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Evaluation of Water Quality and Heavy Metal Indices of Some Water Resources at Kafr El-Dawar Region, Egypt

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ABSTRACT

Kafer El-Dawr is a major industrial and municipality city at the western area of Nile Delta, northern Egypt. Many factories are founded in Kafr El-Dawar region that discharges many pollutant elements. Assessment of Water quality is an important issue to know whether it is safe or not for irrigation. So, twenty-five water samples were collected from some water sources established in Kafer El-Dawr region. These sources are Yarn and Fabric (YD), Kafer El-Dawr Defshu (KDD), Dabora Abu Qir (DAD), Dabora Defshu Canal (DC) and Abu Qir (AD). Whisker box plot-median indicated that the heavy metals in the waters of these drains can be classified according to their concentration homogeneity into (a) wide spread-heterogeneous included: Cr, Co and Cu. (b) Moderate spread - moderately homogeneous included: Pb, Ni and Zn, and (c) narrow spread - homogeneous included: Fe, Cd, Li and Mn. The correlation study classified the heavy metals into three groups: The positively highly correlation between Pb and Cd, Co and Cr concluded that the water resources have the same pollution source. Contrary, the negatively highly correlated between (Pb_Mn), (Mn_Cu) and (Co_Li) might be a tool to assume that these heavy metals originated from different pollution resources.

Water quality for irrigation was evaluated by water quality index (WQI), heavy metals pollution in short and long-term use by conventional scale, heavy metals contamination index (CI) and metal index (MI). According to EPA the concentrations of heavy metals was generally safe except cadmium for short-term use. For long-term use, Co occupied the polluted class in all water resources and Mn in water resource (KDD). The risky pollution was found in Cd and Cr in all resources as well as Mn in (DAD) and (AD) resources.

Water quality index (WQI) showed that these water resources are good for irrigation utilization. Metal index values cleared that drains or canal are seriously threatened with metal pollution for irrigation usage (MI>1). Only KDD drain has no heavy metal problems to use in irrigation. The contamination index (CI) showed that the water resources (YD), (DAD) and (AD) had negative values of -5.67, -7.26 and -7.49, respectively. This is indicated that these water resources are safe to use in short-term run. Contrary, all studied water resources were highly contaminated and cannot be use at the long run.

Keywords: Heavy metals, Kafr El-Dawar, Water quality index, contamination index, Metal index

INTRODUCTION

Water pollution of natural water bodies like lakes, rivers, streams, oceans, and groundwater is due to inflow or deposition of pollutants directly or indirectly into water systems. Pollution very often is caused by human activities (Mwegoha and Kihampa, 2010). The use of water for different purposes such as drinking, irrigation, domestic and industrial, mainly depends on its intrinsic quality. So, It is necessary to examine quality of water resources available in the region (Mohrir, 2002). Owing to industrial and agricultural activities large amounts of untreated urban, municipal and industrial wastewater are discharging into the canals or agricultural drains which become an easy dump sites for wastes containing toxic metals (Karbassi and Bayati, 2005 and Goher *et al.*, 2014).

Heavy metals are regard as serious pollutant of aquatic ecosystem because of their environmental persistence and toxicity effects on living organisms (Khalil *et al.*, 2007). The increased load of heavy metals in the aquatic ecosystems have severely disrupted water quality which threatend aquatic organisms and human health (Sasmaz *et al.*, 2008 and Elshemy and Meon, 2011).

Heavy metal water pollution has been studied by standard tables of pollution (EPA, 2004) or by applying contamination indices, such as contamination index (CI), water quality index (WQI) and Metal Index (MI) as reported by Brraich and Jangu (2015) and Manoj *et al.*, (2012). The water quality index (WQI) is a single number that expresses water quality by aggregating the measurements of water quality parameters (Lumb et al., 2011). A Wisker boxplot can give information regarding the shape, variability, and center (or median)

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of a statistical data set. It is particularly useful for displaying skewed data (Rumsey, 2016). This boxplot can graphically present heavy metal distribution pattern (Sany *et al*, 2013).

At Kafr El-Dawar region, west Nile Delta, the sources of pollutants are due to the largest industrial zones in the region which include the activities of Albayda Dyers Co., Albayda Tinning and Chemicals Co., Egyptian Textile and Spinning which caused dramatic changes in its water quality by discharging wastewater.

This study aims to: (a) assess the water quality index approach for some water resources in Kafr El-Dawar region, (b) statistical analysis approaches of the water quality data such as correlation analysis, (c) assess heavy metals pollution risk, and (d) improve capability of water environmental monitoring and supervision.

MATERIALS AND METHODS

Kafer El-Dawar region is a major industrial and municipality city in the western area of Nile Delta, northern Egypt. Twenty Five water samples were collected from some water resources, Kafer El-Dawr region: Yarn and fabric Drain (YD), Kafer Dawr Defshu Drain (KDD), Dabora Abu Qir Drain (DAD), Dabora Defshu Canal (DC) and Abu Qir Drain (AD). Details of water sampling locations along with their longitude and latitude are presented in Fig. 1 and Table 1. Several heavy metals were determined in the water recourses.

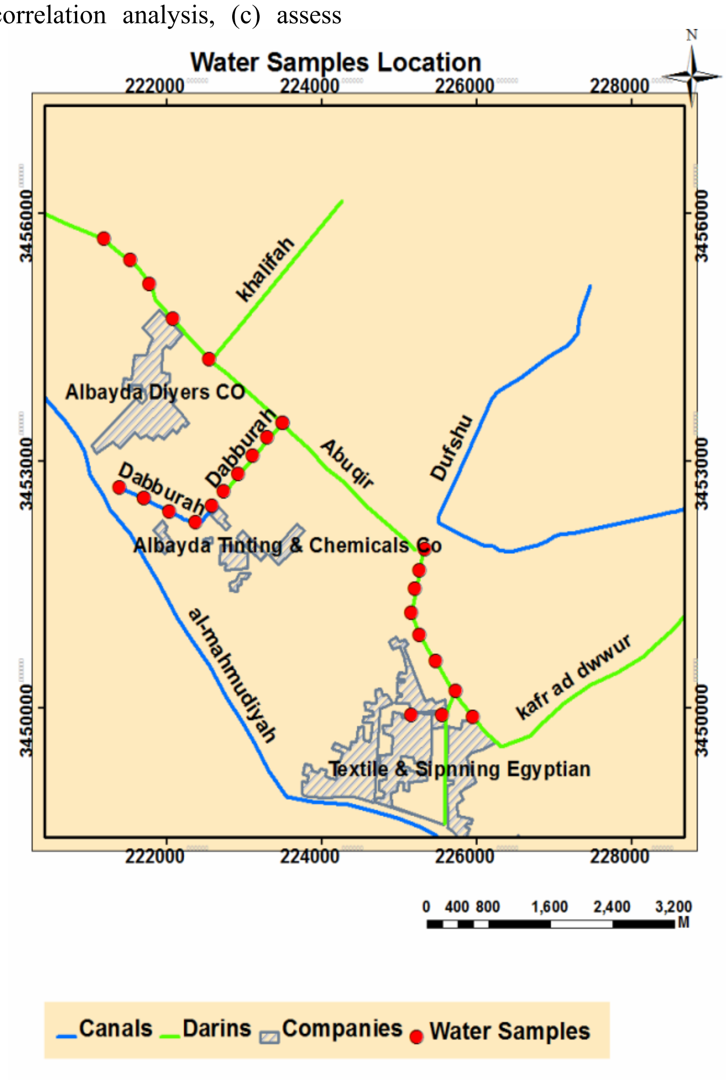

Fig 1. Location of water samples resources in Kafr El-Dawar region

Table 1. Water samples coordinates

Water resource		Coordinates (UTM)		Water resource		Coordinates (UTM)	
Name	Symbol	E	N	Name	Symbol	E	N
Yarn and fabric Drain	YD	225159	3449988	Dabora Defshu Canal	DC	222627	3452223
		225553	3449908			222920	3452831
		225726	3450183			223110	3453057
		225949	3449891			223299	3453281
		225467	3450562			223488	3453453
KAFR El-DAWR Defshu Drain	KDD	225467	3454498	Abu Qir Drain	AD	222544	3454497
		225261	3450889			221475	3455484
		225158	3451147			221527	3455432
		225261	3451663			221767	3455140
		2253330	3451922			222077	3454727
Dabora Abu Qir Drain	DAD	222573	3452200	Dabora Abu Qir Drain	DAD	222026	3452386
		221389	3452696			222370	3452249
		221699	3452541				

Laboratory analysis:

Water sampling technique was carried out according to the methods outlined in APHA (2005). The area samples were kept in 25 polyethylene bottles in ice box for analysis in the laboratory. The methods of analyses were carried out according to Page *et al*. (1982) and Ayers and Westcot (1994).

Water electrical conductivity (EC) and pH value were measured in situ, using YSI model. Chloride was measured using Mohr's method and Calcium and magnesium were determined by direct titration using versinate method (Na_2 EDTA), Na^+ and K^+ were measured using flame photometer Model "Corning 400". Sodium Adsorption Ratio (SAR) was calculated. Heavy metals (Cd^{+2}, Cu^{+2}, Fe^{+2}, Mn^{+2}, Ni^{+2}, Pb^{+2}, Cr^{+2}, Co^{+2}, Li^{+2} and Zn^{+2}) were measured using atomic absorption Spectrophotometer (Thermo model iCE 3300).

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 resources for irrigation 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 variables. The method of calculation 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:

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

where Q_i is the sub quality index of *i*th parameter (or Q_i is the quality rating scale of each parameter). W = weight unit of each parameter, n = number of parameters. The Q_i can be calculated as:

$$Q_i = \left[\left(V_i - V_0 \right) / \left(S_i - V_0 \right) \right]$$

V_i = measured value of *i*th parameter, S_i =standard permissible value of *i*th parameter, Vo =ideal value of $_i$th parameter in pure water, V_0 = zero for all parameters except for pH =7.0 (Tripaty and Sahu, 2005).

The contribution or importance to water quality of each indicator is usually different, and can be indicated by weighting coefficient. The calculation of weights assigned to each indicator is as follows (Lumb *et al*., 2011):

1- The sum squared deviation from the mean was obtained for each observation,

2- This amount was summed up for all observations for a specific indictor,

3- Obtaining the total sum squared deviation from the mean for all indictors,

4- The weight was obtained by dividing step 2 by step 3 and

5- The sum of all weights was normalized to 100%.

WQI has been classified into 5 classes; 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).

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

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 (unfit)	E

(i) Contamination Index (CI):

The contamination index (CI) summarizes the combined effects of several quality parameters considered harmful to irrigation (Hakanson 1980). This index is calculated from the formula:

$$CI = \sum_{i=1}^{n} C_{fi}$$

Where:

$$C_{fi} = \frac{C_{Ai}}{C_{Ni}} - 1$$

Where C_{fi} ,C_{Ai} and C_{Ni} represent contamination factor, analytical value and upper permissible concentration of the *i*th component, repectively (N denotes the "normative value"). Interpretative scale of contamination factor (C_{fi}) is illustrated in Table (3) which conducted to describe individually the pollution potentialty of each heavy metal.

Table 3. Interpretative scale of contamination factor (C_{fi})

N	C_{fi} value	C_{fi} Category
1	-0.5 - 0.0	Safe
2	0.0 – 9.0	Risky
3	> 9.0	Polluted

(ii) 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 maximum allowable concentration (MAC) value, the worse the quality 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:

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

Where: C_i: the concentration of each element, MAC: maximum allowable concentration.

Statistical analysis:

Data were analyzed for descriptive statistics to measure homogeneity of data that may indicate the HM resources. Whisker box Plot was drawn to represent graphically the HM distribution patterns. Data also classified using the standard tables of EPA (2004). In addition, the correlation coefficient (r) between the measured parameters was examined.

RESULTS AND DISCUSSION

The minimum, maximum, mean, median values and standard deviations of the obtained results are presented in Table (4).

The values of EC showed a spatial difference and ranged between 830 – 2060 μSm^{-1} and the pH values were in the alkaline side (7.44–8.66). There are high positive correlations between pH/Pb (r = 0.80), pH/Cd (r = 0.71) and high negative correlations between pH/EC (r = -0.64), pH/Ca^{2+} (r = -0.79), pH/Mg^{2+} (r = -0.71), pH/HCO_3^- (r = -0.62) and pH/Mn (r = -0.85) (Table 5). HCO_3^- and Cl concentrations varied between 195.2-518.5 and 92.3-284.0 mg/l, respectively. HCO_3^- and Chloride positively correlated with Mg^{+2}, Na^+ and K^+. Calcium and Magnesium values ranged between 60.0-160.0 and 19.2-66.0 mg/l, respectively. Sodium and potassium values ranged between 64.4-230.0 and 7.8–23.4 mg/l, respectively. The valued of sodium adsorption ratio (SAR) reported in this study ranged from 1.7 to 5.3.

The concentrations of Pb, Cd, Zn, Mn, Cr, Ni, Cu, Fe, Co and Li were in the ranges of (3.2-29.5), (1.0-10.0), (43.8-96.8), (7.6-63.5), (25.2-26.3), (13.1-14.0), (1.2-5.1), (3.0-98.0), (10.1-11.4) and (3.3-6.4) µg/l, respectively. According to Ibrahim and Omar (2013), the amount fluctuations of agricultural drainage water, sewage effluents and industrial wastes discharged into the drains or canal, are the main reasons for the difference in the concentration of heavy metal.

Water quality index:

Figure (4) showed that the values of WQI of some water resources in Kafr El-Dawar. The WQI score for irrigation water was computed using guidelines of FAO (1994). The results showed that WQI values ranged between 25.28 and 37.02 with respect to irrigation water according to the irrigation guidelines (Table 2). This study indicate that the water quality fluctuation of Kafr El-Dawar water resources could be classified as "good" water for irrigation utilizations.

Heavy Metals Content in Water Resources:

Heavy Metals water resources content was determined and listed in (Table, 5) and illustrated in Figure (3).

The determination of the heavy metals in water resources conducted to compose the different increasing concentration sequence of heavy metals (Figure, 3). The sequences showed that all studied water resources begin with Cu. The sequences of YD, DC and AD water resources ended by Zn as maximum concentration. Thus, the source of heavy metals contamination is the same in the three water resources. Whereas DAD and KDD water resources have Mn and Fe as maximum concentration.

Distribution Pattern of Heavy Metals in water resources

The descriptive statistics of heavy metals content in water resources (Table, 4) indicated that, there were great variations between the mean and median of heavy metals concentrations in waters. This heterogeneity of heavy metal concentration was confirmed by the high values of standard deviation (S.D.).

The distribution pattern was graphically presented by Whisker box plot –median (Fig 4: a, b, and c). This type of whisker plot was preferred because of heterogeneity of the data. This figure indicated that the population of heavy metals can be classified, according to their homogeneity of concentration, into three distribution patterns:

- Wide spread – heterogeneous distribution pattern; Cr, Co and Cu
- Moderate spread – moderately homogeneous subpopulation Pb , Ni and Zn
- Narrow spread - homogeneous subpopulation; Fe ,Cd, Li and Mn.

Source of Heavy Metals Pollution:

The heavy metals (HM) intercorrelation matrix was calculated (Table, 6) to assess their associations. These associations conducted to classify the HM into three groups:

- Positively highly correlated HM: (Pb_Cd), (Pb_Co), (Pb_Cr), (Cd_Co), (Cd_Cu) (Zn_Fe), (Ni_Co) and (Ni_Fe)
- Negatively highly correlated HM: (Pb_Mn), (Mn_Cu) and (Co_Li)
- Intermediate cases (moderate positive and negative correlation): (Cr_Co), (Cd_Mn), (Pb_Li), (Zn_Ni), (Zn_Cu), (Cr_Li) and (Fe_Co).

The positively highly intercorrelated HM between Pb and Cd, Co and Cr led to conclude that the studied water resources have been submitted, by these four heavy metals to the same pollution source. Contrary, the negatively highly intercorrelated between (Pb_Mn), (Mn_Cu) and (Co_Li) might be a tool to assume that these heavy metals originated from different pollution resources. The intermediate cases of low positive and negative correlation coefficients indicated multiple pollution resources.

Table 4. Descriptive statistics of water parameters compared to guidelines used in WQI, CI and MI computations

Parameter	Min.	Max.	Mean	Median	S.D.	Guideline*
pH	7.44	8.66	8.142	8.4	0.54	8.5
EC (µSm^{-1})	830	2060	1506	1560	441.28	3000.0
Ca^{2+} (mg/l)	60	160	88.8	76	40.34	400
Mg^{2+} (mg/l)	19.2	66	42.48	45.6	17.01	60
Na^{+} (mg/l)	64.4	230	188.6	211.6	69.91	919
K^{+} (mg/l)	7.8	23.4	16.38	15.6	5.78	2
HCO_3^-(mg/l)	195.2	518.5	396.5	439.2	130.97	610
Cl^- (mg/l)	92.3	284.0	211.58	234.3	83.01	1063
SAR	1.7	5.3	4.1	4.7	1.45	16
Pb (µg/l)	3.2	29.5	19.78	19.7	10.54	500
Cd (µg/l)	1.0	10.0	8.06	9.9	3.95	10
Zn (µg/l)	43.8	96.8	63.52	56.8	20.24	200
Mn (µg/l)	7.6	63.5	35.76	43.8	26.38	200
Cr (µg/l)	25.2	26.3	25.70	25.4	0.55	10
Ni (µg/l)	13.1	14.0	13.58	13.6	0.35	200
Cu (µg/l)	1.2	5.1	3.00	3.3	1.68	200
Fe (µg/l)	3.0	98.0	23.96	7.5	41.46	500
Co (µg/l)	10.1	11.4	10.80	11.0	0.61	5
Li (µg/l)	3.3	6.4	5.66	6.3	1.33	250

*FAO (1994)

Table 5. The Correlation matrix for water parameters

Parameter	pH	EC	Ca	Mg	Na	K	HCO3	Cl	SAR	Pb	Cd	Zn	Mn	Cr	Ni	Cu	Fe	Co	Li
pH	1																		
EC	-0.64	1																	
Ca	-0.79	0.70	1																
Mg	-0.71	0.98	0.79	1															
Na	-0.38	0.90	0.32	0.82	1														
K	-0.49	0.96	0.68	0.96	0.85	1													
HCO3	-0.62	0.90	0.49	0.83	0.90	0.76	1												
Cl	-0.12	0.81	0.46	0.78	0.79	0.93	0.58	1											
SAR	0.01	0.60	-0.15	0.46	0.89	0.56	0.72	0.60	1										
Pb	0.80	-0.78	-0.84	-0.78	-0.54	-0.65	-0.80	-0.41	-0.18	1									
Cd	0.71	-0.71	-0.98	-0.77	-0.35	-0.68	-0.55	-0.50	0.08	0.90	1								
Zn	-0.49	-0.08	-0.13	-0.08	-0.01	-0.32	0.22	-0.60	0.02	-0.13	0.20	1							
Mn	-0.85	0.81	0.69	0.87	0.65	0.75	0.67	0.47	0.30	-0.60	-0.58	0.26	1						
Cr	0.42	-0.58	-0.22	-0.46	-0.64	-0.37	-0.86	-0.23	-0.61	0.71	0.35	-0.37	-0.26	1					
Ni	-0.29	-0.07	-0.13	0.02	0.00	-0.09	-0.11	-0.26	-0.03	0.32	0.34	0.55	0.48	0.35	1				
Cu	0.26	-0.81	-0.61	-0.83	-0.70	-0.94	-0.51	-0.96	-0.43	0.43	0.60	0.59	-0.60	0.08	0.12	1			
Fe	-0.44	0.10	-0.20	0.07	0.26	-0.10	0.35	-0.34	0.32	-0.03	0.30	0.91	0.42	-0.35	0.71	0.34	1		
Co	0.18	-0.39	-0.51	-0.33	-0.21	-0.33	-0.43	-0.34	-0.05	0.71	0.68	0.32	0.09	0.58	0.89	0.25	0.51	1	
Li	-0.36	-0.06	0.23	-0.09	-0.20	-0.27	0.21	-0.44	-0.27	-0.54	-0.34	0.45	-0.16	-0.58	-0.43	0.48	0.10	-0.62	1

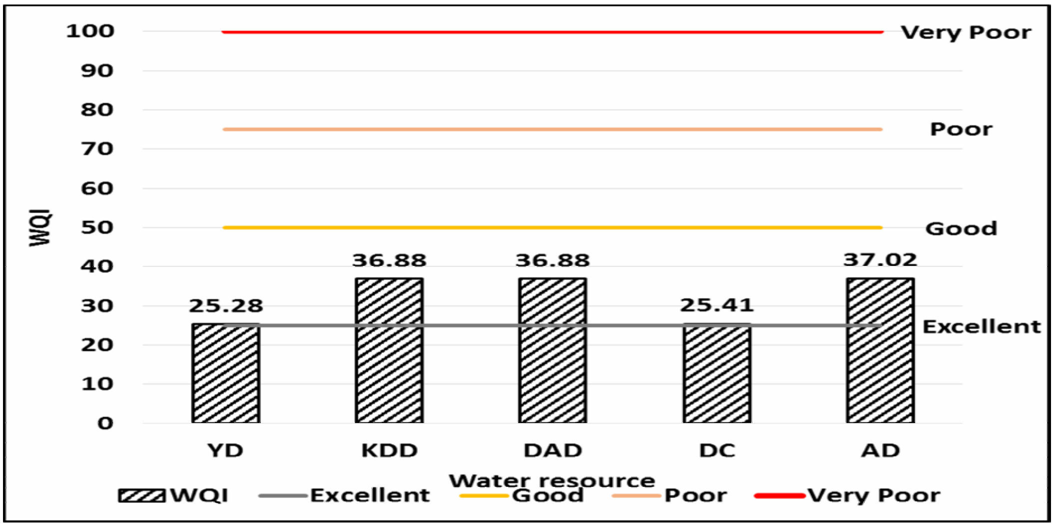

Fig. 2.WQI of Kafr El-Dawar water resources for irrigation utilizations

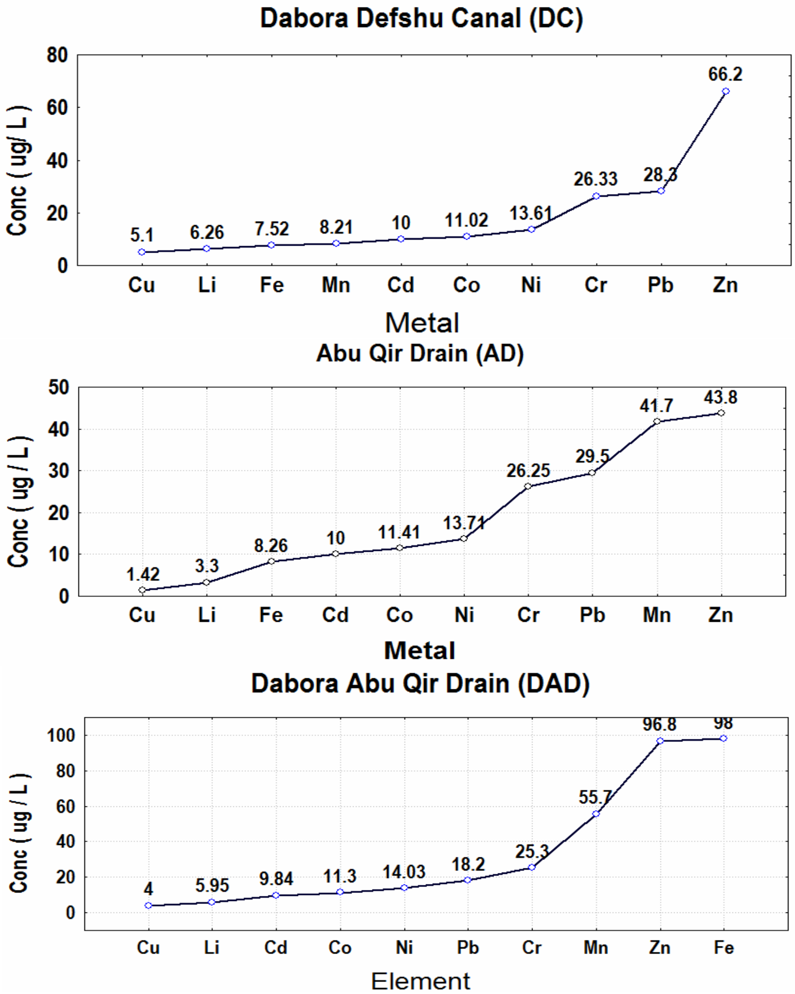

Fig 3. Increasing sequence of heavy metals of water resources DC, AD and DAD

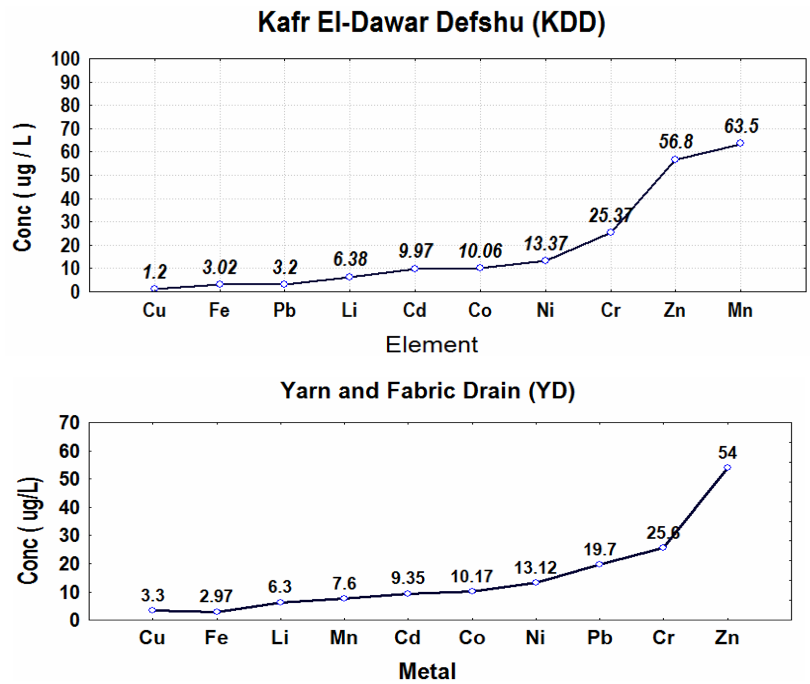

Fig 3 cont. Increasing sequence of heavy metals of water resources KDD and YD

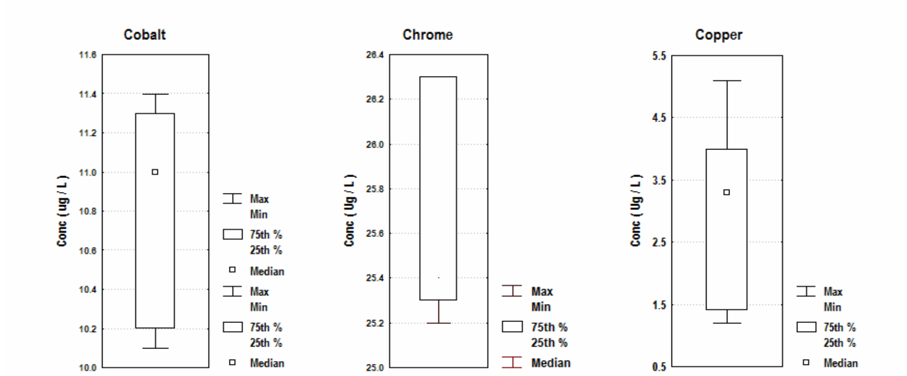

Fig 4, a. Wide spread - distribution pattern of Cr ,Co,Cu water resources

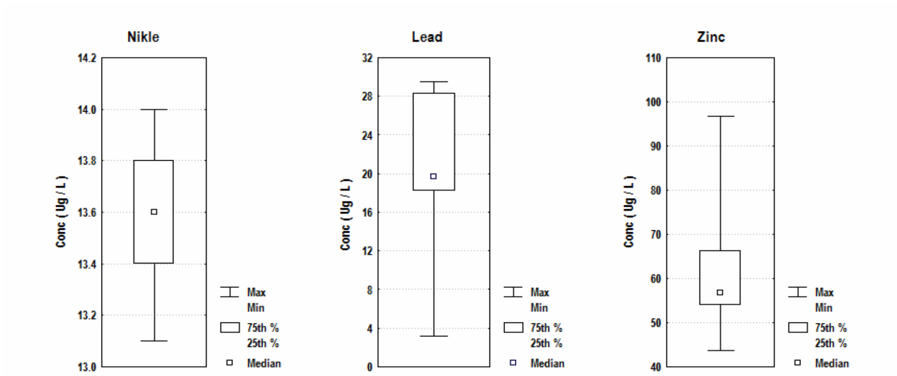

Fig 4. b.Distribution pattern : moderately spread of Pb , Ni and Zn in water resources

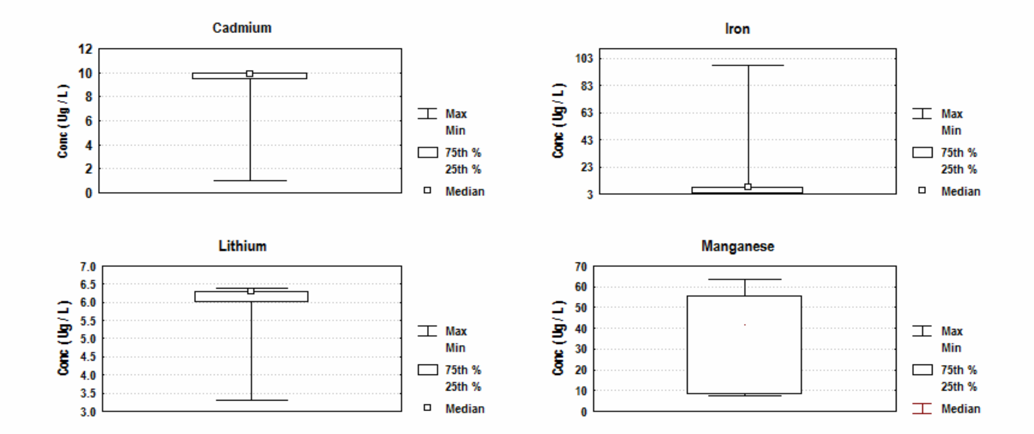

Fig 4.c. Distribution pattern : narrow spread of Fe, Cd, Li and Mn in water resources

Assessment of heavy metals pollution:

Heavy metals in water resources, in the cases of short and long term use, was assessed based on: (i) heavy metals conventional scale, (ii) indexing approach of contamination index (CI), and (iii) metallic Index (MI).

(i) Heavy Metals conventional scale:

A conventional scale was derived from recommended limits for constituents in reclaimed water for irrigation (EPA, 2004) to determine the classes of heavy metal in water pollution (Table 6). This conventional scale was based on MAC_s and MAC_l that are maximum admissible concentrations (upper permissible limits) in cases of short and long term uses, respectively. The values of MAC_s and MAC_l were considered as the lower limits of polluted class. The lower and upper limits of the safe concentrations of *i* th heavy metal assume to be less than 5 % and 10% of MAC_s and MAC_l . The risky class of water pollution by heavy metals was represented by a range from the value greater than the upper limit of safe class and the value of the lower limit of polluted class.

Table 6. Conventional interpretative scale of heavy metals in water

metal	Short Term Use (µg/L)				Long Term Use (µg/L)			
	Ideal	**Safety**	**Risky**	**Polluted**	**Ideal**	**Safety**	**Risky**	**Polluted**
Cd	< 2.5	2.5-5.0	5-50	>50	< 0.5	0.5-1.0	1-10	>10
Co	< 250	250-500	500-5000	>5000	< 2.5	2.5-5	5-50	> 50
Cr	< 50	50-100	100-1000	>1000	< 5	5-10	10-100	> 100
Cu	< 250	250-500	500-5000	>5000	< 10	10-20	20-200	>200
Fe	< 1000	1000-2000	2000-20000	>20000	< 250	250-500	500-5000	> 5000
Li	< 125	125-250	250-2500	>2500	< 125	125-250	250-2500	>2500
Mn	< 500	500-1000	1000-10000	>10000	< 10	10-20	20-200	>200
Ni	< 100	100-200	200-2000	>2000	< 10	10-20	20-200	>200
Pb	< 500	500-1000	1000-10000	>10000	< 250	250-500	500-5000	>5000
Zn	< 500	500-1000	1000-10000	>10000	< 100	100-200	200-2000	>2000

Table 7. Classes of heavy metals pollution in case of short-term use, based on conventional interpretative scale of heavy metals pollution in water

Water resource	Class									
	Cu	**Fe**	**Li**	**Mn**	**Cd**	**Co**	**Ni**	**Pb**	**Cr**	**Zn**
YD	Ideal	Ideal	Ideal	Ideal	Risky	Ideal	Ideal	Ideal	Ideal	Ideal
KDD	Ideal	Ideal	Ideal	Ideal	Risky	Ideal	Ideal	Ideal	Ideal	Ideal
DAD	Ideal	Ideal	Ideal	Ideal	Risky	Ideal	Ideal	Ideal	Ideal	Ideal
DC	Ideal	Ideal	Ideal	Ideal	Risky	Ideal	Ideal	Ideal	Ideal	Ideal
AD	Ideal	Ideal	Ideal	Ideal	Risky	Ideal	Ideal	Ideal	Ideal	Ideal

Table 8. Classes of heavy metals pollution in case of long-term use, based on conventional interpretative scale of heavy metals pollution in water

Water resource	Class									
	Cu	Fe	Li	Mn	Cd	Co	Ni	Pb	Cr	Zn
YD	Ideal	Ideal	Ideal	Ideal	Risky	Polluted	Safe	Ideal	Risky	Ideal
KDD	Ideal	Ideal	Ideal	Polluted	Risky	Polluted	Safe	Safe	Risky	Ideal
DAD	Ideal	Safe	Ideal	Risky	Risky	Polluted	Safe	Ideal	Risky	Ideal
DC	Ideal	Ideal	Ideal	Ideal	Risky	Polluted	Safe	Ideal	Risky	Ideal
AD	Ideal	Ideal	Ideal	Risky	Risky	Polluted	Safe	Ideal	Risky	Ideal

Table 9. Contamination factor (C_{fi}) and level of heavy metals in water

Water resource	Contamination factor(C_{fi}) of heavy metals in water									
	Cd	Co	Cr	Cu	Fe	Li	Mn	Ni	Pb	Zn
YD	0.87	0.98	-0.74	-0.99	-1.00	-0.98	-0.99	-0.93	-0.98	-0.95
	Risky	Risky	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe
KDD	0.99	-0.98	-0.75	-1.00	-1.00	-1.00	-0.65	-0.93	-1.00	-0.95
	Risky	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe
DAD	0.97	-0.98	-0.75	-1.00	-0.78	-0.98	-0.94	-0.93	-0.98	-0.90
	Risky	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe
DC	1.00	-0.98	-0.74	-0.99	-1.00	-0.98	-1.00	-0.94	-0.97	-0.93
	Risky	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe
AD	1.00	-0.98	-0.74	-1.00	-1.00	-1.00	-0.96	-0.93	-0.97	-0.96
	Risky	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe

Application of the conventional interpretative scale on heavy metals water pollution indicated that the concentrations of heavy metals generally at the safe levels, at case of short term use, (Table 7). This had an exception represented by Cd concentration in all water resources which is risky. Also, classes of heavy metals pollution (case of long-term use) were assessed based on their conventional interpretative scale (Table 8). The data showed that Co concentrations of all studied water resources, occupied the polluted class. Meanwhile, Mn concentration of the water resource (KDD) represents polluted class at the long-term use. The risky pollution class was found in Cd and Cr in all water resources under investigation as well as Mn in DAD and AD resources.

Contamination index (CI)

The contamination index of the studied waters was calculted to assess indivdually the contamination degree of each heavy metal (Table, 9) .The data indicted that the values of contamination factor (C_{fi}) ranged from 0.0 to 1.00. The contamination factor of cadmium (C_{fCd}) had generally the highest values which refer that cadmium is the more effective polutant. This data showed that the majority of heavy metals had low values of contamination factor (C_{fi}), to point out that the studied water resources at safe use level. This certainly with expection of cadmium.

The contamination index (CI) was calculated in cases of short and long term use to assess the heavy metals pollution in water. For the cases of short use, the CI values ranged from -7.49 (water of AD) to 7.51 (water of DC). As for the cases of long-term use, the CI values extended from 5.49 (water of YD) to 33.20 (water of KDD). The contamination index was used as reference to evaluate the extent of metal pollution (Table 10). This interpretation scale of contamination was modified by introducing the case of long use. An additional development was introduced by considering the CI negative values to have safe water use. The data showed that the CI of water of (YD), (DAD) and (AD) had the negative values of -5.67, -7.26 and -7.49, respectively. This indicated that water in the studied resources are safe in use at the short time run. Contrary, all studied water resources were highly contaminated that they cannot be used at the long time run (Table, 11).

Table 10. Interpretative scale of contamination index

N	Contamination Degree	Contamination Index (CI)	
		Short Use	Long Use
1	Safe	< 0.0	< 0.0
2	Low	0.0 - ≤ 1	0.0 - ≤ 0.5
3	Medium	>1 - < 3	> 0.5 - < 1.5
4	High	≥ 3	≥ 1.5

Table 11. Contamination Index of studied water resources

Water resource	Contamination Index (CI)			
	Short-term Use		Long-term Use	
	value	Class	value	Class
YD	-5.67	Safe	5.49	High
KDD	2.80	Medium	33.20	High
DAD	-7.26	Safe	9.75	High
DC	7.51	High	6.61	High
AD	-7.49	Safe	8.06	High

Metal index (MI):

Another index is used to estimate the pollution of water by heavy metals under investigation for irrigation utilization. Metal index denotes the trend evaluation of the present status by computing all measured metals (Table 12). According to the values of metal index, four of five selected drains or canal are seriously threatened with metal pollution for irrigation usage (MI>1), since MI reaches to 9.12 at DAD drain for irrigation usages. Only KDD drain has low value of MI (-0.21) less than MI threshold of warning value. Therefore, no heavy metal problems expected as a result of use KDD drain for irrigation usage.

Table 12. Metal index in Kafr El-Dawar water resources for irrigation water utilizations

Water Resource	MI value	MI class
YD	5.50	Threshold of warning
KDD	-0.21	No warning
DAD	9.12	Threshold of warning
DC	6.60	Threshold of warning
AD	8.06	Threshold of warning

Conclusion and recommendation

Water resources in Kafr El-Dawar region receive wastewater from textile companies which suppress the water quality. Although WQI results showed that the water quality of the studied resources is good for irrigation usage according to the selected parameters in the present study. Using contamination index to evaluate heavy metal pollution indicated that water in these resources are safe in use at the short time run. However, high contaminated was noticed at the long time run. Also, metal index parameter agree with the data of contamination index except in water of KDD source. Therefore, the study recommends tightening the control on the discharged wastewaters into these water resources, to meet with the effluent concentration discharge standards set in Egyptian Law 48/1982 for the protection of the waterways in the region against pollution.

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الملخص العربي

تقييم جودة المياه ومؤشرات المعادن الثقيلة لبعض مصادر المياه بمنطقة كفر الدوار- مصر

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كفر الدوار تعتبر مدينة صناعية وسكنية كبرى في منطقة غرب دلتا النيل في شمال مصر. ويوجد بها العديد من المصانع التي تفرز كثير من العناصر الملوثة. تقييم نوعية المياه مهم جدا لمعرفة ما إذا كانت آمنة أم لا للرى. لذاك تم تجميع خمسة وعشرين عينة من بعض مصادر المياه في منطقة كفر الدوار. هذه المصارف هي الغزل والنسيج(YD)، كفر الدوار دفشو (KDD)، دبارة أبو قير (DAD)، ترعة دبارة دفشو (DC) ومصرف أبو قير (AD).

أوضح مربع وسكر (Whisker Box-plot) أن المعادن الثقيلة يمكن تصنيفها وفقا لتجانس تركيزهم إلى(أ) غير متجانسة واسعة الانتشار وتشمل: الكروم والكوبلت والنحاس. (ب) متوسطة الانتشار- متوسط التجانس وتشمل: الرصاص والنيكل والزنك(ج) ضيقة الانتشار- متجانسة وتشمل: الحديد والكادميوم والليثيوم والمنجنيز. دراسة الترابط (correlation) تصنف المعادن الثقيلة إلى ثلاث مجموعات: عناصر ذات ترابط إيجابى مرتفع بين الرصاص وكل من الكادميوم والكوبلت والكروم وهذا يدل على أن مصادر المياه لها نفس مصدر التلوث. وعلى النقيض عناصر ذات ترابط سلبى مرتفع بين (الرصاص- المنجنيز)، (المنجنيز-النحاس)، (الكوبلت-الليثيوم) وهذا يفترض أن هذه العناصر الثقيلة نشأت من مصادر مختلفة.

تم تقييم نوعية موارد المياه للري من خلال دليل جودة المياه WQI عند الاستخدام على المدى القصير والطويل من خلال مقياس اتفاقى(conventional scale)، دليل التلوث بالمعادن الثقيلة (CI) ودليل المعادن (MI). طبقاً لوكالة حماية البيئة الامريكية فإن تركيز المعادن الثقيلة بشكل عام آمن باستثناء الكادميوم وذلك فى حالة الاستخدام على المدى القصير. بينما في حالة الاستخدام على المدى الطويل فان تركيز الكوبلت في مدى التلوث في جميع مصادر المياه وكذلك المنجنيز في مصرف كفر الدوار دفشو (KDD). وصل التلوث بالكادميوم والكروم لحد الخطورة في جميع المصادر وكذلك المنجنيز في المصرفين دبارة أبو قير (DAD)ومصرف أبو قير (AD).

يوضح دليل جودة المياه WQI أن مصادر المياه "جيدة" وفقا لاستخدامها في الري. توضح قيم دليل المعادن (MI) أن المصارف أو القناة تحت الدراسة مهددة بشدة بالتلوث بالمعادن الثقيلة عند استخدامها للرى (MI> 1). مصرف KDD الوحيد الذى لا يوجد لديه مشاكل من المعادن الثقيلة عند استخدامه في الري. قيم دليل التلوث CI في مصارف (YD) و(DAD) و(AD) كانت سالبة -٥,٦٧، -٧,٢٦ و -٧,٤٩ بالترتيب. والذي يشير إلى أن هذه المصادر للمياه آمنة لاستخدامها في المدى القصير. على العكس من ذلك، كانت جميع مصادر المياه ملوثة ولايمكن استخدامها على المدى الطويل.