 to 58.36 meq/l with an average value of 54.14 meq/l (Table 4). On the basis of PI classification, majority of water samples of the study area belong to class II (PI ranges from 47.97 to 58.36 with average 54.14 %) and are of good irrigation quality. PI index, suggesting that the water of the study area is generally suitable for irrigation. Residual sodium carbonate (RSC), the RSC values are varying from 0.00 to 1.66 meq/l with an average value of 0.70 meq/l. The present study illustrating that, these waters is safe/good to Marginal/doubtful and is appropriate for irrigation purpose (Table 5).

Potential Salinity (PS), the Potential salinity values in the collected canal water are varied between 3.47 and 6.01 with an average value of 4.56 meq/l. El-Minia canal water showed higher PS values compared to El-Fayuom water. Ion Balancing, for groundwater and surface water, the % error should be less than 10. If it is greater, the analysis does not pass the validation check. This is less than the allowed error, so the sample results can be accepted. If error > 10 % then check results, and possibly re-analyse samples. The % balance error is varying from 0.27 to 6.84 with an average value of 3.25. The present study illustrating that, these waters is less than the allowed error, so the sample results can be accepted. Kelly's ratio (KR), the KR values are varying from 0.40 to 0.61 meq/l with an average value of 0.51 meq/l. The present study illustrating that, on the average, the values are below the permissible limit of 1.0 and are therefore considered suitable for irrigation purposes.

The development of a Nile Chemical Pollution Index (NCPI):

To produce the NCPI that reflects the chemical quality of the water, the data from some key chemical pollution parameters were selected. BOD, DO and NH_3-N are almost certainly directly linked to pollutant inputs. However, there may be some instances where the levels of the other parameter are affected by other factors. For example TSS may be raised by algal blooms, and TDS by the solution of mineral rich deposits from the catchment or from industrial chemical discharges. For BOD, NH_3 and NO_3^- there is likely to be a sequential change as the organic matter measured by BOD is gradually broken down by bacteria first to ammonia and then to nitrate. It has been observed that nitrate levels in the Nile are generally low due to the rapid uptake by algal production (Abdel-Hamid, 1991).

The scoring categories have been selected on the basis of known levels in clean and grossly polluted sites from the literature (Stiff, 1980, Armitage *et al.*, 1983, Chapman, 1992). This is supplemented with background information on clean sites on the Nile (Fishar & Williams, 2006; Fishar *et al.*, 2006; Fishar and Williams 2008 and Fishar *et al.*, 2015).

Table (6) shows the calculated NCPI values for each sampling site on the Bahr Yusuf canal water, using the score system presented in Table (2 a,b).

Table 6: The NCPI for each site on the Bahr Yusuf canal water

Seasons	Site	Site code	DO mg/l	BOD mg/l	NH_4 mg/l	NO_3 mg/l	Orth-PO_4 mg/l	TDS mg/l	TSS mg/l	NCPI
Autumn 2016	El-Menia 1	M1	8.86	1.86	0.786	0.141	0.024	347	18	14
	El-Menia 2	M2	9.02	2.06	0.707	0.104	0.019	351	16	15
	El-Menia 3	M3	9.42	2.48	0.710	0.169	0.021	350.5	11.5	14
Winter 2017	El-Menia 1	M1	8.16	2.88	0.207	0.026	0.021	188	52	13
	El-Menia 2	M2	8	3.1	0.107	0.051	0.017	200	35	10
	El-Menia 3	M3	7.95	2.92	0.154	0.041	0.019	196	34	10
Autumn 2016	El-Fayuom 1	F1	7.6	2.4	0.233	0.034	0.746	415	35	14
	El-Fayuom 2	F2	8.2	2.56	0.220	0.048	0.751	414	46	14
	El-Fayuom 3	F3	7.8	2.5	0.225	0.040	0.749	410	45	14
Spring 2017	El-Fayuom 1	F1	8.16	4.01	0.859	0.054	0.868	443	32	18
	El-Fayuom 2	F2	8.4	4.08	0.937	0.059	0.961	419	51	19
	El-Fayuom 3	F3	8.24	4.02	0.871	0.058	0.890	426	24	17
Sprin g 2018	El-Fayuom 1	F1	8.06	3.7	0.089	0.058	0.075	325	57	13
	El-Fayuom 2	F2	8.2	4	0.114	0.052	0.064	329	64	15
	El-Fayuom 3	F3	7.62	4.2	0.118	0.060	0.068	335	60	15
	Mean		8.25	3.12	0.42	0.07	0.35	343.23	38.70	14.33

The present study revealed that, the average score of NCPI was ranged 13 - 19 indicating clean (less than 15) to slightly polluted ranges (16 - 20). While the mean average of NCPI value of El-Minia canal water was recorded 15 but El-Fayuom was 14, this score revealed that, NCPI of both El-Minia and El-Fayuom canal water were clean (less than < 15).

CONCLUSION

Access to safe drinking water and irrigations are one of the basic human rights and is essential for healthy life. The abundance of the major ions of Bahr Yusuf canal water is in following order: $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ and $HCO_3^- > Cl^- > SO_4^{2-} > CO_3^{-2}$. The concentrations of the major water quality parameters are generally low and are within the recommended water quality standards for drinking and agricultural utilization. In addition to, the score of NCPI of both El-Minia and El-Fayuom canal water were clean (less than < 15).

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ARABIC SUMMARY

تطبيق مؤشر التلوث الكيميائي لتقييم جودة مياه الشرب والرى لمياه فرع بحر يوسف ، نهر النيل ، مصر

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يعتبر بحر يوسف أحد أهم فروع نهر النيل في مصر ، حيث يعتبر المصدر الرئيسي لمياه الشرب ، الزراعة ، الصناعة وتغذية المزارع السمكية المنتشرة داخل محافظة الفيوم وايضاً للعديد من المحافظات التى يمر خلالها بدءاً من محافظة المنيا بعد التفرع من ترعة الإبراهيمية وصولاً الى محافظة الفيوم. حيث يأتى أهمية هذا البحث كدراسة بيئية للوقوف على نوعية جودة مياه هذا الشريان الحيوى ودراسة التغيرات الطارئة عليه نتيجة للنشاط البشرى ، وذلك بإستخدم مؤشر (NCPI) لتقييم جودة مياه الفرع ومدى ملائمتها للشرب والرى. حيث تم تجميع عينات المياه من ٦ مناطق مختلفة على طول الفرع بمحافظتى المنيا والفيوم ، وتم تحديد سبعة خصائص كيميائية لدراسة هذا المؤشر وهم: الأكسجين المذاب ، والأكسجين المستهلك بيولوجيا ، والأمونيا ، والمواد الصلبة الذائبة والثابتة ، والنترات والفوسفات. حيث أظهرت النتائج ان قيم مؤشر (NCPI) تتراوح بين ١٣ - ١٩ ، وأن الخصائص الفيزيائية والكيميائية لمياه بحر يوسف كانت منخفضة فى محافظة المنيا بالمقارنة بمحافظة الفيوم وذلك نتيجة لكثرة المزارع السمكية وكثرة الأراضى الزراعية حولها ، على الرغم من ذلك كانت اغلب النتائج المتحصل عليها من الخصائص الفيزيائية والكيميائية ضمن الحدود المسموح بها طبقاً للمعايير المصرية ومنظمة الصحة العالمية وذلك عن مياه الشرب وطبقا لمعايير منظمة التغذية والزراعة عن مياه الري. لذلك فإن جميع نتائج مياه بحر يوسف مقبولة طبقا للمعايير العالمية المختلفة ، مما يشير إلى ملاءمتها لأغراض الشرب والري.