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Assessment of Drains Water Quality for Irrigation Purposes Using Pollution Indices in Egypt

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Abstract

The drainage systems are a major source of water that can be used again in agriculture. The current objective of this study is to evaluate the suitability for irrigation of 50 drain water samples collected during summer 2021 surrounding Rosette Branch. According to statistical analyses of the physicochemical parameters measured, the average temperature of the drain water was around 28.192 °C, with a range of 23.3 to 32.4 °C. The mean pH value was 7.64, which ranged from 6.51 to 8.71. The conductivity (EC) showed a mean value of 848.52 µS/cm, which ranged between 330 to 1591 µS/cm. The total dissolved solids (TDS) showed a mean value of 547.5 mg/L, which was acceptable for irrigation use. The range of TDS values was varied from 211.2 to 1034 mg/L. The average concentration of trace element values for the collected drainage samples were in the following sequences: Zn > Fe > Al > Mn > Cr > Pb > Ni > CO > Li > Cd, respectively. The pollution indices, including the heavy metal pollution index (HPI), metal index (MI), contamination index (C_d), and pollution index (PI), were estimated. For instance, The MI values revealed that 36% of samples were slight affected, 10% of samples were moderately affected, 42% of samples were strongly affected, and 12% of samples were seriously affected on water quality for irrigation. In the long-term irrigation water use, the MI had a median value of 4.10, which ranged from 1.01 to 23.35.

Keywords: Physicochemical properties, Water Quality, Pollution indices, Egypt.

Introduction

Surface water is one of the most important irrigation resources, particularly in areas with severe water shortages (**Mosaad, 2017**). Additionally, Egypt uses several water sources for irrigation, including treated domestic wastewater and agricultural drainage water. Desalination is increasingly used in multiple places along the Mediterranean and Red Sea coasts to supply domestic water supplies in addition to nonconventional water resources (**El-Amier et al., 2021**). Documented contamination indices for metals have been applied in many research investigations monitoring water quality and water contamination (**Gad and El- Hattab, 2019)**.

In addition, drain water contains the highest amounts of trace elements such as iron, manganese, chrome, lead, aluminum, cooper, barium, nickel, cadmium, cobalt, and zinc (**El-Bana et al., 2003; El-Bana et al., 2006**). The high concentrations of trace elements in drain water are mostly caused by industrial and agricultural activities. Other sources of metal pollution in drain water are atmospheric interaction and inorganic deposits, metal-related production activities, and city waste discharges. By constructing a control strategy that assesses the improvement, new manufacturing technology, and human activity planning to limit adverse impacts on water quality supplies, water pollution indices are seen as an economical means to maintain safety.

With respect to various heavy metals, the pollution index (PI) quantifies the effects of water contamination rates on water quality. The contamination degree (C_d) measures the total effect of all metals on water quality and independently evaluates the relative harmful effects of various metals (**Caerio et al., 2005**). The impact of heavy element on water is measured qualitatively using the heavy metal pollution indices. These measurements were developed in accordance with the significance of measuring the negative impacts of heavy metals **(Prasad and Bose, 2001**). The heavy element pollution technique is used to evaluate water suitability for irrigation depends on heavy metals and pollution indices to describe the quality of water and help identify and quantify water quality trends (**Balakrishnan and Ramu, 2016).** The varied levels of contamination and their effects on the water quality are clarified by the pollution indices. The pollution indices (PIs) are usually present for the evaluation of any system's quality and provide information regarding pollution in relation to specific standers.

Materials and methods

Study area

The area of the study representing the southern part of the Nile Delta is situated between 30^{O} $05^{/}$ $96^{//}$ and 30^{O} 39/ 61″ N latitudes 30^{O} $51^{/}$ $19^{//}$ and 31^{O} $06^{/}$ $99^{//}$ E longitudes (Fig. 1).

Samples collection and analysis

Fifty samples of drain water were obtained for this study in 2021. The samples had been collected in 1000 mg polyethylene bottles, kept in a 4 °c refrigerator, and then put through the standard analysis process. Using GPS, the sampling site's geoposition was determined, and sample positions were then mapped.

The sampling bottles were rinsed twice or three times with the sample water to decrease the chance of contaminating. two ml of concentrated HNO_3 was added to each batch to lower the pH below 2, reduce the amount of metal ions in the solution, and prevent adsorption and deposition on the bottle walls.

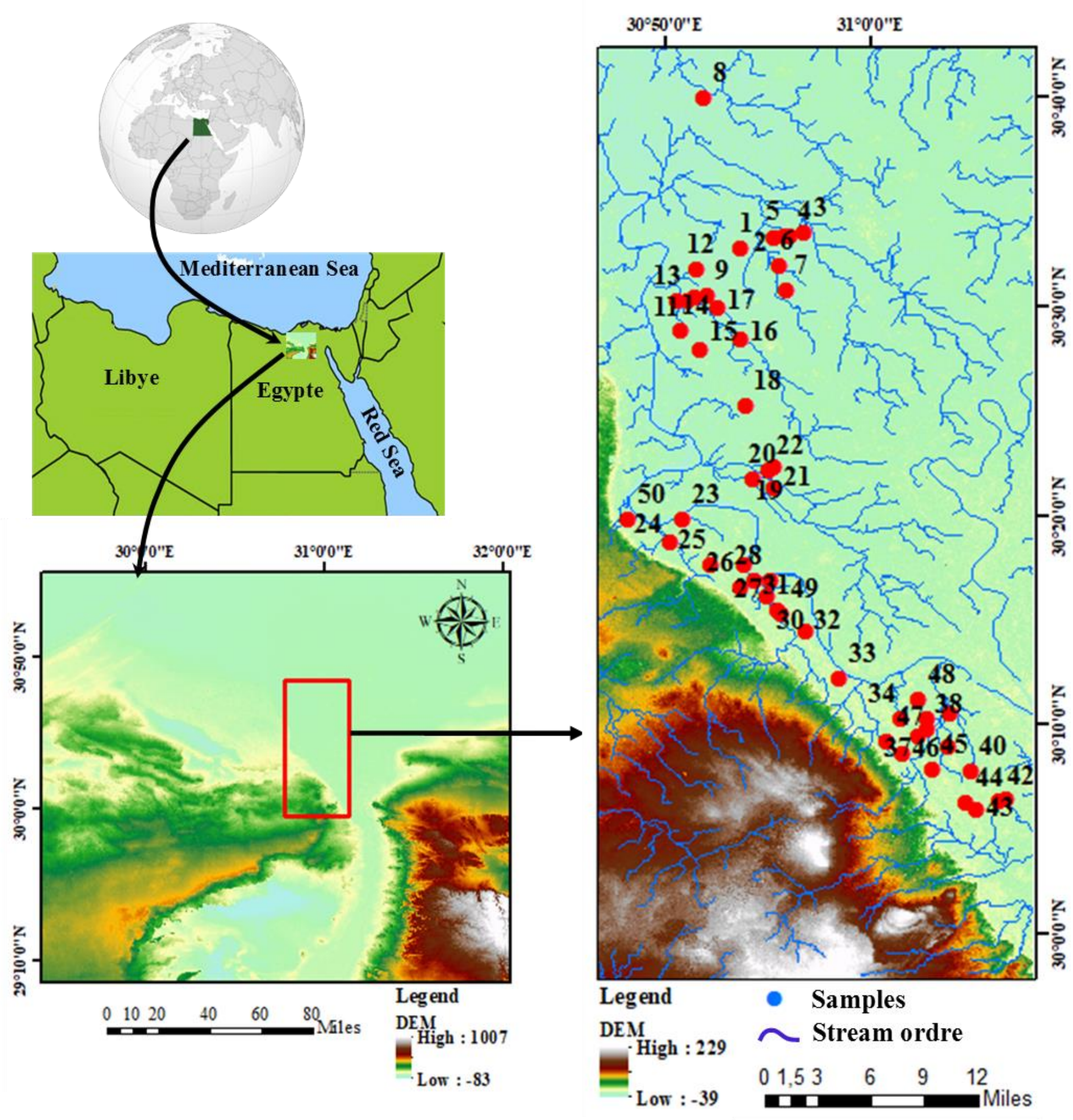

Fig. 1. Location map of the drains water samples in the study area.

The Hanna HI 9811-5, manufactured by Hanna Instruments Italia Srl in 35030 Sarmeola di Rubano-PD, Italy, calibrated salinity multi-parameter device was used to measure in situ a variety of physicochemical parameters, including pH, temperature (T°c), electrical conductivity (EC), and total dissolved solids (TDS). The inductively coupled plasma mass spectroscopy (ICP-MS) was used to measure the metal concentrations. The average and relative standard deviation were calculated using Qtegra software (APHA, 2005). The laboratory has EGAC/ILAC accreditation with the number 217006. The outcome of the metal recovery was within the approved bounds.

Pollution indices (PIs)

Drain water contains the high amounts of trace metals such as iron, manganese, chrome, aluminum, cooper, nickel, and zinc. The heavy metal pollution index (HPI), metal index (MI), contamination index (C_d), and pollution index (PI) are some documented pollution indices (PIs), which depend on the concentration of different metals, such as B, Cd, Cr, Cu, F, Fe, Mn, Ni, Pb, and Zn. It is not appropriate to evaluate water quality using just one parameter because it might be limited and lead to inadequate results. Water pollution indicators, such as the HPI, MI, C_d, and PI are useful for examining water quality (**Edet et al., 2002; Sobhanardakani et al., 2012**). As concentrations increase over time, water quality and purification are under a lot of pressure. Heavy elements are becoming one of the most significant problems for the environment as a result of new regulations (**El-Amier et al., 2020)**.

Heavy metal pollution index (HPI)

Water quality is evaluated using HPI based on element concentrations. The combined impact of various metals on the purity of water is measured by the HPI rating (**Edet and Offiong, 2002; Nasrabadi , 2015**). Low metal pollution (HPI < 100), metal pollution with threshold risk (HPI = 100), and excessive metal pollution (HPI > 100) were the three groups into which the HPI values were classified. The HPI provides information on the overall quality of water and aids in identifying and quantifying trends in water quality with respect to metals, according to the following equation:

$$\mathrm{HPI} = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i-1}^{n} W_i}$$

Where n = 10, which denotes the number of metals monitored, and W_i and Q_i, respectively, are the unit weights and sub-indices for Al, Cd, Co, Cr, Li, Fe, Mn, Ni, Pb, and Zn.

Metal index (MI)

The MI represents the metal-induced stress on water quality using the following formula:

$$\mathrm{MI} = \sum_{i=1}^{n} \frac{H_c}{H_{max}}$$

Where H_{max} is the maximum permitted concentration for each metal, subscript i is the number of the sample, and H_c is the metal concentration **(Tamasi and Cini, 2004)**. The MI for water quality can be categorized for different levels according to Table 1.

Table 1. Classification of water quality according to MI.

Class	MI	Characteristics
I	< 0.3	Very pure
II	0.3-1	Pure
III	1.0-2.0	Slightly affected
IV	2.0-3.0	Moderately affected
V	3.0-6.0	Strongly affected
VI	>6	Seriously affected

Contamination index (C_d)

The contamination factors of specific metals that exceeded permitted limits, which are expressed as C_d values, were used to calculate the surface water contamination levels **(Caerio et al., 2005; Edet and Offiong, 2002)** according to the formula below:

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

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

Where C_{Ni} is the allowed concentration of each metal, C_{Ai} is the analytical value for each metal, C_{fi} is the contamination factor for that metal, and C_{Ni} is selected as the maximum allowable concentration (MAC). Table 2 shows the characteristics of water quality according to the pollution levels.

Table 2. Classification of water quality according to contamination index (c_d).

Class	**C_d**	**Characteristics**
Low	< 0.3	>1
Medium	0.3-1	1-3
High	1.0-2.0	< 3

Pollution index (PI)

The effect of pollution on metals in surface water was calculated using PI. The PI was divided into five classes (**Caerio et al., 2005; Goher et al., 2014**), represent the particular pollution effects of each metal on the quality of surface water, and it can be calculated using the following formula:

$$PI = \frac{\sqrt{\left[\left(\frac{C_i}{S_i}\right)^2_{max} + \left(\frac{C_i}{S_i}\right)^2_{min}\right]}}{2}$$

Where S_i is the metal level determined by the concentration of each metal in water, and C_i is the concentration of each metal. Moreover, the level of pollution in water can be classified according to its effects on water quality (Table 3).

Table 3. Classification of water quality according to level of pollution.

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

Results and discussion

The pollution indices including HPI, MI, C_d, and PI were calculated for the concentrations of metals, such as Al, Cd, Cr, Co, Li, Fe, Mn, Ni, Pb, and Zn. The results were statistical presented as shown in Table 4.

Table 4. Statistical analysis of metal concentration in the obtained samples.

Metals	Al	Cd	Co	Cr	Fe	Li	Mn	Ni	Pb	Zn
Min	0.091	0.001	0.001	0.018	0.016	0.002	0.042	0.005	0.007	0.041
Max	0.986	0.009	0.245	0.807	1.407	0.009	2.281	0.636	0.326	9.570
Mean	0.484	0.002	0.008	0.078	0.633	0.004	0.260	0.032	0.038	2.454
Stand. Dev	0.217	0.001	0.035	0.147	0.219	0.002	0.332	0.091	0.053	2.901

Heavy metal pollution index (HPI)

The HPI results showed that long-term irrigation water ranged between 13.29 and 154.11, with an average of 30.71, which showing about 96% of samples fell under the recommended value and 4% of samples above the recommended value (100) (Table 5 and Fig. 2). The HPI values for short-term usage varied from 2.22 to 17.24, with a mean value of 4.91, indicating that 100% of samples was below the recommended value (100), indicating low pollution and suitable water for irrigation (Fig. 2). During long-term use, the metals had increased concentrations of Zn, Fe, Al, Mn, and Cr, which cause water contamination in two drains.

Table 5. Statistical analysis of HPI, MI and C_d during long term and short-term use for irrigation.

	Pollution indices (PIs)	HPI	MI	C_d		HPI	MI	C_d
Short-term use	Min	2.22	0.14	-9.86	**long-term use**	13.29	1.01	-8.99
	Max	17.24	1.69	-8.31		154.11	23.35	13.35
	Mean	4.91	0.48	-9.52		30.71	4.10	-5.90
	Stand. Dev	2.45	0.39	0.39		24.30	3.87	3.87

Metal index (MI)

The MI result indicated that metals slowly impacted on the collected drain water samples. The MI values revealed that 36% of samples were slight affected, 10% of samples were moderately affected, 42% of samples were strongly affected, and 12% of samples were seriously affected on water quality for irrigation. In the long-term irrigation water use, the MI had a median value of 4.10, which ranged from 1.01 to 23.35 (Table 5). According to the statistical chemical analysis of drainage system (Fig. 3), the top portion of Sabal drainage was revealed the activity of industry

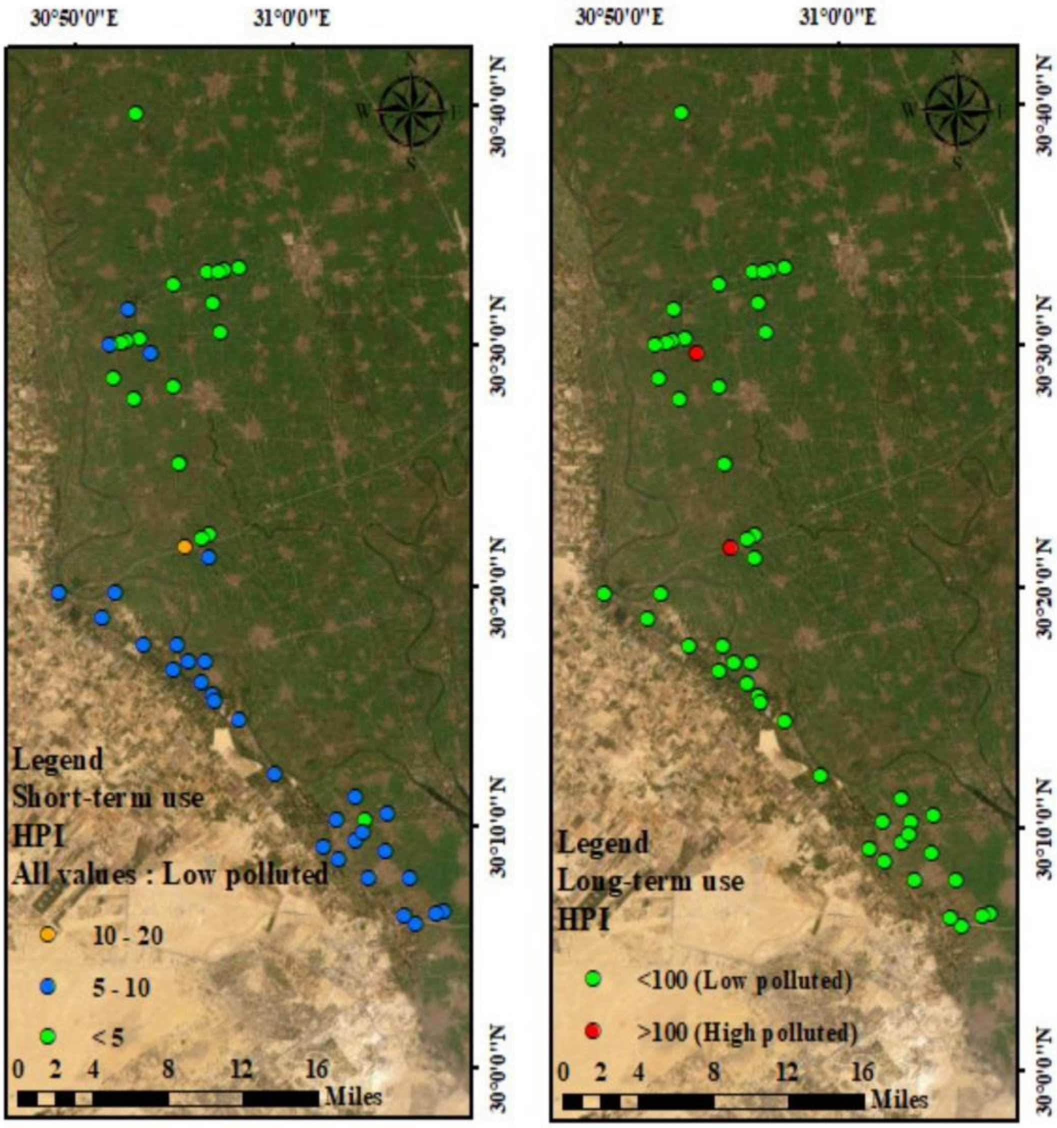

Fig. 2. Heavy metal pollution index distribution maps of drains water network for long term and short term use.

wastewater, as shown by the spatial variation map of MI results (Tables 5 and 6, and Fig. 3). The MI values revealed that about 58% of samples were very pure for short-term usage, while 32% of samples were pure, and 10% of samples were slightly affected with metals (Fig. 3).

Contamination index (C_d)

The C_d levels for the water samples from the investigated drainage ranged between -8.99 and 13.35, with an average of -5.9 (Table 5). Table 2 and Fig. 4 showed that most of the drain water samples (94%) were low contaminated with metals, while about 6% of the samples were high contaminated water over a long period of time. In the case of a

Table 6. The National Academies of Science and Engineering (1972) established recommended upper limits for trace element concentrations in irrigation water (Gupta and Gupta, 2003; Gupta and Gupta, 2015; Fipps, 2015; Rowe and Abdel-Magid, 1995).

Trace element	Recommended maximum concentration (mg/L)		Maximum concentrations of trace elements in drains water (mg/L) in study area	
	Standard for short-term use	Standard for long-term use	PI for short term use	PI for long term use
Al	20.0	5.0	0.02	0.10
Cd	0.05	0.01	0.09	0.45
Cr	1.0	0.10	0.40	4.04
Co	5.0	0.05	0.02	2.45
Fe	20.0	5.0	0.04	0.14
Pb	10.0	5.0	0.02	0.03
Li	2.5	2.5	0.00	0.00
Mn	10.0	0.2	0.11	5.70
Ni	2.0	0.2	0.16	1.59
Zn	10.0	2.0	0.48	2.39

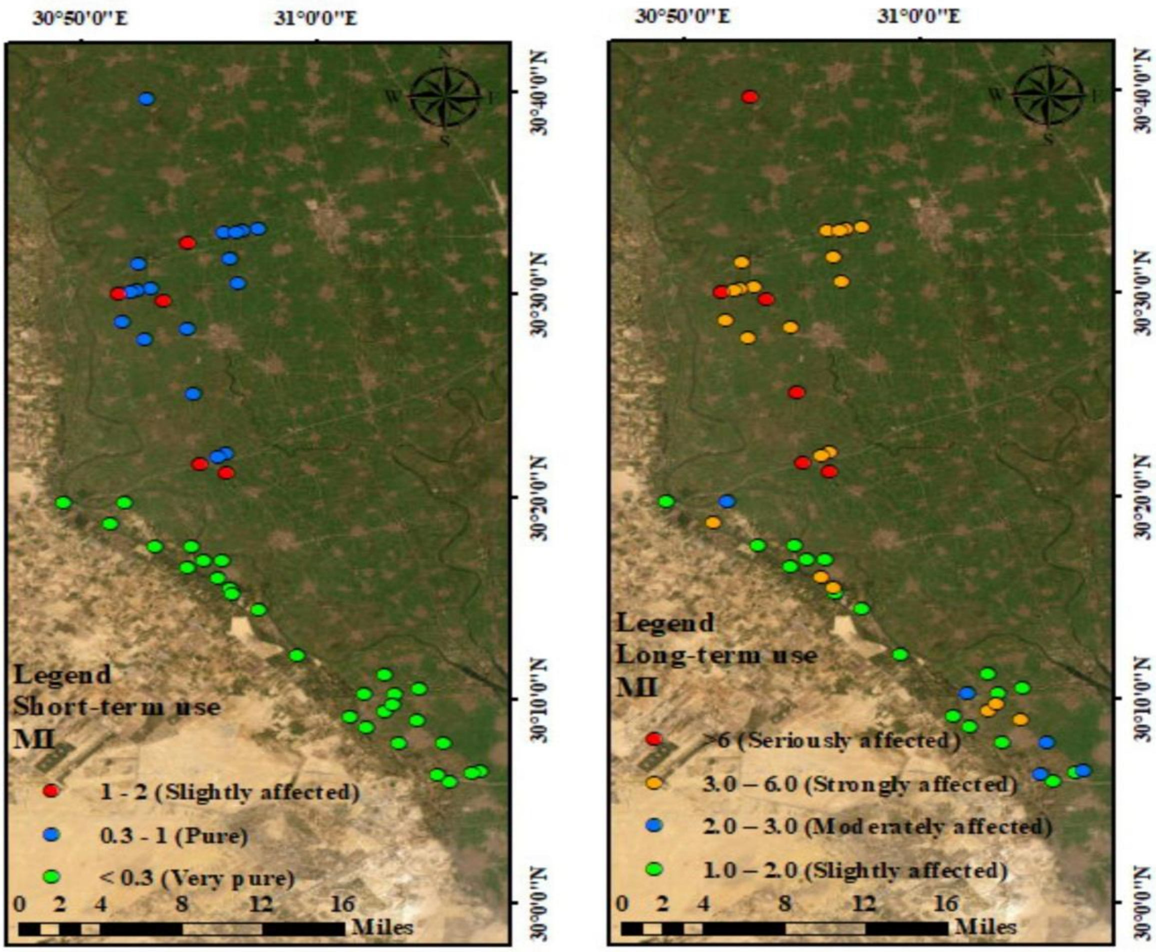

Fig. 3. Metal evaluation index distribution maps of drains water network for long-term and short-term use for irrigation.

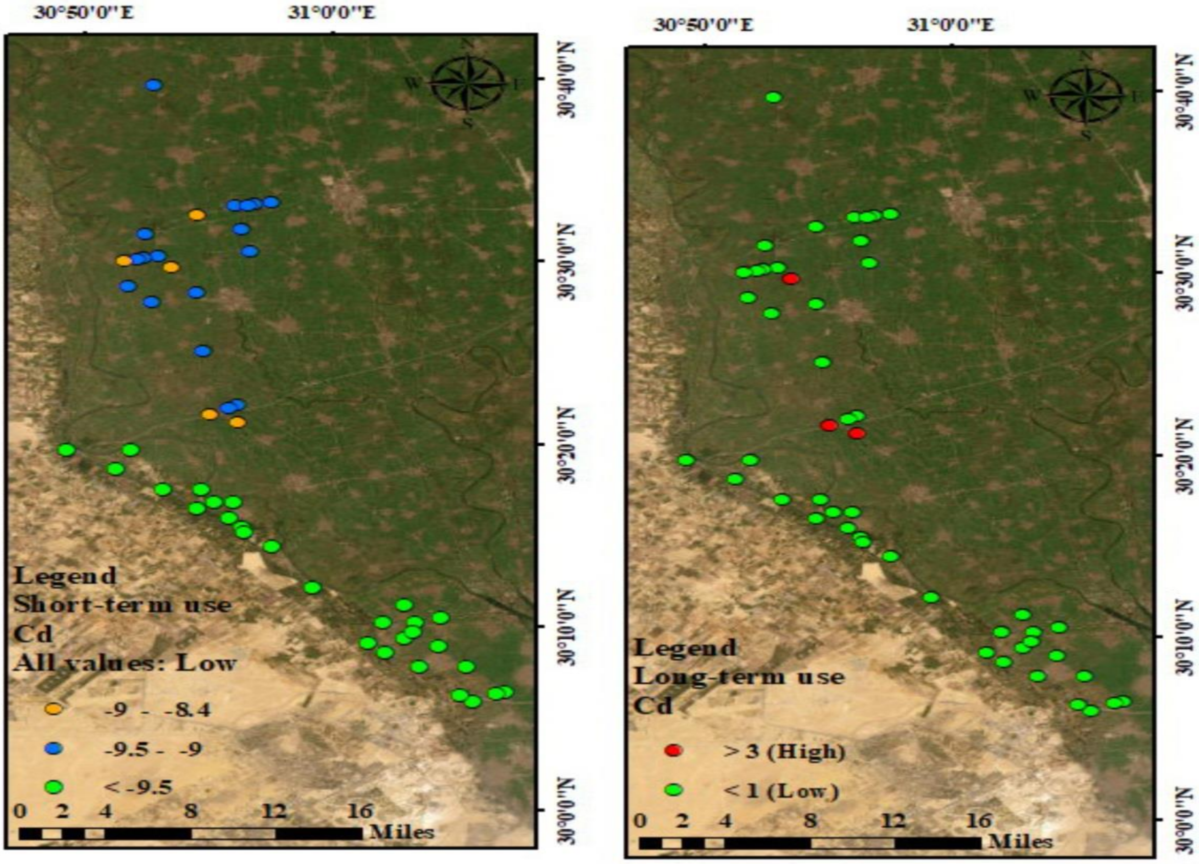

Fig. 4. Contamination index distribution maps of drains water network, for long term and short term.

short-used period of time, the majority of drain water samples (100%) had C_d levels with negative values, which can use for irrigation.

Pollution index (PI)

The following metals were found to be present in the collected water samples in order of their mean concentrations in mg/L, as the following: Zn (2.454), Fe (0.633), AL (0.484), Mn (0.260), Cr (0.078), Pb (0.038), Ni (0.032), Co (0.008), Li (0.004), and Cd (0.002). The effect of pollution on drain water was assessed for metals using PI. The five classes of data indicate the various contamination effects of each metal on the quality of the drains' water (Table 1 and Fig. 5).

Based on the recommended maximum trace element concentrations for long-term usage established by the National Academies of Science and Engineering 1972, the PI was used to assess the water quality of the drains for long-term irrigation and to estimate the toxicity and pollution resulting from trace elements (Al, Cd, Cr, Co, Li, Fe, Mn, Ni, Pb, and Zn) on plants. According to (**El-Amier et al., 2020**), anthropogenic activities increase pollution, increase metal levels in ecosystems, and put human health in danger. According to Table 6 and Fig. 6 and 7, most of trace element concentrations were high level of contamination and should be removed before being used for irrigation.

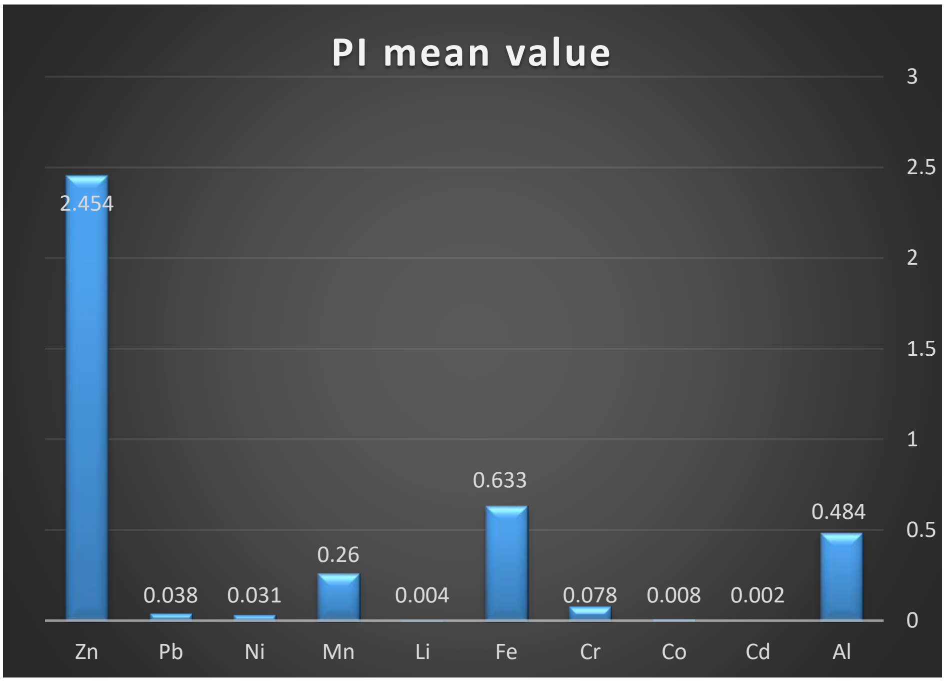

Fig. 5. The mean values pollution indices of metals from drains water in study area.

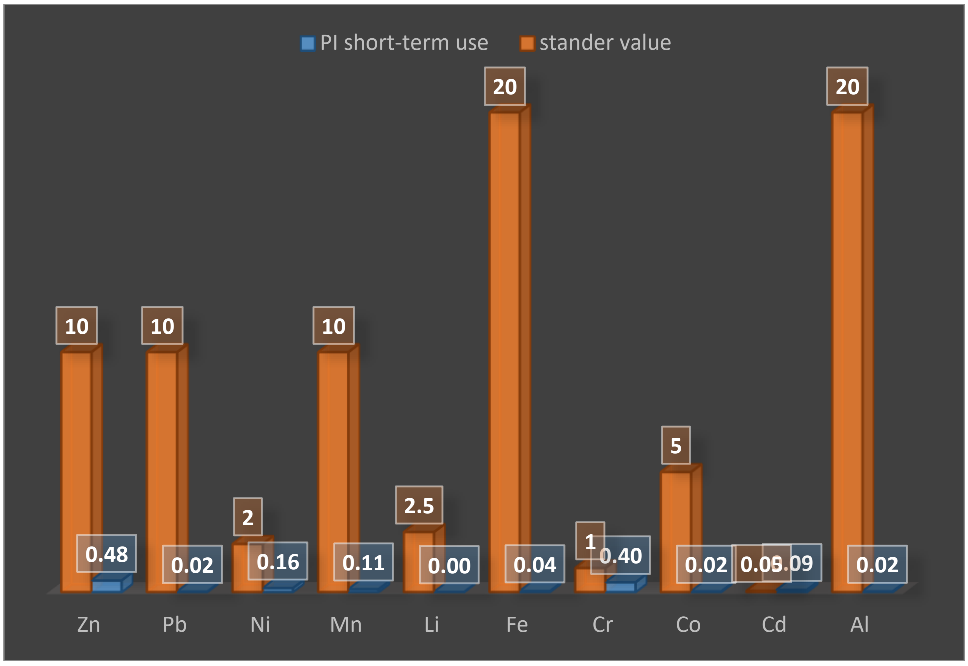

Fig. 6. The PI of the collected water samples for short term use for irrigation with standard values.

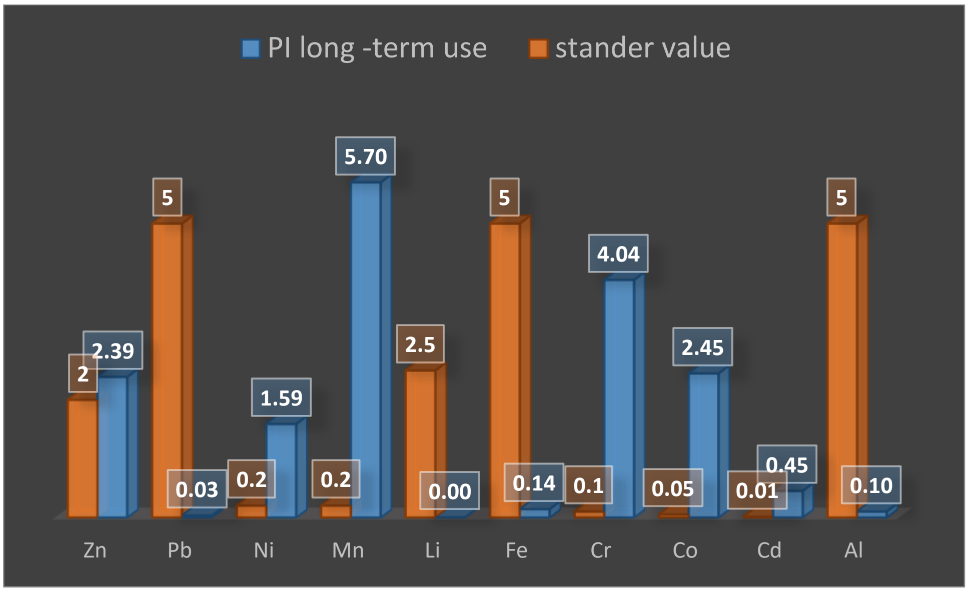

Fig. 7. The PI of the collected water samples for long term use for irrigation with standard values.

Conclusion

Based on the physicochemical analytical data of the drainage water in the research region, the conductivity (EC) showed a mean value of 848.52 µS/cm, which ranged between 330 to 1591 µS/cm. The total dissolved solids (TDS) showed a mean value of 547.5 mg/L, which was acceptable for irrigation use. The range of TDS values was varied from 211.2 to 1034 mg/L. The average concentration of trace element values for the collected drainage samples were in the following sequences: Zn > Fe > Al > Mn > Cr > Pb > Ni > CO > Li > Cd, respectively. According to the PIs results, The C_d levels for the water samples from the investigated drainage ranged between -8.99 and 13.35, with an average of -5.9. In addition, most of the drain water samples (94%) were low contaminated with metals, while about 6% of the samples were high contaminated water over a long period of time. In the case of a short-used period of time, the majority of drain water samples (100%) had C_d levels with negative values, which can use for irrigation. Large-scale agrochemical pesticide applications, industrial activity, and inadequate drainage networks can be blamed for the worsening of drain water quality. In order to properly address the deterioration of drain water quality in the research area, effective treatment methods for wastewater must be applied before disposal into the network of drains. Additionally, this sewage (human waste) was collected and taken to water treatment stations to be filtered for any metal contamination. The treated water was then used to grow plants in the desert to make wooden trees, avoiding the passing of metals to the plants and animals and preserving the ecosystem.

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