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Water Chemistry and Quality Indices of El-Serw, Hadous, and Bahr Elbaqar Drains, East Nile Delta of Egypt

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Abstract

The study focused on the comparison between water quality and its suitability for irrigation in three important drains (El-Serw, Hadous and Bahr Elbaqar Drains), East Nile Delta of Egypt using different indices and factors. The analyses of various water parameters namely; physiochemical parameters (pH, T°C, EC and TDS), organic indicators (OM, DO, BOD and COD), soluble anions (CO_3, HCO_3, Cl and SO_4), cations (Na, K, Ca and Mg), Nutrients (TP, TN, NH_4, NO_2, NO_3, SiO_4 and PO_4) and metal ions (Fe, Ni, Cd and Co). The data were supported by different statistical analyses (Principal Component Analysis (PCA) and Box plots). Sodium adsorption ratio values give indication to unsuitability for use in the three drains. Water quality index values are more than 100 in three drains meaning unsuitability for use, which attained value of 106.47, 136.87 and 176.63 for El-Serw, Hadous and Bahr El-Baqar drains, respectively. The National Sanitation Foundation-water quality index NSF-WQI also categorized water into medium for El-Serw drain and bad for Hadous and Bahr Elbaqar drains. The permeability index (PI) showed a moderate class for each drain. The potential salinity (PS) give indication to unsatisfactory for use. The Kelly index (KI) and percent sodium Na% give indication to unsuitability except the magnesium hazard that ranked water as good where magnesium percent in the normal range. Heavy metals concentrations of Fe, Ni and Co are within the limits of Environmental Protection Agency (EPA 2002) except for Cd that exceed those limits, this is may be attributed to the high usage of phosphatic fertilizers and pesticides especially in Bahr Elbaqar drain.

Keywords: irrigation water; KI; Na%; WQI; NSF-WQI; heavy metals; drains.

1. Introduction

In a survey of world freshwater, it has been reported that Egypt is among the ten countries to be scarce of water by the year 2025 due to the rapidly increasing population [1]. Now, major challenge facing Egypt is the need for better development and management of the available limited resources of water, land and energy to meet the requirements of a population growth [2]. Among these challenges are seepage losses from canals and drains, evaporation loss from water surfaces, evaporation losses so as infiltration losses from agricultural lands and aquatic weeds in canals [3].

The water amount that returns to drains from irrigated lands is relatively high (about 25 to 30%). The total amount of reused water is estimated to be 13 BCM in 2013. The reuse practices increase the overall efficiency of the system as comparable to the efficiency of new irrigation systems [4]. Abd El-Fattah and Helmy [5] referred that the discharge of industrial, agricultural and municipal wastewaters in drains water led to contamination of soils, which irrigated by water of these drains. Cao *et al.* [6] mentioned that using wastewater in irrigation sector can reduce the pressure on the usage of freshwater but its disadvantage is that may accumulate metal ions in the soil.

The main source of fresh water in Egypt is the Nile. Based on treaties among the Nile riparian countries, Egypt's share from the Nile is 55.5 bcm/year, an amount which is secured by the multi-year regulatory capacity provided by the Aswan High Dam [7]. Egypt is also reusing an important portion of the effluent generated from irrigation and domestic water uses; thus, while Egypt is increasing the overall water use efficiency, it is also approaching a closed water system which brings with it all possible environmental problems [8, 9]. Moreover, the Nile Delta and its 2.27 million ha of irrigated land makes up two thirds of Egypt's agricultural land. It is also the terminal part of a river basin that spans and feeds 11 countries. Increases in dam and irrigation development in upstream parts of the basin are poised to conflict with agricultural expansion and population growth in Egypt [9, 10].

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Today, pollution is occurring on a vast and unprecedented scale around the globe. Pollution not only harms our planet, but it also has negative effects on humans. Pollution is the introduction of contaminants into the natural environment that causes adverse change [11, 12]. Our land and water can also become polluted. This can be caused by littering or even the dumping of chemicals by industries. This pollution can affect our wildlife and our plants and trees, and it can even contaminate our drinking water. In other words, pollution is dangerous for us all. In 2015, pollution killed 9 million people in the world [13, 14].

It is possible to safely use agricultural drainage water if the quality of the water, soil, and the intended crop is identified and can be economically managed. For using toxic water, it requires selection of crops with appropriate salt tolerances, improvements in water management, and maintenance of soil structure and infiltration [15].

Application of management systems and practices may increase the crop productivity and improve the soil to be suitable for agricultural activities. However, more information is needed to be introduced to farmers about using wastewater or recycled wastewater in farming activity [16].

In fact, the using of drains water in irrigation should be studied again for its suitability for farming, and what types of crops that can irrigated by these waters and any types of soils that accommodate within this water. So, the objective of this research is to eliminate the suitability of some drains wastewater east Nile Delta in irrigation and the degree of water quality based on large number of parameters using different indices.

There are many drains south to Manzala Lake which are consider as source of agricultural, industrial and domestic wastes into the lake [17]. The most important drains are Fareskour, El-Serw, Hadous and Bahr Elbaqar. Three of these except Fareskour were chosen in this study. Each drain was represented by five samples.

The type of wastes in studied drains are agricultural wastes in both Hadous and El-Serw drains and mixed wastes in Bahr El-Baqar drain [18, 19]. They mentioned that the mean inflow of drains with 5.44, 1.64 and 50.4 m^3/s for Hadous, El-Serw and new Bahr El-Baqar drains, respectively. Bahr El-Baqar represents the serious among these drains as it is the largest lake, begins at east Cairo and reach at the Manzala Lake carrying most types of wastewaters either agriculture, industrial and sewage wastes. It is poured these wastes at the areas of El-Genka and Bahr El-Bashtir [20]. The study focused on the comparison between water quality and its suitability for irrigation in three important drains (El-Serw, Hadous and Bahr Elbaqar Drains), East Nile Delta of Egypt using different indices and factors.

2. Materials and methods

2.1. Study area

There are many drains south to Manzala Lake which are consider as source of agricultural, industrial and domestic wastes into the lake [17]. The most important drains are Fareskour, El-Serw, Hadous and Bahr Elbaqar. Three of these except Fareskour were chosen in this study. Each drain was represented by five samples. Geo-referenced sampling sites of El-Serw drain (sites from 1 to 5); Hadous drain (sites from 6 to 10) and Bahr El-Baqar drain (sites from 11 to 15) are as shown in Figure 1.

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2.2. Analyses of water samples

Samples of water were collected from 15 sites distributed and represented by five samples for each drain (Figure 1) during wet season (March- 2019). Coordinates of the sampling stations were recorded by Global Positioning System (GPS). For nutrients analyses, samples were preserved and analyzed according to Grasshoff et al. [21]. Water temperature and dissolved oxygen (DO) were measured using DO-meter (Lutron YK-22 DO meter). Values of pH were obtained using pH meter. While electrical conductivity (EC) and total dissolved solids (TDS) were measured using conductivity meter and results was expressed as ms/cm and mg/l, respectively. Biological oxygen demand (BOD) was determined using conventional Winkler method and chemical oxygen demand (COD) was determined using the dichromate reflux method according to APHA [22].

Determination of alkalinity was occurred as methods of APHA [23]. The extractable cations (Na, K, Ca and Mg) were achieved by the methods of Allen et al. [24]. The result was expressed as mg/l. Carbonates (CO_3) and bicarbonates (HCO_3) were analyzed by titration method according to Pierce et al. [25]. Chloride (Cl) and sulphates (SO_4) were analyzed as Piper [26] methods. Fe (iron), Ni (nickel), Cd (cadmium), Co (cobalt), Cr (chromium) and Pb (lead) were determined in water samples by Atomic

Absorption Spectrophotometer (ASS Perkin Elmer Analyst 100) according to the methods of APHA [23].

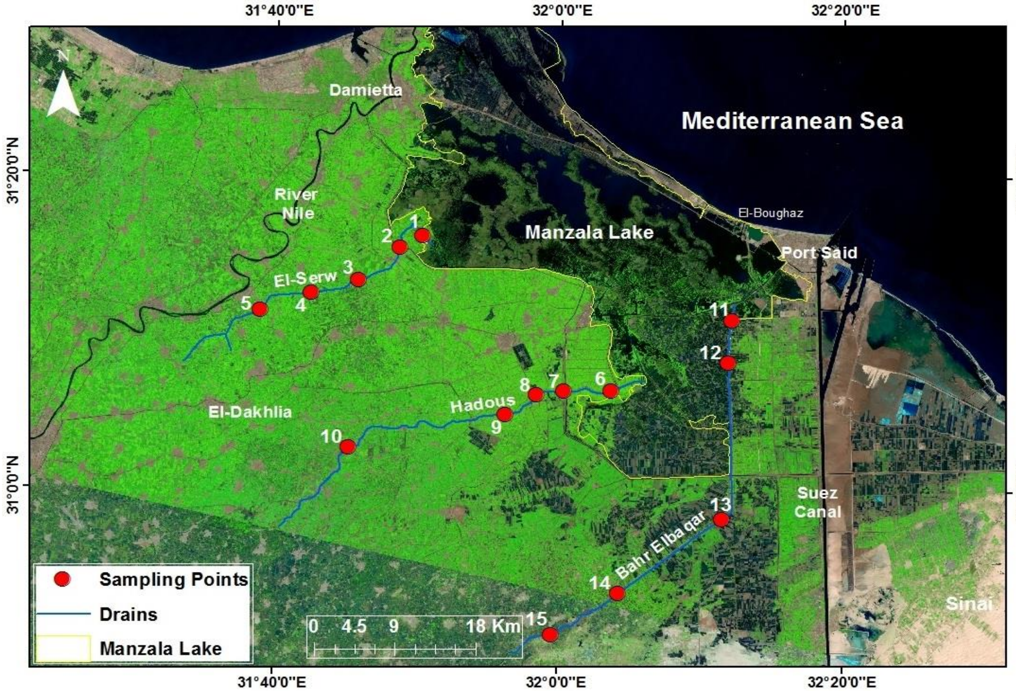

Fig. 1. Sampling sites within El-Serw, Hadous and Bahr El-Baqar drains, south Manzala Lake.

2.3. Water quality indices

The water quality indices (WQI) were applied to determine the availability of wastewater of drains in the irrigation systems of surrounded agricultural lands and to evaluate the quality and suitability of these waters (Table 1). The preliminary analytical results of different water quality parameters with different values and units are converted into a single value by a special kind of mathematical averaging calculation function [27]. In many countries have applied different quality indicators considering different water quality parameters and the indices are applied worldwide. Some researchers and some countries have suggested different quality indicators taking into account different water quality standards, and the indicators are applied all over the world. WQI was first proposed by Horton [28] and used to analysis of drinking water quality [29, 30, 31, 32]. Later on, Pesce and Wunderlin [33] also suggested the WQI method which is used by many countries and researchers. Some WQIs proposed by some countries are National Sanitation Foundation Water Quality Index (NSFWQI) by USA. The WQI, here, has been calculated following the method given by Sener et al. [30] and Singh et al. [32]. The mathematical formula and classes of this WQI method is Tables 2 & 3.

The suitability of irrigation water is assessed mainly in terms of the presence of undesirable dissolved salts or constituents, and in some limited cases assessed on plant nutrients [34, 35]. The major fresh water parameters in river of most countries, which help determine their suitability for irrigation, are pH, EC, TDS, hardness, sodium, potassium, calcium, magnesium, chloride, sulphate, nitrate, carbonate, bicarbonate, etc. [35, 36]. Some calculated indices and its classes that also help to assess the suitability of irrigation water are discussed in the following Tables 2 and 3.

2.4. Statistical analysis

The data of water analysis were subjected to one-way ANOVA followed by Duncan's post hoc test at probability level 0.05 using COSTAT software program (CoHort Software, Monterey, CA, USA). The box and whisker plots of the water parameters have also been drawn of for three drains to show the variations of studied parameter values using PAST program (multivariate statistical package, ver. 1.72). On the other hand, the data water analysis of the three drains was subjected to principal component analysis (PCA) to construct a matrix of correlation and to identify whether a significant difference exists between different treatments. PCA was performed using PAST-statistical program (multivariate statistical package, ver. 1.72).

Table 1. Water quality indices (WQI) formulas used in the present study.

Water Quality Index (WQI)	$S_i = \left(\frac{V_{actual} - V_{ideal}}{V_{standard} - V_{ideal}}\right) \times 100$ $RW_i = \frac{W_i}{\sum_{i=1}^{n} W_i}$ $W_i = \frac{1}{V_{standard}}$ $WQI = \sum_{i=1}^{n} S_i \times RW_i$	[29, 30, 32]
National Sanitation Foundation Water quality index (NSFWQI)	$NSFWQI = \sum_{i=0}^{n} W_i \, x \, Q_i$ W_i: weight score Q_i: Sub-index value	https://water-research.net/index.php/water-treatment/water-monitoring/monitoring-the-quality-of-surfacewaters

Table 2. The used indices for water quality in the present study.

Index	Formula	References
Permeability Index (PI)	$PI = \frac{[Na^+ + \sqrt{HCO_3^-}]}{Na^+ + Ca^{2+} + Mg^{2+}} * 100$	[37, 38]
Sodium Adsorption Ratio (SAR)	$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$	[39, 40]
Percent sodium (Na %)	$Na\ \% = \frac{Na^+ + K^+}{Na^+ + K^+ + Ca^{2+} + Mg^{2+}} * 100$	[41]
Magnesium Hazard (MH)	$MH\ \% = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} * 100$	[42, 43]
Kelly Index (KI)	$KI = \frac{Na^+}{Ca^{2+} + Mg^{2+}}$	[44, 45]
Potential Salinity (PS)	$PS = Cl^- + \frac{1}{2} SO_4^{2-}$	[46, 43]

Table 3. Classes of used indices for water quality and Irrigation water qualities in the present study.

Index	Value	Water quality	References
Permeability Index (PI)	PI > 75% PI = 25-75% PI < 25%	Suitable Moderate Unsuitable	[36, 47]
Sodium Adsorption Ratio (SAR)	SAR < 10 SAR = 10-18 SAR = 19-26 SAR > 26	Excellent Good Doubtful/Fair Poor Unsuitable	[48, 41]
Percent sodium (Na %)	Na% < 20 Na% = 20-40 Na% = 40-60 Na% = 60-80 Na% > 80	Excellent/Safe Good/Safe Permissible/Safe Doubtful /unsafe Unsuitable/unsafe	[49, 43]
Magnesium Hazard (MH)	MH < 50% MH > 50%	Suitable Unsuitable	[41]
Kelly Index (KI)	KI < 1 KI > 1	Suitable Unsuitable	[44, 36]
Potential Salinity (PS) (meq/L)	PS < 3.0 PS = 3.0-5.0 PS > 5.0	Excellent to good Good to injurious Injurious to unsatisfactory	[46, 50]
Water Quality Index (WQI)	WQI = 0-25 WQI = 26-50 WQI = 51-75 WQI =76-100 WQI > 100	Excellent Good Poor Very poor Unsuitable	[30, 32]
NSF-WQI	0-25 26-50 51-70 71-90 91-100	Very bad Bad Medium Good Excellent	Water research center; https://water-research.net/index.php/water-treatment/water-monitoring/monitoring-the-quality-of-surfacewaters

3.Results & Discussion

3.1. Chemistry of water drains

3.1.1. *Assessment of physiochemical parameters*

The mean concentrations of different parameters in El-Serw, Hadous and Bahr El-Baqar drains are shown in Table (5). The one-way ANOVA analysis showed non significance for temperature, pH, OM, DO, BOD, COD, HCO_3, SO_4, K, Mg, SAR, PAR, NO_2, Ni, Co and Pb. It showed low significance for EC, TDS, Cl, Na, Ca, TP, NH_4, NO_3, Fe, Cd and Cr; moderate significance for TN, SiO_4 and PO_4; and high significance for only alkalinity among these three drains. Water temperature exerts a major influence on biological activity and growth, has an effect on water chemistry, can influence water quantity measurements, and temperature fluctuations can also affect the kinds of organisms that live in water bodies [52, 53]. The temperature values are ranging from 17.31 to 23.24°C in El-Serw drain, where the maximum mean value was recorded in Bahr El-Baqar drain.

Results indicate that the pH values ranged between 6.91 and 8.19 in El-Serw drain; 7.58 – 8.12 in Hadous drain and 7.34 – 8.02 in Bahr El-Baqar drain (Table 4). They indicate the presence of alkaline water in most of the three drains, with a significant difference between the sites. The estimated pH values in the water samples were within the permissible limits (6.0-8.5) for irrigation [5, 54]. The pH values at upstream of the drains were higher than the samples at the downstream of the drains for the three drains. This may be due to the quality and components of the wastewater, which have low pH values and this may be due to organic acids or to the increase in CO_2 production, which may reduce pH values in water. These results are consistent with those obtained by Ezekiel et al. [55], Mahmoud and Ghoneim [56]. In wastewater treatment, alkalinity is an important parameter in determining the susceptibility of waste to the treatment process [57]. The alkalinity varied in the range of 0.11-1.75% in El-Serw and Bahr El-Baqar drains, respectively, with the maximum mean value (1.182%) recorded in Bahr El-Baqar drain (Table 5). Middelburg *et al.* [58] stated that alkalinity is the ability of a liquid or substance to resist a change in pH. The fluctuations in organic matter are significantly reflected during seasonal changes in climatic conditions and human activity (i.e., land use, upstream drainage) [59, 60]. Organic matter of the three studied drains ranged from 0.19 to 3.48% for Hadous drain, with the maximum mean value (1.464%) recorded in Bahr El-Baqar drain (Table 4). The higher BOD and COD values negatively affect water quality and reflect the relatively high loads of organic matter [61, 62] of all forms of organic matter.

The values of DO, BOD and COD were varied in the ranges of 2.42 – 9.53 mg l^{-1}, 4.49 – 26.52 mg l^{-1} and 14.62 – 86.41 mg l^{-1}, in El-Serw and Bahr El-Baqar drains, respectively, with the maximum mean value (6.53, 17.27 and 56.28 mg l^{-1}) recorded in Hadous drain. The high values of COD and BOD were recorded at downstream in Hadous and Bahr El-Baqar drains, but in El-Serw drain the high value recorded in upstream, may be due to the decomposition process of organic matter by microbes consuming oxygen and discharge effluent from Industrial pollution [63, 64]. The basic nutrients show highly significant differences ($p < 0.05$) at the sites of three drains, and ranged between 2.84-35.76, 25.47-67.24, 0.11-2.64 and 0.02-0.18 mg l^{-1} for TP, TN, NH_4 and NO_2 in Hadous and Bahr El-Baqar drains, and ranges from 3.68-15.71, 0.54-0.95 and 0.58-0.89 mg l^{-1} for NO_3, SiO_4 and PO_4 in El-Serw and Bahr El-Baqar drains, respectively. Results indicate that the basic nutrients in water samples had the same distribution, as the highest mean values were recorded in Bahr El-Baqar drain. Anthropogenically derived water pollution is another major perturbation in aquatic ecosystems that results in increased influx of pollutants and nutrients into aquatic systems [65, 66].

One of the most important thermo physical properties of water is its electrical conductivity (EC) and this maintains almost a linear relationship with total Dissolved solids (TDS) in aquatic ecosystem [67, 68]. Values of EC and TDS ranged from 1.52 to 5.14 mS cm^{-1} and 0.85 to 1.44 g l^{-1} in in El-Serw and Bahr El-Baqar drains, respectively, with the maximum mean value (3.84 mS cm^{-1} and 2.60 g l^{-1}) recorded in Hadous drain. The Relative abundance of cations in water of El-Serw, Hadous and Bahr El-Baqar drain was Na^+ (200.1-859.38 mg l^{-1}) > Ca^{2+} (64-194 mg l^{-1}) > Mg^{2+} (34.8-134.4 mg l^{-1}) > K^+ (0.74-7.37 mg l^{-1}), respectively. Regarding anion abundance for the studied three drains are: Cl- (275.48-1022.42 mg l^{-1}) > SO_4^{-2} (148.8-777.6 mg l^{-1}) > HCO_3^- (146.4-541.65 mg l^{-1}) except HCO_3^- > SO_4^{-2} in El-Serw drain.

The order of heavy metal in water of three studied drains is: Fe > Co > Cd > Ni > Pb > Cr; Fe > Co > Cd > Cr > Ni > Pb and Fe > Co > Cd > Pb > Cr > Ni in El-Serw, Hadous and Bahr El-Baqar, respectively. The mean concentrations of metals (Fe, Cr, Ni and Pb) in the drains are within the limits of EPA (2002) of (300, 100, 10 and 50 µg l^{-1}) for each metal, respectively. While the mean concentrations of Cd in the three drains are higher than EPA (2002) limit of 2.37 µg l^{-1}. This is may be attributed to the use of phosphatic fertilizers and the use of pesticides is another probable source especially in Bahr El-Baqar drain [69, 70,71].

A box and whisker plot are a way to show the spread and centers of a data set. The box and whisker plots of the actual values of water parameters (15 stands × 30 parameters) have also been drawn for three drains to show the ranges of variation, mean and standard deviation as well as the variation of parameters with their standard error are shown by box plots (Figure 2; a, b and c). Box and whisker plots show that most water variables in three drains have the same trend. The most parameters of varying concentration are greater in Bahr El-Baqar drain than that of El-Serw drain and Hadous drains. This is probably because of amount and type of water discharge along the drain [72, 73].

3.1.2. Principal Component Analysis (PCA)

The application of multivariate statistical analysis as principal component analysis (PCA), agglomerative hierarchical clustering (AHC) techniques and FA aid in identification of the important components or factors accounting the vaiances in a system [74, 75]. In this study, first three principle components were considered for three drains to explain 61.55% of the total variance (PC1= 33.87%, PC2 = 16.79% and PC3 = 10.47%). Wang et al. [75] and Liu et al. [76] stated that the factor loadings (FL) are classified as strong (FL > 0.75), moderate (0.75 ≤ FL ≥ 0.50) and weak (0.50 ≤ FL ≥ 0.30). It is evident that PC1 showed high positive significant correlation with EC, TDS, Alkalinity and Cl; it showed moderate significant correlation with cations, SO_4, PO_4, TN, Cd, Cr and Pb. While it showed low significant correlation with CO_3 and Co. While PC2 showed moderate positive significant correlation with temperature, TN and NO_3; low positive significant correlation with TP, SiO_4 and PO_4.Also it showed negative correlation with D. In both El-Serw and Hadous drains, the variables are purely anthropogenic influences, while the water variables in Bahr El-Baqar drain are hydrochemical and originate from geogenic sources in addition to human activities [77] (Figure 3).

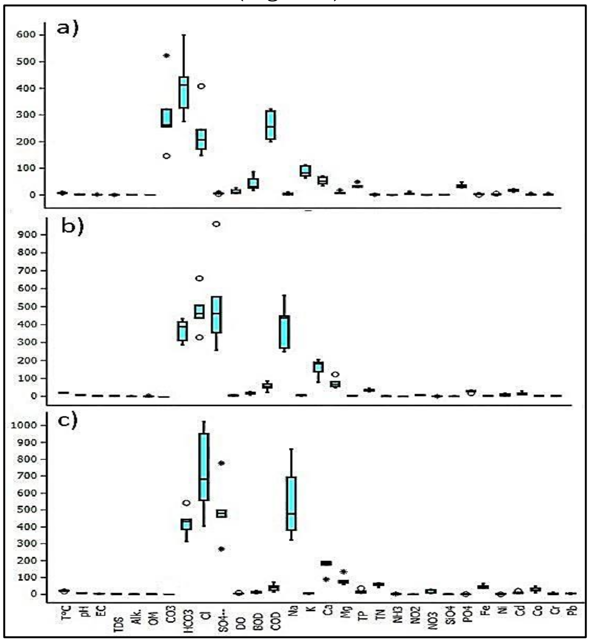

Fig. 2. Box plot showing variation of physico-chemical parameters of the three studied drains. a) El-Serw drain, b) Hadous drain, and c) Bahr El-Baqar drain.

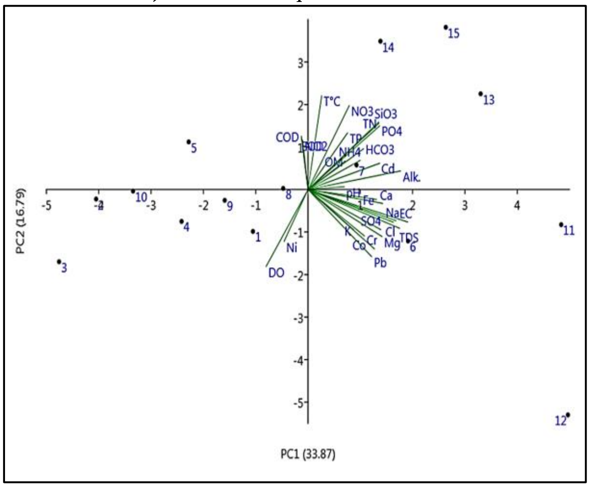

Fig. 3. Classification of water quality based on the principal component analysis (PCA).

3.1. Salinity hazard

The assessment of water suitability for irrigation use in three drains, USSL (US Salinity Laboratory) diagrams is performed by plotting the values of sodium absorption ratio (SAR) against electrical conductivities data (Figure 4) on a two-dimensional graph [48]. SAR gives indication to sodium hazard in water, in this wastewater of El-Serw drain give indication to unsuitable for use in irrigation generally at all three drains as (SAR > 26). According to Figure (6) that indicate SAR against EC for rating irrigation water in different classes which indicate the extent that the water can affect the soil in terms of salinity hazard. It showed high degree for Elserw drain and very high for both Hadous and Bahr Elbaqar drains. The order of significance degree is Bahr Elbaqar > Hadous > El-Serw. Very high-salinity water (C4) from this and other sources is not appropriate for irrigation under normal circumstances, although it may be utilized infrequently in really exceptional situations. While in the case of (C3), which symbol to high-salinity water (C3) cannot be used on soils with restricted drainage. Also (S3) which is high sodium water may produce alkalinity problem and (S4) represent very high sodium water that isn't suitable for irrigation purbose [78]. From Table (6), the order degree of WQI is Bahr Elbaqar < Hadous < Elserw. While it give indication to unsuitable for use.

Table 4. Mean, standard deviation and range of water parameters of three main drains (n=15) south Manzala Lake of Egypt.

Water parameters	**Studied Drains (East Nile Delta)**												***P-value***
	El-Serw drain (n=5)				**Hadous drain (n=5)**				**Bahr El-Baqar drain (n=5)**				
	Min.	Max.	Mean	±SD	Min.	Max.	Mean	±SD	Min.	Max.	Mean	±SD	
T °C	17.31	23.24	19.24	2.39	18.33	22.04	20.30	1.51	17.24	23.22	20.70	1.85	0.532^{ns}
pH	6.91	8.19	-	-	7.58	8.12	-	-	7.43	8.02	-	-	0.274^{ns}
EC $mS.cm^{-1}$	1.52	2.58	2.02	0.47	1.84	3.98	2.78	0.85	2.90	5.14	3.84	1.00	0.012*
TDS g/l	0.85	1.59	1.10	0.29	1.07	2.59	1.93	0.65	1.44	4.21	2.60	1.15	0.032*
Alk. %	0.11	0.42	0.202	0.124	0.32	0.7	0.476	0.15	0.87	1.75	1.182	0.37	0.0001***
OM %	0.41	0.91	0.682	0.196	0.19	3.48	1.082	1.37	0.88	2.3	1.464	0.61	0.393^{ns}
DO mg/l	3.87	9.53	6.35	2.05	2.94	7.54	4.96	1.89	2.42	8.08	4.46	2.23	0.362^{ns}
BOD mg/l	5.44	26.52	13.57	8.72	7.1	26.27	17.27	7.14	4.49	21.87	12.34	6.72	0.581^{ns}
COD mg/l	17.73	86.41	44.21	28.41	23.14	85.61	56.28	23.26	14.62	71.26	40.19	21.89	0.572^{ns}
Soluble anions (mg/l)													
CO_3^{--}	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
HCO_3^-	146.4	522.83	301.85	138.77	287.51	431.87	366.59	63.96	313.48	541.65	423.57	83.92	0.203^{ns}
Cl^-	275.48	599.84	411.28	124.65	328.54	657.27	478.13	119.67	404.7	1022.42	723.70	260.86	0.043*
SO_4^{-2}	148.8	408	236.31	102.62	257.48	960	517.55	271.22	268.42	777.6	496.71	182.19	0.081^{ns}
Soluble cations (mg/l)													
Na^+	200.1	322	260.26	56.99	249.42	561.32	392.82	131.51	322.56	859.38	546.92	224.74	0.038*
K^+	0.74	11.21	4.822	4.194	2.44	7.78	5.352	2.25	2.21	7.37	4.912	2.12	0.957^{ns}
Ca^{+2}	64	112.42	87.93	21.88	78.64	204	158.57	50.92	88.67	194	167.00	44.49	0.019*
Mg^{+2}	34.8	70.8	53.17	15.60	49.78	122.40	75.46	28.99	58.42	134.4	83.608	29.56	0.192^{ns}
Nutrients (mg/l)													
TP	6.60	17.04	9.05	4.49	2.84	5.16	3.81	0.93	6.84	35.76	16.67	11.63	0.046*
TN	27.55	48.41	34.72	8.06	25.47	44.98	33.89	7.57	41.55	67.24	57.42	10.03	0.0014**
NH_4	1.23	1.72	1.57	0.20	0.11	2.52	1.28	1.15	2.57	2.89	2.64	0.14	0.019*
NO_2	0.14	0.28	0.22	0.06	0.02	0.33	0.13	0.16	0.02	0.44	0.18	0.20	0.648^{ns}
NO_3	3.68	9.00	5.16	2.18	6.20	8.41	7.22	0.94	6.45	27.54	15.71	10.17	0.039*
SiO_4	0.54	0.74	0.64	0.08	0.64	0.82	0.76	0.07	0.69	1.14	0.95	0.17	0.0046**
PO_4	0.58	0.79	0.70	0.08	0.77	0.79	0.78	0.01	0.78	0.98	0.89	0.07	0.002**
Heavy metals (µg/l)													
Fe	26.82	48.83	34.32	8.95	17.96	33.42	27.72	6.03	36.00	64.70	46.93	11.53	0.0179*
Ni	0.66	4.70	3.08	1.53	1.66	3.36	2.34	0.67	0.20	4.26	2.49	1.50	0.641^{ns}
Cd	1.88	4.75	2.94	1.11	2.72	15.92	7.95	6.62	6.11	19.73	10.71	5.41	0.047*
Co	10.93	23.51	17.13	4.75	8.19	31.40	17.03	9.21	9.25	47.00	27.29	14.53	0.235^{ns}
Cr	0.84	4.06	1.91	1.26	0.75	5.14	2.98	1.66	0.68	11.44	4.57	4.31	0.034*
Pb	1.71	4.12	2.38	1.00	1.52	3.22	2.14	0.72	0.82	9.18	4.62	3.18	0.132^{ns}

Non-significant ($P > 0.05$), * = low significant ($P \leq 0.05$), ** = intermediate significant ($P \leq 0.01$) and *** = highly significant ($P \leq 0.001$).

3.2. Suitability of water for aquatic life via WQI and NSF-WQI

Water quality index (WQI) is valuable and unique rating to show the overall water quality rank in single term that is helpful for appropriate remediation methods to meet the concerned problems [29]. It is based on different parameters namely; pH, EC, HCO_3, Cl^-, SAR, PI, MH, different heavy metals (Fe, Ni, Cd, Co, Cr and Pb). The calculated single values of WQI are 106.47, 136.87 and 176.63 for El-Serw, Hadous and Bahr El-Baqar drains, respectively. It showed values (> 100), so it is unsuitable for use in three drains (Table 5).

There are nine dependent parameters being used in NSFWQI namely; DO, BOD, total phosphate, turbidity, fecal coliform, temperature, nitrate, total solids and pH. In this research all of these dependent parameters were calculated except to turbidity and fecal coliform. The calculation of new weight score is agreed with Effendi et al. [79] and Radwan et al. [80] as the total remain is one. The used dependent parameters being used are DO, pH, BOD, T°C, TP, NO_3 and TDS (is used instead of TS) with new modified values of 0.206, 0.144, 0.144, 0.134, 0.134 and 0.104, respectively.

The mean values of NSF-WQI in the three drains ranged between medium in Elserw drain and bad for both Hadous and Bahr Elbaqar drains with this order; Elserw > Hadous > Bahr Elbaqar (Figure 5). According to the individual parameters, for DO, it showed good quality in Elserw and medium in Bahr Elbaqar and Hadous drains. For NO_3, it showed good quality in both Elserw and Hadous drains and medium in Bahr Elbaqar. For temperature, it showed bad category. While it showed bad in Elserw and Bahr Elbaqar except Hadous with very bad for BOD. The NSFWQI in TP and TS showed very bad category in three drains. While pH values give excellent category in three drains. Radwan et al. [80] showed medium to good water quality on his study in Idku Lake.

For irrigation purposes, the most suitable EC of water may ranged between 0.25 and 2 mS, while more than this range isn't benfit. The water in these drains ranged between Doubtful in Elserw and Hadous drains and unsuitable in Bahr Elbaqar drain.

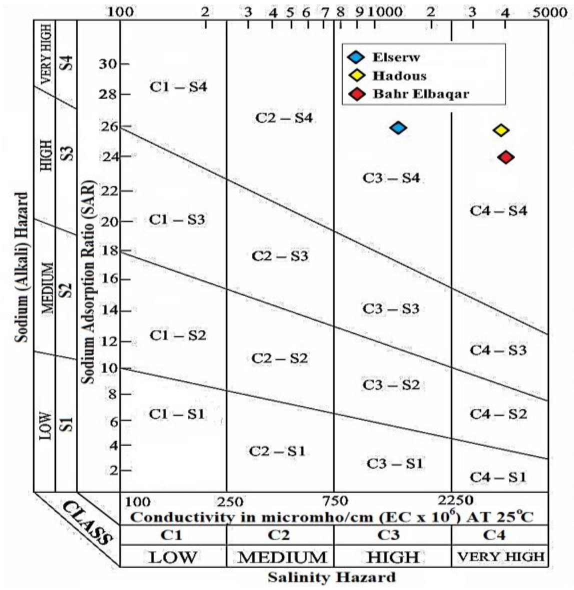

Fig. 4. Plot of calculated values of SAR and EC of water samples for classification of irrigation water (after US Salinity Laboratory Staff, 1954).

3.1. Suitability of water for irrigation

The Permeability Index (PI) is also used to reflect the usability of water for irrigation purposes [81]. The PI values of three drains water are 69.17%, 65.72% and 71.16% for El-Serw, Hadous and Bahr El-Baqar drains, rspectively (Table 6). All the samples of the three drains fall in moderate class [36, 47] Das and Nag, 2015), possibly because the mean values of actual data are close. High PI values are related to high levels of Na^+ and HCO_3^-, which may be due to the cation exchange and carbonate dissolution (such as calcite and dolomite) [82]. Reduced in water permeability causes salt accumulation on the soil surface, and prevents water absorbtion by plants, which leads to reduced plant growth, and productivity [83].

The Potential salinity (PS) values of the drainage water samples in the study area falls out those limits and give indication to injurious and unsatsfactory. Abdel-Fattah and Helmy [5] found that tested drainage water falls under recommended permissible limits in his study.

Na% is an indicator of sodium hazard. The increase in Na% can have different impacts on soil structure, aeration and infiltration [84]. Na % varied between 62.98, 65.26 and 68.77 % for Hadous, El-Serw and Bahr El-Baqar drains, respectively. So, Na% in water of these drains ranked as doubtful or unsafe for use.

Magnesium present in high values in water would adversely affect on the soil quality and may deteriorate it, making it unsuitable for cultivation [85]. The MH% ranged between 32.24, 33.36 and 37.68 % for Hadous, Bahr Elbaqar and El-Serw drains, respectively and it ranked as suitable for each. According to the category of KI, three drains' waters have KI more than 1; consequently, they are unsuitable for using in irrigation purposes. Abdel-Fattah and Helmy [5] found that KI in three drains namely; Bahr Elbaqar, Bilbies and El-Aqlyubia drains is lower than 1 and suitable for irrigation.

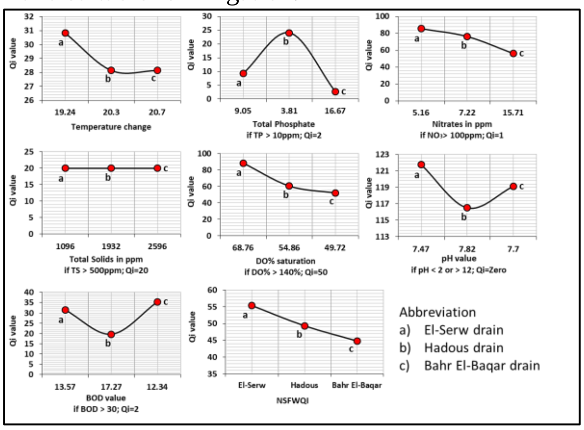

Fig. 5. Weigting Curve Charts for NSFWQI in three studied drains, East Nile Delta.

Table 5. Water quality index (WQI) and relative weight of water parameters of three main drains (n=15) south Manzala Lake of Egypt.

Water parameters*	V (standard)	Weight	Relative_wt	Si			WQI		
				El-Serw	Hadous	Bahr El-Baqar	El-Serw	Hadous	Bahr El-Baqar
pH	8.4	0.119	0.156	33.57	58.57	50.00	5.23	9.13	7.80
EC mS.cm^{-1}	3	0.333	0.437	67.33	92.67	128.00	29.39	40.45	55.87
HCO^{3-} mg/l	518.6	0.002	0.003	58.20	70.69	81.67	0.15	0.18	0.20
Cl$^-$ mg/l	354.5	0.003	0.004	116.02	134.87	204.15	0.43	0.50	0.76
SAR	9.	0.111	0.146	343.71	410.93	548.56	50.01	59.79	79.82

PI %	25	0.040	0.052	276.69	262.88	284.63	14.50	13.77	14.91
MH %	50	0.020	0.026	75.37	64.49	66.72	1.97	1.69	1.75
Fe µg/l	5000	0.0002	0.0003	0.69	0.55	0.94	0.00	0.00	0.00
Ni µg/l	200	0.005	0.007	1.54	1.17	1.25	0.01	0.01	0.01
Cd µg/l	10	0.100	0.131	29.40	79.50	107.10	3.85	10.41	14.03
Co µg/l	50	0.020	0.026	34.26	34.06	54.58	0.90	0.89	1.43
Cr µg/l	100	0.010	0.013	1.91	2.98	4.57	0.03	0.04	0.06
Pb µg/l	5000	0.0002	0.0003	0.05	0.04	0.09	0.00	0.00	0.00
		∑Wi=0.76	∑RWi= 1						
Water quality index (WQI)							**106.47**	**136.87**	**176.63**

*Mean value for each parameter.

Table 6. Mean values of various indices of three drains south Manzala Lake for water quality assessment

Indices	Studied Drains (East Nile Delta)					
	El-Serw		Hadous		Bahr El-Baqar	
	Value	WQI	Value	WQI	Value	WQI
PI %	69.17	Moderate	65.72	Moderate	71.16	Moderate
SAR	30.98	Unsuitable	36.31	Unsuitable	48.86	Unsuitable
Na%	65.26	Doubtful /unsafe	62.98	Doubtful /unsafe	68.77	Doubtful /unsafe
MH %	37.68	Suitable	32.24	Suitable	33.36	Suitable
KI mg/L	1.84	Unsuitable	1.68	Unsuitable	2.18	Unsuitable
PS meq/L	14.21	Injurious to unsatisfactory	19.05	Injurious to unsatisfactory	25.85	Injurious to unsatisfactory

PI: Permeability Index; SAR: Sodium Adsorption Ratio; Na%: Percent sodium; RSC: Residual Sodium Carbonate; MH: Magnesium Hazard; KI: Kelly Index; PS: Potential Salinity; WQI: Water Quality Index

Conclusion

It's concluded that wastewater of three drains being classified according to different indicators:

- SAR and EC values indicated unsuitability for irrigation in the three studied drains.
- WQI showed unsuitability for use in three drains
- NSFWQI give indication to medium quality in El-Serw drain and bad quality in Hadous and Bahr Elbaqar drains.
- In drain water, residual sodium carbonate percent is acceptable.
- Potential salinity in wastewater of drains is out of limits of irrigation waters
- Kelly index gives unsuitability of water for use and Na% is out of the limits
- Magnesium value is suitable for irrigation
- Wastewater of these drains, if being used in irrigation, some crops (not for feeding) only should be used
- Salinity of wastewater is high and may effect on the soil quality, so more dillution is needed before being used in irrigation.
-

Conflicts of interest

There are no conflicts to declare.

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