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Hydrochemistry and Quality Assessment of El Tebbin Surface Water, South Cairo, Egypt

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ABSTRACT

The water quality is greatly affected by the urbanization activity. Physical and chemical properties of surface water at El Tebbin area were quantified and evaluated for drinking, irrigation and industrial purposes. Twenty water samples collected from different streams were analyzed according to the standard methods. Different standard limits were used (WHO, EU and FAO) as well as numerical methods (WQI). The studied water at El Tebbin area was found to be unfit for drinking till simple and primary treatment. Canals water is suitable for major crops with minor degree of threat while Nile water is excellent for irrigation. All water samples require treatment for specific industries. Generally the studied samples showed no heavy metals pollution. The statistical analysis indicated the impact of pH and temperature (T) on chemical nature of water.

Key words: El Tebbin, WQI, water quality, drinking water, irrigation water

Introduction

The quality of water depends on various physicochemical parameters such as temperature, pH, total dissolved salts (TDS), TH, ALK, Ca, Mg, Na, K, Cl, SO_4, HCO_3 and NO_3 (Patil, *et al*., 2012). Changes in any of these parameters can significantly alter the composition of water (Appelo and Postma, 2005). High level of TDS may aesthetically be unsatisfactory for bathing and washing and high values of chloride impart a salty taste to water and accelerate corrosion of metals. The high total hardness would lead to heart disease and kidney stone formation, the excess amount of nitrate causes breath shortness and blue baby syndrome in infants (Sirajudeen *et al*, 2013). Estimating heavy metals contents is very important to get exact idea about the quality of water. Heavy metals accumulate in tissues and subsequently affect the nervous system, endocrine system, immune system and cause hematopoietic function, normal cellular metabolism (Singh, *et al*., 2011).

El Tebbin area is one of the highly industrialized areas in Egypt (Melegy, 2005). It extends between longitudes 31° 17' - 31° 21' E and latitudes 29° 45' – 29° 48' N (Fig. 1). Geologically it consists of Quaternary deposits and floodplain sediments of the River Nile, (Said, 1990). El Tebbin area can be divided into three regions, domestic region, industrial region and agricultural farms. The area includes a few small villages (Ezabs) connected to the old and deteriorated sewage network. Some of the scattered communities and houses are not connected to the public sewage network. They dispose domestic waste either in private septic tanks (latrines) or directly to the water canals. Besides industrial wastes, the study area might exhibit some inputs from agricultural activities (El-Sayed *et al* 2004; Taha *et al* 2004; Tawfik 2008). This study aims to provide a basis for an interpretation of the quality of water resources in El Tebbin area (River Nile, and three canals are El Tarkhaniya, El Khashab and El Hager canal).

Materials and Methods

Twenty water samples (Fig. 1) were collected by immersion of pre-acid washed polypropylene bottles below the water surface, Samples were collected from four water bodies in April 2014. Five samples were collected from River Nile, two samples were collected from El Tarkhaniya canal, seven samples were collected from El Khashab canal and six samples from El Hager canal. Position of sampling sites was recorded by the aid of a Global Positioning System (GPS) technology.

The pH, TDS, EC and T were determined in situ by using portable combined electrode (Hanna HI 991301). Hardness, alkalinity, some major cations and anions and heavy metals were determined using the standard methods for water and Waste Water Analysis (APHA, 1995). Total heavy metals were determined by digestion with Nitric acid and analyzed using Atomic Absorption Spectrophotometer (model buck scientific 200A). SPSS 16 software is used for statistical analysis of the results.

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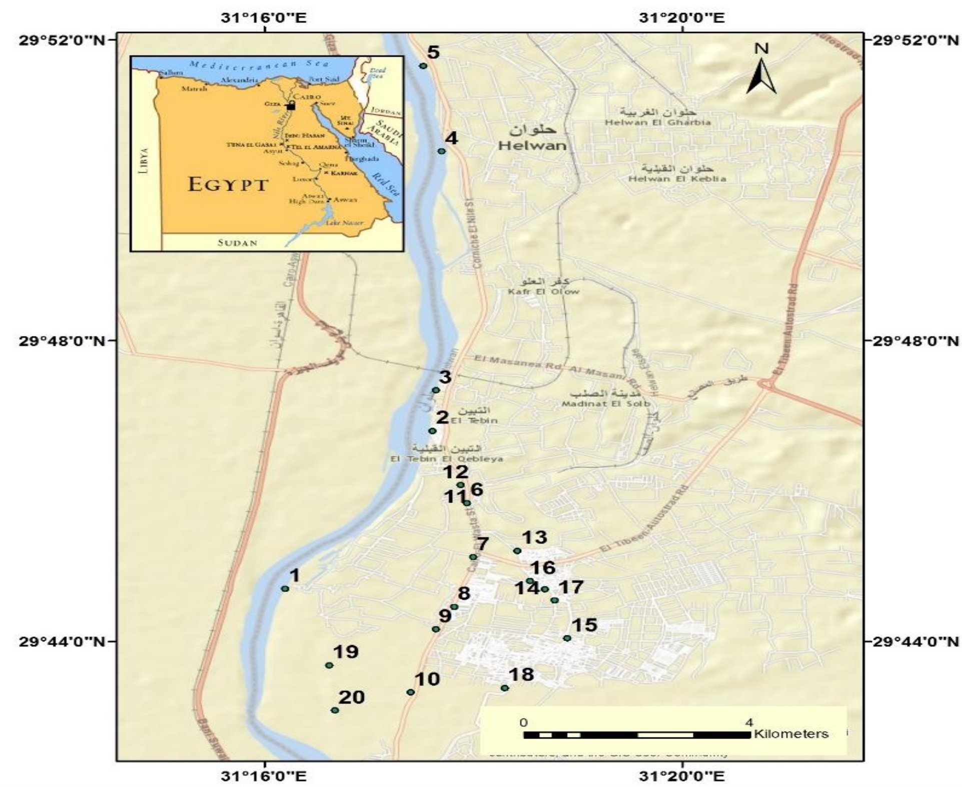

Fig.1: Location Map of the study area showing sampling sites.

Results and Discussion

Physicochemical parameters

Physiochemical parameters of surface water collected from different water bodies in El Tebbin area during April 2014 are summarized in table 1.

The recorded temperature values (Table 1) are within the limit recorded by EU (2004). However a temperature > 15°C facilitates the development of microorganisms and activates the geochemical reactions (Dwivedi and Pandey, 2002, SCCG, 2006 and Patil, *et al*., 2012) as indicated from the positive correlation between temperature and almost other chemical constituents of water (Table 2). The slightly higher temperatures of the canals water comparing with River Nile may be attributed to the composite composition of sewage effluents.

The pH values (Table 1) were found to be within the permissible limit 6.5-8.5 for drinking water (WHO, 2011) and irrigation water (FAO, 1994). Conductivity values varied from 251.6 to76655.2 μS/cm. The maximum limit of EC in drinking water is prescribed as 1500 μS/cm (WHO 2011). The abnormal EC value of sample No. 3 of El Hager Canal may be resulted from the abandoned of canal at this site and its neighbor houses and enclosed coke factory.

TDS value ranged from 211 ppm to 5220 ppm, averaging 2666.1 ppm, the most desirable limit of TDS is 500 ppm (WHO, 2011). River Nile, El Tarkhayia and most of El Khashab samples showed TDS values much lower than the permissible limits recommended by WHO, 2011 (1000 ppm). Most of El Hager samples are higher than 2000 ppm (MPL in irrigation water FAO, 1994). The increase in the amount of TDS is due to addition of sewage waste and laundry water detergents from the surrounding region, which led to release of organic substance in the water responsible for high TDS value (Murugesan *et al*., 2006). According to Todd (2007) classification based on TDS value, the river Nile, El Tarkhaniya and El Khashab samples are classified as fresh water except samples No. 2 and 12 at El Khashab canal which are classified as slightly fresh water subjected to human activity. El Hager samples are flocculated between slightly fresh water to brackish water. This result is fairly in agreement with that of Abdalla and Scheytt (2012), they reported that, the chemical characters of surface water of Helwan catchment range from fresh water to brackish water according to TDS values.

Table 1: Physiochemical Parameters of surface water of El Tebbin area.

Locality		T (°C)	pH	EC (µS/cm)	TDS (ppm)	T.H. (ppm)	Alk (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Cl (ppm)	HCO_3 (ppm)	CO_3 (ppm)	SO_4 (ppm)	NO_3 (ppm)
River Nile	Min	27.70	7.00	274.34	219.00	147.00	209.00	36.00	25.75	25.29	7.80	47.20	80.52	28.80	72.00	0.28
	Max	28.20	7.50	464.49	371.00	245.00	704.00	48.00	49.08	45.99	11.57	75.52	234.24	36.00	207.00	0.82
	Av	27.90	7.14	352.47	282.20	176.40	355.20	41.60	33.63	30.37	8.56	60.14	120.62	34.56	112.60	0.44
El Tarkhaniya	Min	27.00	7.00	375.36	243.00	98.00	583.00	46.80	9.59	335.00	10.00	400.00	392.20	ND	69.00	ND
	Max	29.40	7.50	385.77	328.00	196.00	704.00	58.50	36.25	335.00	16.00	405.00	437.60	ND	80.00	0.27
	Av	28.20	7.25	380.57	285.50	147.00	643.50	52.65	22.92	335.00	13.00	402.50	432.90	ND	74.50	ND
El Khashab	Min	27.60	7.00	251.63	211.00	245.00	275.00	46.80	47.21	25.30	7.00	50.00	175.00	ND	13.00	ND
	Max	28.60	7.00	2215.13	1826.00	588.00	528.00	136.50	109.71	355.00	37.00	620.00	355.20	36.00	278.00	0.70
	Av	28.07	7.00	837.46	755.37	380.97	402.87	80.86	72.77	133.40	15.35	256.25	268.52	4.50	163.75	0.36
El Hager	Min	26.50	7.00	1520.96	1195.00	568.40	495.00	136.50	76.52	355.00	28.00	600.00	333.00	ND	176.00	ND
	Max	31.20	8.00	76655.18	15220.00	1421.00	2200.00	253.50	283.70	2290.00	240.00	3425.00	1480.00	110.70	351.00	0.92
	Av	28.85	7.37	16062.93	5901.00	919.50	1155.00	228.46	167.79	786.60	78.66	1351.66	777.00	18.45	280.50	0.58
Standard Limits	WHO		6.50-8.50	1000		500		75	100	50	42289	250			250	50
	EU	13-35	6.50-9.50	300		150-500		200	30-50	200	42289	250				25-50
	FAO		6.50-8.50	2000												30

ND = Not detected

Table 2: Correlation coefficient of different physiochemical parameters of surface water samples in El Tebbin area.

	PH	T	TDS	EC	T.H.	Alk	Ca	Mg	Na	K	Cl	CO3	HCO3	SO4	NO3
PH	1														
T	0.13	1													
TDS	0.62	0.48	1												
EC	0.66	0.36	0.89	1											
T.H.	0.50	0.59	0.89	0.69	1										
Alk	0.64	0.53	00.87	0.82	0.87	1									
Ca	0.45	0.56	0.75	0.47	0.91	0.73	1								
Mg	0.49	0.58	0.90	0.73	0.99	0.88	0.85	1							
Na	0.71	0.47	0.94	0.95	0.81	0.91	0.67	0.82	1						
K	0.76	0.36	0.85	0.93	0.73	0.84	0.62	0.74	0.94	1					
Cl	0.69	0.52	0.96	0.92	0.88	0.92	0.76	0.88	0.99	0.93	1				
CO3	0.45	0.11	0.55	0.78	0.24	0.39	0.03	0.30	0.59	0.64	0.53	1			
HCO3	0.63	0.52	0.86	0.80	0.87	1	0.74	0.88	0.91	0.83	0.91	0.34	1		
SO4	0.41	0.18	0.66	0.45	0.79	0.58	0.75	0.78	0.57	0.53	0.63	0.03	0.60	1	
NO3	0.23	-0.34	0.07	0.02	-0.05	-0.16	0.04	-0.08	0.02	0.07	0.04	0.10	-0.17	0.11	1

The minimum hardness values were recorded from the River Nile and El Tarkhaniya canal whereas the maximum hardness values were recorded from El Hager and El Khashab canals (Table 1). The recorded high values of hardness in some investigated samples may be due to their high content of calcium, magnesium and sulfate. According to Body (2000), surface water in the study area is classified into three water types: 1- River Nile and El Tarkhaniya canal represent moderately hard to very hard waters class. 2- El Khashab canal represent hard to very hard waters class. 3- Very hard waters as in El Hager canal. Moderately hard surface water in the studied area is permissible for laundry usage and domestic purposes after primary treatment (Durfor and Becker, 1964).

Water alkalinity at the study area varies between 209-2200 ppm (Table 1) it is obviously higher than the value recorded by Pescode, 1992 (200 ppm). The excess alkalinity values in El Hager and El Khashab may result from high concentration of bicarbonate, addition of soap and detergent used by the local residential for bathing and washing purpose could be reasonable sources of alkalinity.

Major Cations

Calcium (Ca^{2+}) concentration in River Nile and El Tarkhaniya canal samples were found below the limit prescribed by WHO, 2011 (75 ppm), oppositely El Hager and the most of El Khashab canal exceed this permissible limit (Table 1). The higher concentrations of Ca^{2+} may be due to the addition of sewage waste and released dust of cement factory in the area.

Magnesium (Mg^{2+}) concentration is directly related to hardness. Magnesium concentrations in the River Nile, El Tarkhaniya canal and most of El Khashab were found below WHO, 2011 limit (100 ppm) and EU, 2004 limit. On the contrary, El Hager canal samples are considered the most polluted locality at El Tebbin area; it is characterized by (Mg^{2+}) content (283.7 ppm) above the permissible level. High concentration of Mg^{2+} is most probably resulted from household uses of water and fertilizers use effect.

The concentration of sodium (Na^{+}) in both River Nile and almost of El Khashab canal water samples is more or less similar to that recorded in natural rivers in comparison with WHO, 2011 (50 ppm) and EU, 2004

(200 ppm) . El Tarkhaniya canal and El Hager canal samples are characterized by (Na^+) content higher than the permissible level (Table 1). El Hager water shows the highest sodium concentrations in the study area. The addition of sewage waste, organic pollutants, fertilizers used in agriculture purposes and action of detergents is most probably responsible for the increased sodium level in El Tarkhaniya canal and El Hager, similar discussion was found by Umakant, 2011.

Potassium (K^+) concentrations (Table 1) show a noticeable variation along the study area, it was found that River Nile samples show K^+ content below WHO, 2011 limit and EU, 2004 limit (10-12 pm). K^+ content varied in both El Khashab and El Tarkhaniya canals from lower to higher than permissible limits. El Hager show K^+ content above WHO and EU limits. The observed over ranged values in some localities is most probably due to Pollution with sewage water, Potassium-rich irrigation water from the farmlands in the area, industrial waste areas and uses of detergents.

Major anions

For chloride (Cl^-), in comparison with WHO, 2011 (250 ppm) River Nile samples and some of El Khashab canal, are fluctuated within the standard limits. El Hager, El Tarkhaniya and the majority of El Khashab samples exceed the permissible limit. The high content of chloride is an indicator of organic pollution, reflecting the increase of input from agricultural activities, domestic and industrial waste water discharge into the three canals.

Bicarbonate (HCO_3^-) concentration in all water samples (Table 1) exceeds the value recommended by Langmuir, 1997 (58 ppm). High (HCO_3^-) content may be resulting from sewage and effect of cement factory (Langmuir, 1997).

River Nile and El Tarkhaniya water samples show sulfate (SO_4^{2-}) concentration below that recommended by WHO, 2011 (250 ppm). Whereas, almost all of El Hager and most of El Khashab samples exceed this limit. High sulfate concentration in El Hager and El Khashab canal reflects the effect of industrial wastes, excessive use of fertilizers and pesticides, domestic uses of detergents representing the main sources of sulfate.

Nitrate (NO_3^-) concentration in the studied samples were found to be less than the recorded values by WHO, 2011 (50 ppm), EU, 2004 (25-50 ppm) and FAO, 1994 (30 ppm). Reduction of nitrate due to low dissolved oxygen (DO) concentration (0.1 ppm) in the upper stream part of the canal may be a possible reason for the lowering values of the nitrate contents in the study area (Abdalla and Traugot Scheytt, 2012).

Water Classification and quality assessment

Hydrochemically, depending on Piper tri-linear diagram (1944) in Subramani *et al*., 2005 (Fig 2) the type of water that predominates in the study area is mixed (Ca-Mg-Cl) water type followed by (Na-Cl) type and (Ca-Cl) water type, and Co in this study comes in harmony with that reported by El-Makawy (2007) and Abd El Hady (2007). Generally El Tebbin surface water is within the national and international permissible limits for all studied metals.

The suitability of water for irrigation is evaluated based on SAR (Karanth, 1987 and Subramani *et al*., 2005), Electrical conductivity (Subramani *et al*., 2005), US salinity diagram (Richards, 1954) and WQI (Naik and Purohit, 2001). Sodium adsorption ratio (SAR) results (Table 3) showed that, except for few samples most of the water samples fall in class (S1) representing excellent waters for irrigation. EC results indicated the suitability of River Nile and El Tarkhaniya water for irrigation purposes, as good water class, the opposite is true for El Hager canal. El Khashab canal varied from good for irrigation to doubtful. Using Richard, 1954 (US Salinity diagram) surface water at El Tebbin area varied from good water for irrigation to intermediate water class (Fig 3).

Water quality index technique is used for water quality determination in El Tebbin area. Assembling different parameters into one single number leads to an easy interpretation of water quality. Table 4 summarizes WQI values for average physiochemical parameters for three mentioned purposes. However the water quality index values in the present investigation indicated that, the water is unfit for drinking until simple and primary treatment (House, 1986; House, 1989; Tyson and House, 1989). On the other hand, water canals are suitable for major crops with minor degree of threat while Nile water is excellent for irrigation (Bahargava, 1983; Nguyen and Bahargava, 1989 House, 1986 and House and 1989). All of the investigated water samples required treatment for specific industries (Bahargava, 1983; Nguyen and Bahargava, 1989 House, 1986; and House, 1989).

Heavy Metals

Surface water samples in the study area were examined for Fe, Co, Zn, Cd, Mn, Ni, Pb, Cu and Cr concentrations (Table 5). Almost all of the studied heavy metals show negligible concentrations, however cobalt in sample No. 2 in El Khashab canal is closed to permissible limit and sample No. 11 at El Hager canal recorded Fe concentration (0.365) slightly excess preferred limit, comparing with WHO, 2011 value of (0.3 ppm), that can be attributed to sampling location near to steel and coke industry. The pollution status of Cd, Pb, Ni, Mn, Fe.

Multivariate Statistical Analysis

Multivariate statistical techniques, such as principal component analysis (PCA), Factor analysis and cluster analysis (CA) are powerful tools for segregating of pollution sources (Li and Feng, 2012; Lu *et al*., 2012). In this study, two factors were extracted (Fig. 4).

-Factor 1 is highly positive loading with pH where Na, K, Mg, Ca, Cl, HCO_3 and SO_4 are the main pH contributors. Presence of sulfate indicates that alkali metals may be existed as sulfate salts dissociated into weak acid sulfates and strong base.

-Factor 2 is highly positive loading with Mn and T, Mn is easily reduced with temperature. Positive loading of Ca and Mg with temperature may attribute to effect of the later on metals solubility.

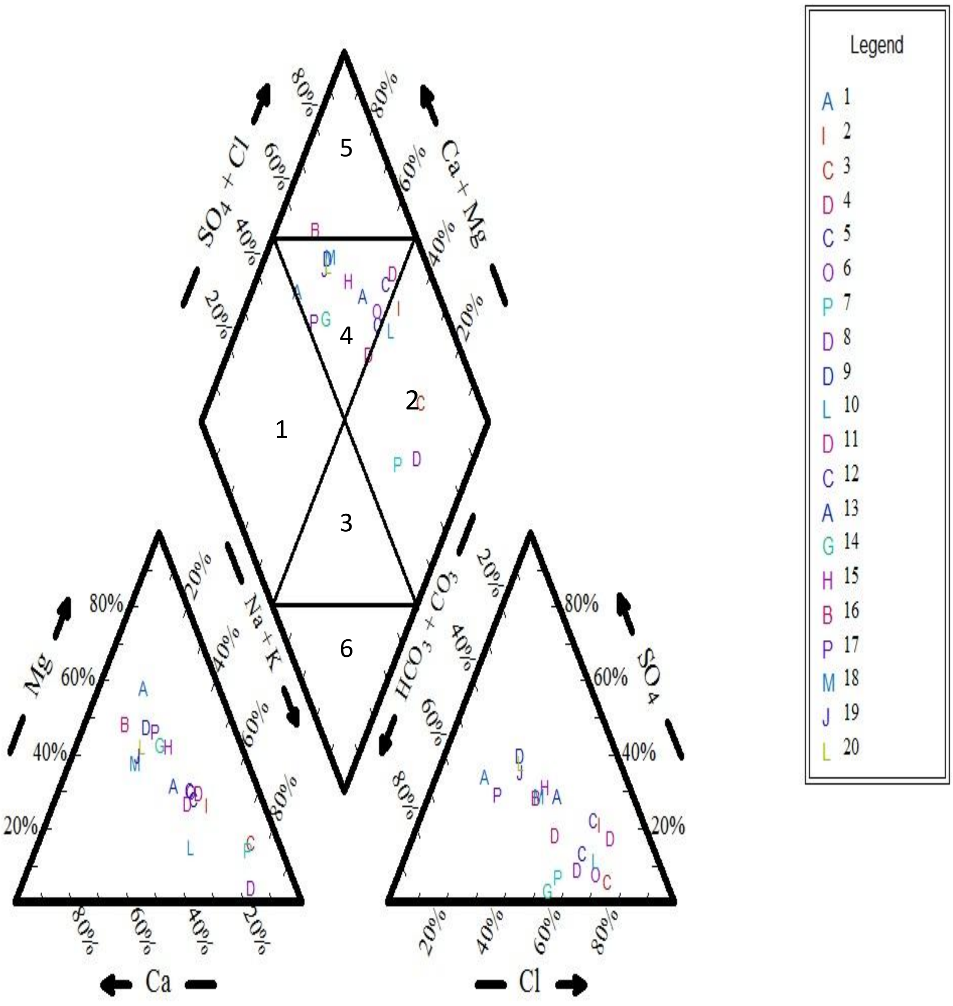

Fig. 2: Water Classification Using Piper Diagram according to (Subramani *et al*., 2005).

Table 3: Min., max. and mean SAR of water Sample at the study area.

Location	Min.	Max.	Mean	SAR (Subramani *et al*., 2005)	Water Class
River Nile	0.70	1.02	0.778	<10	Excellent
El Tarkhaniya Canal	9.47	11.33	10.4	10-18	Good
El Khashab Canal	0.52	6.07	2.76	18-26	Doubtful
El Hager Canal	5.32	23.47	10.42	>26	Unsuitable

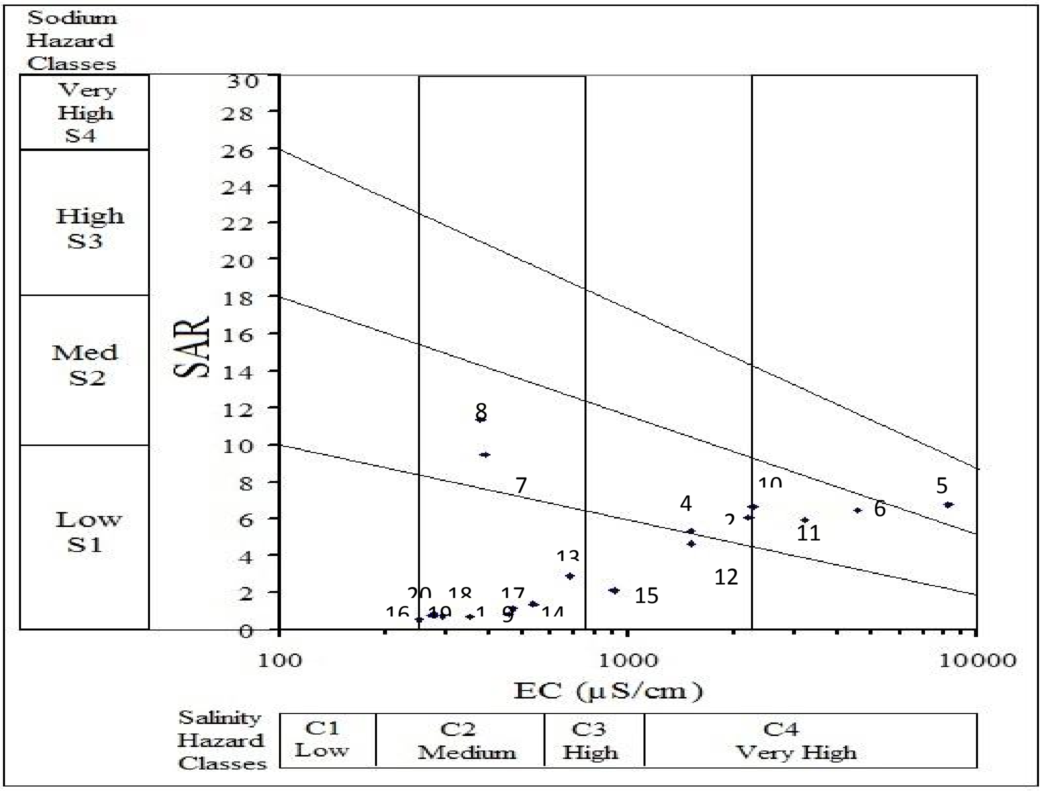

Fig. 3: Surface waters for irrigation at El Tebbin area, according to U.S diagram (Richards, 1954).

Table 4: Water quality index for surface water at the study area.

Location / WQI	WQI for drinking	WQI for irrigation	WQI for industry
River Nile	82.78	98.15	83.50
El Tarkhanyia	74.70	76.90	83.50
El Khashab	65.44	85.50	76.75
El Hager	65.40	74.60	69.50

Table 5: Heavy metals content of the surface water of El Tebbin area.

S/N	Fe (ppm)	Zn (ppm)	Co (ppm)	Mn (ppm)
1	0.06	0.01	BDL	BDL
2	0.24	0.02	0.05	0.03
3	0.18	0.03	0.05	0.20
4	0.07	0.02	0.02	0.03
5	0.07	0.02	0.03	0.03
6	0.13	0.02	0.03	0.40
7	0.22	0.01	BDL	0.10
8	0.04	0.01	BDL	BDL
9	0.04	0.01	BDL	BDL
10	0.10	0.02	0.02	0.09
11	0.37	0.02	0.03	0.17
12	0.12	0.01	0.02	0.11
13	0.04	0.01	0.01	BDL
14	0.16	0.01	0.01	0.14
15	0.05	BDL	0.01	BDL
16	0.03	0.02	BDL	BDL
17	0.05	BDL	BDL	BDL
18	0.02	BDL	BDL	BDL
19	0.05	BDL	BDL	BDL
20	0.08	BDL	BDL	BDL
Min	0.02	0.01	0.01	0.03
Max	0.37	0.03	0.05	0.40
Average	0.11	0.01	0.02	0.14
BDL = Below detection limit				
Elements Cd, Ni, Pb, Cu and Cr are BDL.				

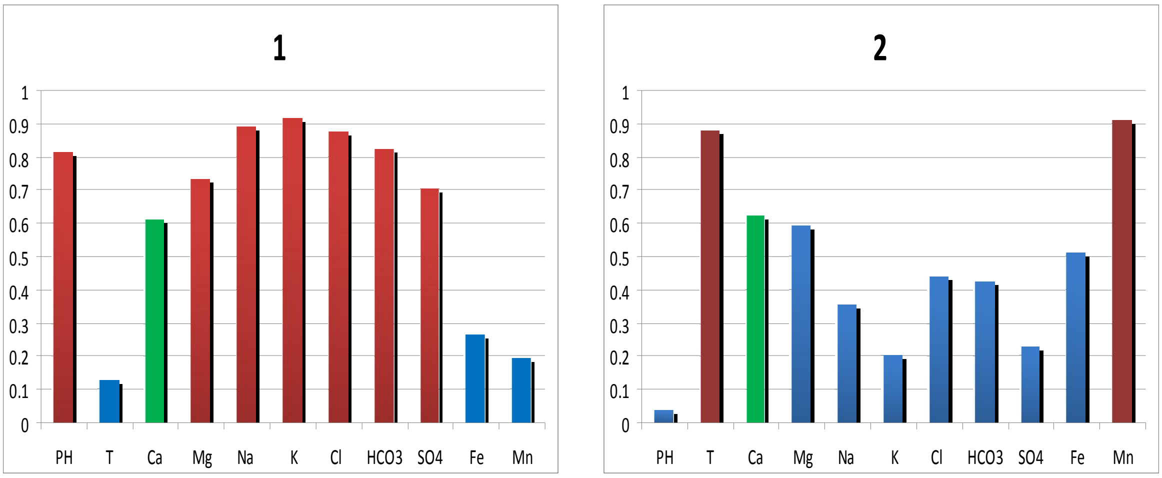

Fig. 4: Factor analyses of surface water in study area.

Summary and Conclusion

TDS values indicated that, surface water of El Tebbin area range from fresh water to brackish water; following the order, El Hager Canal > El Khashab Canal > El Tarkhaniya Canal > River Nile. Hydrochemically, mixed (Ca-Mg-Cl) water type is the most predominate one followed by (Na-Cl) type and (Ca-Cl) water type. Hardness of surface water ranges between moderately and very hard class for laundry usage and from permissible to poor classes for domestic purposes. The water can be used under special conditions. Generally El Tebbin Surface water area shows no heavy metals pollution.

Concerning use of Nile water for drinking purposes, physicochemical parameters, major ions and heavy metals within range of WHO, 2011, except bicarbonate concentrations were in an alarming state. This is fit with WQI calculation that Nile water is better for drinking purposes after simple treatment. Almost all three water canals exceed the limits for chloride, sulfate, sodium, potassium and calcium, regarding drinking purpose. WQI indicated the unfit of this water for drinking until primary treatment. The suitability of water for irrigation is evaluated based on SAR, EC, US Salinity diagram and WQI. The Nile water was found to be excellent for irrigation while the canals water is good for many types of crops with minor degree of threat. All water samples require treatment for specific industries according to WQI values.

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