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Evaluation of water quality and pollution for some drains in south of Dakahlia Governorate, Egypt

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Abstract

Water scarcity is one of the most pressing challenges facing agriculture worldwide, particularly in arid and semi-arid regions such as Egypt. Agricultural drainage water represents an important non-conventional water resource which, if properly treated and managed, can play a vital role in mitigating water shortages and supporting Egypt's national land reclamation strategies. Dakahlia Governorate is located in the northeastern of the Nile Delta. The present study focuses on the water quality of different drains in south of Dakahlia Governorate *i.e.,* Hod El-tarfa drain, Al-Mekdam, Shobra Sora, Com El-Nour, Kafr EL-Rook and Bahr Saft Al-Kebly drain for agricultural irrigation. Results showed that pH of water in different drains is within the acceptable range, as there was no much variations. The pH value is ranged from 7.52 (in Bahr Saft Al-Kebly drain) to 7.63 (in Shobra Sora drain). Bahr Saft Al-Kebly drain showed the highest values of EC (highly saline category). The lowest value of EC was obtained in Hod El-tarfa drain (highly salinity). The classification of waters indicates that all drains *i.e.*, D1 to D6 have waters of high salinity-low sodicity (C3S1)**.** The highest value of SSP and SAR were found in Com El-Nour (58.28% and 5.20, respectively), while The lowest value was found in Al-Mekdam drain ((3.83 and 49,20, respectively). The highest values of turbidity, biological oxygen demand (BDO), chemical oxygen demand (COD) and dissolved oxygen (DO), $NO3^-$, B, Fe, Mn, Zn, Cu, Co, Cd, Ni and Pb were obtained in Kafr EL-Rook drain, while the lowest values were found in Hod El-tarfa drain.

Keywords: Water quality, Drains, Hod El-tarfa drain, Com El-Nour, Dakahlia Governorate.

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1. Introduction

In recent years, freshwater resources in Egypt have been insufficient to meet the annual irrigation needs of agricultural production. Therefore, it has become necessary to find solutions to compensate for this water shortage, including the use of drainage water. However, its quality for irrigation must be studied before use. Water scarcity is one of the most pressing challenges facing agriculture worldwide, particularly in arid and semi-arid regions such as Egypt [1,2]. The growing demand for freshwater, coupled with limited renewable resources, necessitates the search for alternative water supplies for agricultural use. Agricultural drainage water represents an important non-conventional water resource which, if properly treated and managed, can play a vital role in mitigating water shortages and supporting Egypt's national land reclamation [3,4].

Egypt is classified as one of the most water-scarce countries worldwide, with annual renewable freshwater resources limited to approximately 55.5 billion m³ from the Nile River, in addition to minor contributions from rainfall and groundwater. At the same time, total water demand exceeds 80 billion m³ per year, resulting in a significant deficit that is met through water reuse and imports of virtual water in food commodities [5]. With increasing population growth, urban expansion, and climate change impacts, water scarcity is expected to intensify, which highlights the necessity of exploring non-conventional water resources. Agricultural drainage water represents the largest source of non-conventional water in Egypt. National reports estimate that more than 10 billion m³ of drainage water are generated annually, part of which is already reused for irrigation after dilution with canal water [6]. Thus, drainage water reuse has become an integral element of Egypt's national water resources management strategy [7,8].

Water sources can be exposed to contamination risks from agricultural, domestic and industrial activities. The appropriateness of water for agricultural irrigation can be known by determination of some physico-chemical parameters [9,10]. [11] showed EC values below 0.75 dS/m being of " low to medium" salinity hazard, EC of the remaining was between 0.76 and 5.90 dS/m classified as of "high to very high" salinity hazard for irrigation in South El-Kalubia Governorate. [12] showed that the EC, SAR, NO_3 – N , NH4-N , COD, BOD, heavy metals (Pb, Ni and Cd) values at the beginning of the drains were lower than at the end of the different drains in Dakahlia Governorate, Egypt. [13] revealed that pH levels in irrigation water samples in the El-Salam Canal ranged from 7.71 to 8.03, remaining within normal limits, while electrical conductivity (EC) varied from 0.46 to 2.62 dS/m, reflecting differences in salinity. The present study focuses on the water quality of different drains in south of Dakahlia Governorate for agricultural irrigation.

2. Materials and Methods

2.1. Study Area

Dakahlia Governorate, Egypt with a total area 3459 km and population of about 6794000 (2020) and it is located in northeastern sector of the Nile Delta around the Damietta branch. between latitudes 30.5º 31.5º ¸ north and longitudes 30˚¸ 32̊ east. It is bordered on the east by Sharqiyah Governorate, on the west by AL Gharbia Governorate, on the northwest by Kafr EL Sheik, on the North by Mediterranean Sea, Damietta Governorate and Manzala leak.

Six positions geographic selected for water sample collection that were chosen using a GPS device, across the study area. These locations correspond to the eastern side of the Damietta Branch in south of Dakahlia governorate, Egypt i.e., Hod El-tarfa drain, Al-Mekdam, Shobra Sora, Com El-Nour, Kafr EL-Rook and Bahr Saft Al-Kebly drain. Geographic positions for water samples using a GPS device in Table 1. During May 2020, to April 2021 four surface water samples were taken, in order to prevent floating particles, samples were taken from each site 100 cm below the water's surface. Samples were collected from the beginning, middle and end of each drain. The size of the sample was about 4 liters. Subsequently, the samples were filtered using 0.45µm membrane filters. They were also stored at 4°C in dark plastic bottles before being examined using [14] standard analytical methods. Every effort was taken during sample treatment to lessen the chance of sample contamination.

Table 1: Geographic positions for water samples using a GPS device

Drains	Location markes
Hod El-tarfa	2 km north AL Maymon vallage
Al-Mekdam	at fargan vallage
Shobra Sora	500 m south Dearb Negm
Com El-Nour	one km north Dearb Negm
Kafr EL-Rook	seven km south ELSinbellawen
Bahr Saft Al-Kebly	at Abo El Shokoke Mahta vallage

2.2. Water Analyses

Samples were analyzed in the laboratory for the major ions chemistry employing standard method [14]. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined titrimetrically using standard EDTA, chloride (Cl^{-}) by standard $AgNO_3$ titration, bicarbonate (HCO_3^{-}) by titration with HCl, sodium (Na^{+}) and potassium (K^{+}) by flame photometry. EC and pH were measured directly insitu. A pH digital meter (Thermo – ORION STAR A211 PH MEATER) with glass electrode previously calibrated with a standard buffered solution at ph. 4, pH 7, pH10 was used to measure the pH of the surface water at each site. A conductivity meter was used to measure electrical conductivity (EC) and total dissolved salts (TDS) (Thermo – ORION STAR A212 PH MEATER). Chemical oxygen demand (COD) was measured by potassium dichromate method [14]. Biological oxygen demand (BOD) was determined by using dilution and seedling method [14]. Heavy metals content (Cd, Ni and Pb): For determination of total metals, water samples were digested using nitric acid as described in standard methods [14]. The concentration of (Cd, Ni and Pd) were measured using Analytik Jena atomic absorption spectrometer [15].

Soluble sodium percentage (SSP) was calculated using [16]. Sodium adsorption ratio is a measure of the sodicity of the soil [17]. Sodium to calcium activity ratio (SCAR) can be calculated according to the relationships presented by [18] Residual sodium carbonate (RSC) can be calculated according to the relationships presented by [17]. Permeability index (PI) given by the following formula [17,19,20]. Potential salinity (PS) was defined as the chloride plus half of the sulfate concentration [18,19]. Kelly's index (KI) was calculated using [21]. Magnesium adsorption ratio (MAR) calculated according to [22].

Soluble sodium percentage (SSP)

High sodium ion concentration in soil can take a toll on internal drainage patterns in soil as release of calcium and magnesium ions are facilitated due to absorption of sodium by clay particles. SSP was calculated using the following equation:

$$SSP = \frac{Na}{Na+Ca+Mg+K} \times 100 \qquad [16]$$

where, concentrations of all ions have been expressed in mmolc / L. Water with SSP less than 60 is safe with little sodium accumulations that will cause a breakdown of the soil's physical properties [23].

Sodium adsorption ratio (SAR)

Sodium adsorption ratio is a measure of the sodicity of the soil. The SAR was calculated using the following equation:

$$SAR = Na^{+} / ([Ca^{2+} + Mg^{2+}]/2)^{1/2} \quad [17]$$

where, concentrations of all ions have been expressed in mmolc / L. The SAR classes include, low, S1 (<10); medium, S2 (10–18); high, S3 (18–26); and very high, S4 (>26).

Sodium to calcium activity ratio (SCAR)

SCAR can be calculated according to the relationships presented by [18] and presented in the following equation where all ions in mmolc / L.

$$SCAR = Na^{+} / (Ca^{2+})^{1/2}$$

On the basis of SAR/SCAR, the irrigation waters may be classified in six classes of sodicity, Non-sodic water, S0 (<5); Normal water, S1 (5-10); Low sodicity water, S2 (10-20); Medium sodicity water, S3 (20-30), High sodicity water, S4 (30-40) and Very high sodicity water, S5 (>40).

Residual sodium carbonate (RSC)

Excess carbonate and bicarbonate ions over calcium and magnesium ions lead to presence of sodium carbonate, its ion is higher than calcium ions which is considered undesirable, because after evaporation leads to sodicity. The equation is as follows:

$$RSC = (CO_3^{=} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+}) \quad [17].$$

where concentrations of all ions have been expressed in mmolc L^{-1}. RSC classes are no-hazard (<1.25), medium hazard (1.25-2.5) and extreme hazard (>2.5).

Residual sodium bicarbonate (RSBC)

Since carbonate ions do not occur very frequently in appreciable concentrations and as bicarbonate ions do not precipitate magnesium ions, Gupta suggested that alkalinity hazard could be determined through this parameter, which is calculated as follows:

$$RSBC = HCO_3^{-} - Ca^{2+} \text{ (ions concentration in mmolc L-1)}$$

Based on RSC/ RSBC ratio there are six alkalinity classes as the follows: non-alkaline water, A0 (negative value); normal water, A1 (0); low alkalinity water, A2 (2.5); medium alkalinity water, A3 (2.5-5); high alkalinity water, A4 (5-10) and very high alkalinity water, A5 (>10).

Permeability index (PI)

The PI given by the following formula [17,19]:

$$PI= Na^{+} + (HCO_3)^{1/2} \ / Na^{+} + Ca^{2+} + Mg^{2+}$$

where, concentrations of all ions have been expressed in mmolc L-1. The PI classification is as follows: Excellent (>75%), Good (25-75%) and Unsuitable (<25%) [20].

Potential salinity (PS)

Potential salinity (PS) was defined as the chloride plus half of the sulfate concentration [18.19].

$$PS = Cl^{-} + ½ SO_4^{=} \text{ (ion concentration in mmolc } L^{-1}).$$

The PS classification is as follows: permissible 5-20, 3-15 and 3-7, for soils of good, medium and low permeability, respectively [18].

Kelly's index (KI)

Kelly's index is used for the classification of water for irrigation purposes. Sodium measured against calcium and magnesium is considered for calculating this parameter. A KI (>1) indicates an excess level of sodium in waters [21]. Therefore, waters with a KI (<1) is suitable for irrigation, while those with greater ratio are unsuitable [24]. KI is calculated by using the formula; where all the ions are expressed in mmolc/ L.

$$KI = Na^{+} / (Ca^{2+} + Mg^{2+}) \text{ (ion concentration in mmolc } L^{-1})$$

Magnesium adsorption ratio (MAR)

Ca^{2+} and Mg^{2+} maintain a state of equilibrium in most waters [25]. High Mg^{2+} in adversely affects soil rendering it alkaline [26] (Kumar *et al*., 2007). The magnesium hazard of irrigation water is evaluated using the MAR [22] and is calculated by the following equation. The MAR classification is as follows: safe (<50) and having Mg^{2+} hazard (>50)

$$MAR = (Mg^{2+} \times 100) / (Ca^{2+} + Mg^{2+})$$

3. Results and Discussion

3. 1. pH, EC, (dS m^{-1}), cations and anions (mmolc l^{-1}) of different drains in south of Dakahlia Governorate, Egypt

Table 2, shows values of pH, EC, (dS m^{-1}), cations and anions (mmolc l^{-1}) of different drains in south of Dakahlia Governorate. Table 2 shows that pH of water in different drains is within the acceptable range every month, as there was no much variations. Overall, pH values at all sites were close to neutral–slightly alkaline. The pH value is ranged from 7.52 (in Bahr Saft Al-Kebly drain) to 7.63 (in Shobra Sora drain). The main use of pH in a water analysis is for detecting abnormal waters. The normal pH range for irrigation water is from 6.5 to 8.4. An abnormal value is a warning that the water needs further evaluation. Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion [27]. [28] found that the pH values of irrigation water varied between 7.68 and 7.84 for all water resources, (sewage water, secondary treated sewage water, canal polluted water, and fresh water); it is obvious from the data that sewage water has slight decrease of pH than the others. The acidity or basicity of irrigation water is expressed as pH (< 7.0 acidic; > 7.0 basic). The normal pH range for irrigation water is from 6.5 to 8.4. Abnormally low pH's are not common, but may cause accelerated irrigation system corrosion where they occur [29]. [30] found that pH values in the summer season were nearly neutral for all locations but in the winter the pH values in the five locations were nearly neutral and the same as for the Nile water. [31] found that the average pH of water samples for El-Salam Canal and contributed main drains was 8.1. The pH values are slightly alkaline in all the studied drains and El-Salam Canal and ranged between 7.8 and 8.4 indicating possible alkalization by using such waters, although values are in the normal range according to [32]. [31] reported that the greater values of pH may be due to a slight increase in (HCO_3) ions. This result is in agreement with those obtained by [33]. [34] showed that pH values of irrigation water of Port Said Canal, El-Salam Canal and Bahar El-Bakar drain were within permissible range.

Value of EC is approximately 1.36, 1.48, 1.37, 1.39, 1.4 and 1.51 dS m^{-1} in Al Hod El-tarfa (D1), Al-Mekdam (D2), Shobra Sora (D3), Com El-Nour (D4), Kafr EL-Rook (D5) and Bahr Saft Al-Kebly (D6), respectively. Bahr Saft Al-Kebly drain showed the highest values of EC (highly saline category). The lowest value of EC was obtained in Hod El-tarfa drain (highly salinity). According to [17]**,** salinity classes range from moderate to high salinity. Water in all drains are of very high salinity (C3), which should not be used on soils with restricted drainage and if used, special management for salinity control should be done and salt tolerant plants should be used. This water is not used because its use damages the land, and continued irrigation with it increases soil salinity and causes salt stress to plants. It is only used to irrigate crops that are highly tolerant of salts [35, 36]. [34]) reported that EC value of water was 0.28 dSm^{-1} in Port Said Canal and classified as class l, while in El-Salam Canal EC value was 1.24 dSm^{-1} which is classified as Class 2. On the other hand, EC value of Bahar El-Bakar drain was 6.7 dSm^{-1}which classified as Class 3. There is an increase in the EC values of the irrigation water in both Tinah and Sarhan irrigation canals from the start points (near El-Salam Canal) to the end of these canals (near New Sahal road). The EC value of the irrigation water ranged from 0.87 dSm^{-1} at the start to 9.24 dSm^{-1} in the end [37].

According to Gupta classification [38,39] the irrigation waters of different drains are of salinity hazard. Water in Bahr Saft Al-Kebly drain is considered low salinity waters waters (C-2) and can be used if moderate leaching. Most crops irrigated by such water are horticultural and mostly leguminous. A decrease in the productivity of most agricultural crops may also occur [18]. Water of D1, D2, D24, D3 and D4 drains are considered normal waters (C-1) and can be used for irrigation with most crops on most soils with little likelihood that soil salinity to develop. Large areas of citrus trees, (salinity sensitive plants) are irrigated for many years with waters having EC 1.5 dS/m, with small leaching with relatively high Ca^{2+} and low Cl^- [40,41]. Based on the physicochemical analytical data of the drainage water in the research region in the southern part of the Nile Delta, Egypt, 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 [42]. [43] showed that the EC values were 1.10 dSm^{-1} for Nile water, 1.65 dSm^{-1} for drainage water and 1.46 dSm^{-1} for sewage water; being slightly to moderately saline causing salinity problems. [44] found that the average EC values of Bahr El-Bakar drainage water was 1.73 dSm^{-1} which falls within the second category according to FAO classification.

Relative abundance of cations in water of different drains were $Na^+ > Ca^{2+} > Mg^{2+} > K^+$, respectively. Regarding anion abundance for different drains (D1 to D10) the pattern was $HCO_3^- > Cl^- > SO_4^= > CO_3^=$. These results are agreement with those obtained by [45,46,47]. The dominance of sodium indicates a potential sodicity hazard, which may cause soil structural degradation and reduced permeability if the water is used continuously for irrigation [48]. [49] found that the order of soluble cations of fresh water was $Mg^{+2} > Na^+ > Ca^{+2}$ while in the drainage water it was $Na^+ > Mg^{2+} > Ca^{2+}$. The distribution of soluble anions in fresh water was arranged into $HCO^-_3 > SO^{2-}_4 > Cl$, with a dominancy of Cl^- in the other types of irrigation water followed by HCO_3^- and SO^{2-}_4. [50] reported that the Mg^{2+}/ Ca^{2+} ratio in irrigation water was varied from 0.15 to about 1.3 $mmol_c L^{-1}$ and was increased with increasing salinity levels. In the case of anions, the concentrations of Cl^- and SO_4^{2-} were proportionally increased with EC values and ranged from 0.68 to 18.23 $mmol_c l^{-1}$ for Cl^- and from 0.54 to 8.60 $mmol_c L^{-1}$ for SO_4^{2-}. [28] illustrated a relative increase in irrigation water salinity of 81.8, 92.7, 270.9 and 110.4 % for sewage wastewater, secondary treated sewage water, canal polluted water and wastewater, respectively, compared to normal fresh water.

Table 2: pH, EC, (dS m^{-1}), cations and anions (mmolc l^{-1}) of different drains in south of Dakahlia Governorate, Egypt

Name of Drain	Ph	EC, dS m^{-1}	Cations, mmolc l^{-1}				Anions, mmolc l^{-1}			
			Ca^{+2}	Mg^{+2}	Na^+	K^+	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$
Hod El-tarfa	7.57	1.36	3.78	3.06	7.64	0.96	0.00	5.27	2.77	6.79
Al-Mekdam	7.59	1.48	3.38	2.82	6.74	0.76	0.00	7.04	5.14	1.37
Shobra Sora	7.63	1.37	3.06	2.69	7.40	0.91	0.00	6.96	5.39	1.51
Com El-Nour	7.59	1.39	2.99	2.51	8.62	0.67	0.00	7.31	5.43	1.88
Kafr EL-Rook	7.58	1.46	3.50	2.93	8.13	0.70	0.00	7.29	6.14	1.68
Bahr Saft Al-Kebly	7.52	1.51	3.49	2.85	7.63	0.81	0.00	6.52	4.62	3.15
LSD 0.05%	0.162	0.101	0.325	0.294	1.156	0.092	0.00	0.549	0.645	0.987

3.2. Water quality parameters, Gupta's ABC, ICAR, USDA and USSL class of different drains in south of Dakahlia Governorate, Egypt

Table 3, 4. and Fig.1, 2, shows values of water quality parameters *i.e.,* SSP, SAR, RSC, RSBC, SCAR, PI, PS, KR and MAR of different drains in south of Dakahlia

Governorate. There were differences between months of year in all studied cases. The highest SSP was in Com El-Nour drain (58.28%) followed by Kafr EL-Rook (53.28%), Shobra Sora (52.63%), Bahr Saft Al-Kebly (51.62%), Hod El-tarfa (49.48%), and Al-Mekdam(49.20%) According to [51] and recent Egyptian studies [52, 53].

Data in Tables 3,4. and Fig 1,2, shows differences between months. The highest sodium adsorption ratio (SAR) were in Com El-Nour (5.20) followed by Al Kafr EL-Rook (4.53) and Shobra Sora (4.36). The lowest value of sodium adsorption ratio (SAR) were found in Al-Mekdam drain **(**3.83**)**. Therefore, since such values are < 10, this indicates little restriction on the use of this water in irrigation [17]. The classification of waters indicates that all drains ***i.e.,*** D22 to D27 have waters of high salinity-low sodicity (C3S1). The classification of waters indicates that in Jnabiat Sadaqa and Zarfwzaky drains have waters of high salinity-low sodicity (C3S1) according to [17]. classification. Waters in different drains were classified non-sodic water (S0) According to [18]. This water can be used to irrigate all crops, whether field crops, vegetables, fruits, or trees, as well as crops that are affected by sodium, under all soil conditions. The highest value of exchangeable sodium percentage (ESP), Adj.SAR and Adj.RN were found in Kafr EL-Rook drain (6.47, 11.48, and 6.33, respectively), while the lowest value was found in Hod El-tarfa drain (4.37, 8.18 and 4.60, respectively). SAR/SCAR was in D22 (1.05) followed by D23(1.04), D24 (1.03), D25(1.04),D26 (1.04), and D27(1.05). Based on the EC and the value of SAR/SCAR in all drains and can be classified as C2S0 (SAR/SCAR <2.5), (Table 4). [17] proposed sodium adsorption ratio (SAR), for evaluation of sodium hazard of water, the classification system consists of four classes, SAR 10, 18 and 26, where the water having SAR more than 26 is considered unsuitable for irrigation except at low salinity level and using particular soil amendments [13] revealed that Alkalinity indicators showed the following ranges: Sodium Soluble Percentage (SSP): 30.22–51.22%, Sodium Adsorption Ratio (SAR): 1.29–5.72 mmolc/L, adjusted SAR: 2.49–14.61 mmolc/L, adjusted R Na: 1.38–6.30 mmolc/L, and Exchangeable Sodium Percentage (ESP): 0.65–7.25%.

Residual sodium carbonate (RSC) values in in D22 (1.57-) followed by D23 (0.84), D24 (1.21), D25(1.81),D26(0.86) and D27 (0.18). Waters in different drains could be used safely for irrigation purposes since RSC values are less than 1.25 According to [17]. Based on RSC/RSBC ratio all values are negative (Non-sodic waters, A-0) where they were (1.05-) in Hod El-tarfa drain).Water in different drains are normal waters, A1 and this water can be used to irrigate all crops and all soils without restrictions and without any damage to the soil or plants for long periods of time According to [18]. Waters in different drains are of good quality for irrigation purposes since Permeability index (PI) values are lower than 75. The highest value of PI were obtained in Com El-Nour and Shobra Sora drains (80.20 and 76.34, respectively), while the lowest value were found in Hod El-tarfa drain(68.62). These results are agreement with those obtained by [13, 54] . The PI classification is as follows: Excellent (>75%), Good (25-75%) and Unsuitable (<25%**).** [18] stated that irrigation water in semi-arid zones might be classified in five categories, based on sodic hazard, boron, and the salinity hazard. These classifications have been called ABC classification as follows: B_1: normal water < 3 mg l^{-1}, B_2: low boron water 3- 4 mg l^{-1}, B_3: medium boron water 4 - 5 mg l^{-1}, B_4: high boron water 5 - 10 mg l^{-1} and B_5: Very boron water > 10 mg l^{-1}. The last class of water is not suitable for irrigation water under ordinary condition, but may be used occasionally under very special circumstances.

Table 3: Water quality parameters of different drains in south of Dakahlia Governorate, Egypt

Name of Drain	SSP	SAR	Adj.SAR	Adj.RNa	ESP	RSC	RSBC	SCAR
Hod El-tarfa	49.48	4.13	8.18	4.60	4.37	1.57-	1.49	3.93
Al-Mekdam	49.20	3.83	8.84	4.93	4.88	0.84	3.66	3.67
Shobra Sora	52.63	4.36	8.57	4.68	4.42	1.21	3.90	4.23
Com El-Nour	58.28	5.20	9.65	5.28	5.23	1.81	4.32	4.99
Kafr EL-Rook	53.28	4.53	11.48	6.33	6.47	0.86	3.79	4.35
Bahr Saft Al-Kebly	51.62	4.29	10.24	5.57	5.48	0.18	3.03	4.08
LSD 0.05%	4.405	0.671	1.457	0.822	1.001	0.639	0.607	0.644

Note: SSP = Soluble sodium percentage, SAR = Sodium Adsorption Ratio, SCAR = Sodium to Calcium Activity Ratio, RSC = Residual Sodium Carbonate, RSBC = Residual Sodium Bicarbonate,

Table 4: PI, KR, MAR, Gupta's ABC, ICAR, USDA and USSL class of different drains in south of Dakahlia Governorate, Egypt

Name of Drain	SAR/ SCAR	RSC/ RSBC	PI	PS	Ki	MAR	Gupta's ABC	ICAR	USDA	USSL Class

Hod El-tarfa	1.05	1.05-	68.62	6.17	1.12	44.74	A0B1C 2	C1S0	C3S 1	Appropriate
Al-Mekdam	1.04	0.23	72.59	5.83	1.09	45.48	A1B1C 2	C1S0	C3S 1	Appropriate
Shobra Sora	1.03	0.31	76.34	6.15	1.29	46.78	A1B1C 2	C1S0	C3S 1	Acceptable
Com El-Nour	1.04	0.42	80.20	6.37	1.57	45.64	A1B1C 2	C1S0	C3S 1	Acceptable
Kafr EL-Rook	1.04	0.23	74.38	6.98	1.26	45.57	A1B1C 2	C1S0	C3S 1	Acceptable
Bahr Saft Al-Kebly	1.05	0.06	72.89	6.20	1.20	44.95	A1B1C 2	C1S0	C3S 1	Appropriate
LSD 0.05%	0.025	0.230	3.953	0.632	0.241	0.871	-	-	-	-

Note**:** PI = Permeability, Index, PS = Potential Salinity, KI = Kelly Index and MAR = Magnesium Adsorption Ratio.

The Potential Salinity (PS) values of different drainage were ranged from 5.83 to 6.98 mmolc/ L for Al-Mekdam and Kafr EL-Rook, respectively (Table 4 and Fig. 2). [18]. Therefore, all values fall within the permissible limits for collecting different water samples. PS was defined as the Cl^{-1} plus half of the SO_4^{2-} concentration [18.19]. Potential salinity (PS) was defined as the chloride plus half of the sulfate concentration [18,19]. The PS classification is as follows: permissible 5-20, 3-15 and 3-7, for soils of good, medium and low permeability, respectively [18].

Kelly's index (KI) is used for the classification of water for irrigation purposes in all drains (D22 to D27). According to the classification of KI, waters in different drains have KI of > 1.0 **[**21]; therefore, this water are unsuitable for irrigation [24].

The highest value of Magnesium adsorption ratio (MAR) values were found in Shobra Sora drain (46.78), while the lowest value were found in Eumum Al- Hod El-tarfa (44.74) (Table 4). Therefore, the water is suitable for use in irrigation since the values are <50 in different water of drains. These results are agreement with those obtained by [53]. Ca^{2+} and Mg^{2+} maintain a state of equilibrium in most waters [25]. High Mg^{2+} in adversely affects soil rendering it alkaline [26]**.** The magnesium hazard of irrigation water is evaluated using the MAR [22], The MAR classification is as follows: safe (<50) and having Mg^{2+} hazard (>50).

3.3. Turbidity, BOD, COD, DO, B and NO_3-N, (mg L^{-1}) of different drains in south of Dakahlia Governorate Egypt

Data in Table 5 and Fig. 3 shows values of Turbidity, NO_3-N, B, BOD, COD and DO (mg L^{-1}) of different drains in south of Dakahlia Governorate. The highest values of turbidity, biological oxygen demand (BDO), chemical oxygen demand (COD) and dissolved oxygen (DO) were obtained Kafr EL-Rook drain (122, 15.33, 0.068, 105, 207 and 14.08 mg L^{-1}, respectively), while the lowest values were found in Hod El-tarfa drain (70.67, 8.23, 0.040, 54.29, 104 and 7.54 mg L^{-1}, respectively). These results are agreement with those obtained by [13,47,53]. The FAO and Egyptian guidelines state that drainage water is not suitable for use in irrigation, as per the earlier determination. Prior to being used for agricultural irrigation, the heavy metals (Cu and Ni) and organic pollutants (BOD and COD) a pre-treatment should be carried out to reduce pollution and enhance the drainage water's quality. Dissolved oxygen (DO) is crucial in water bodies because it is required for aquatic creatures respiration and primary photosynthesis [42]. DO levels were between 2.2 and 7.9mg/l for water samples obtained from the Kitchener Drain and 0 and 6.5mg/l for water samples collected from the New Damietta Drain, Except for the drains´ outlets (S5 and S10), all DO levels were lower than the allowable limits under Law 48/1982 (not less than 5mg/l). The decrease in DO is due to the discharge of domestic wastewater into these drains, which causes a depletion of free oxygen by bacteria [55].

Boron (B) exhibited notable variability, with the highest mean concentration recorded in the Kafr EL-Rook (0.068 mg L^{-1}), while lower values were observed in Hod El-tarfa drain (0.040 mg L^{-1}), (Table 5). These results are agreement with those obtained by [12,47,50].

The highest mean nitrate concentration occurred in Kafr EL-Rook drain (15.33 mg L^1), followed by Bahr Saft Al-Kebly drain (13.09 mg L^1), while the Hod El-tarfa showed the lowest (8.23 mg L^{-1}). These results are agreement with those obtained by [53,57,58]. [59] showed that nitrate ranged from 18.5 to 112 mg L^1 in the Kafr El-Sheikh drains. These elevated nitrate levels in drainage systems are consistent with agricultural runoff and domestic wastewater discharges. The result of the nitrate contamination causes unhealthy air, polluted drinking water, degraded ecosystem and consequences for climate change. In view of degraded ecosystem, he excesses nitrate might be the reason for water contamination, reduced biodiversity and loss of certain plant species [51,55,60]. Among the various contaminations, nitrate (NO_3^-) pollution is the widespread environmental disaster, which has two different sources such as natural and anthropogenic sources. The excessive anthropogenic loading such as agricultural waste that includes fertilizer, pesticides, organic, inorganic waste from households, and leakage of sewer pipelines are the primary reasons for nitrate contamination in groundwater [59,60].

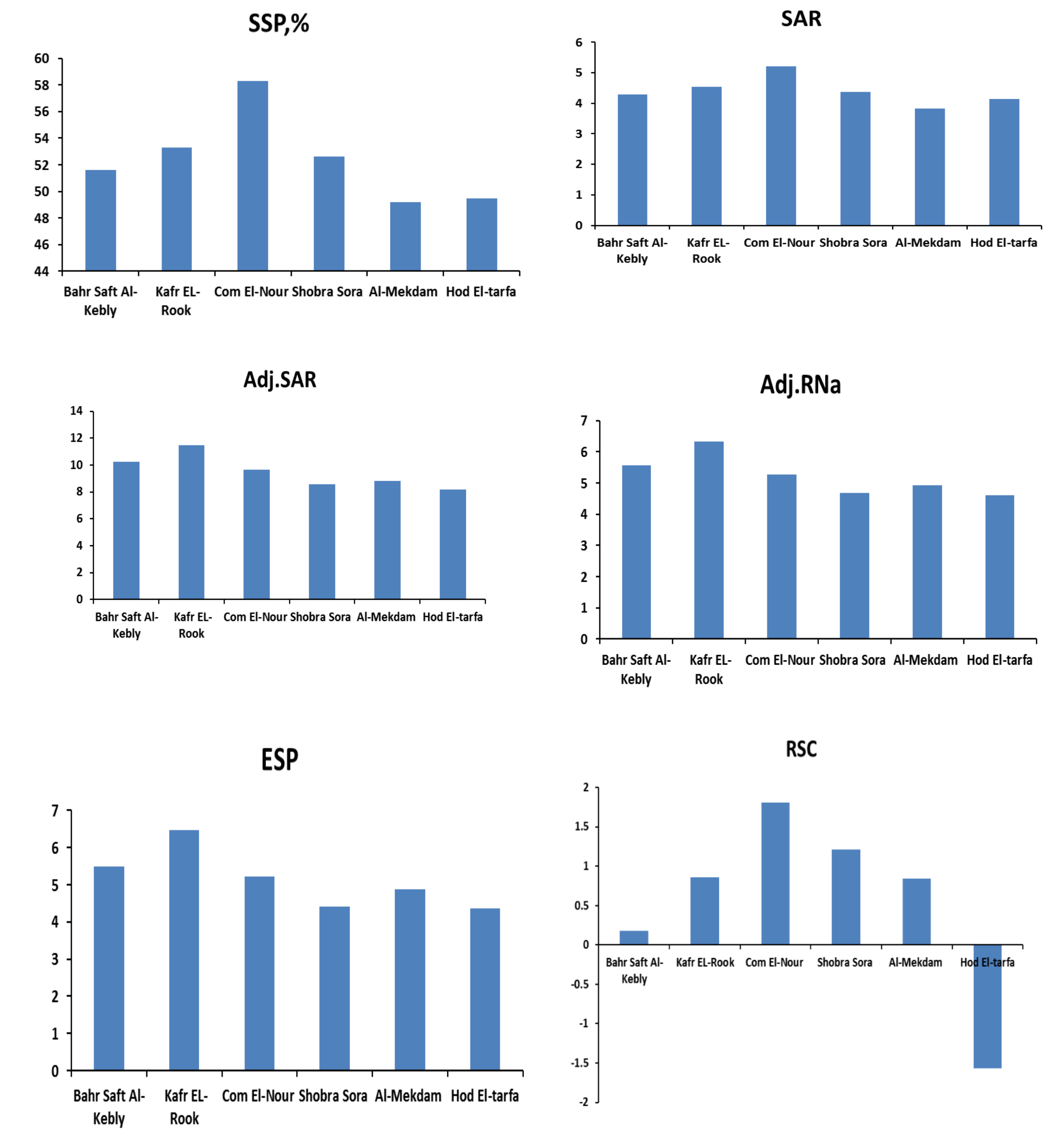

Fig.1: SSP, SAR, Adj.SAR and Adj.RNa of different drains in south of Dakahlia Governorate, Egypt

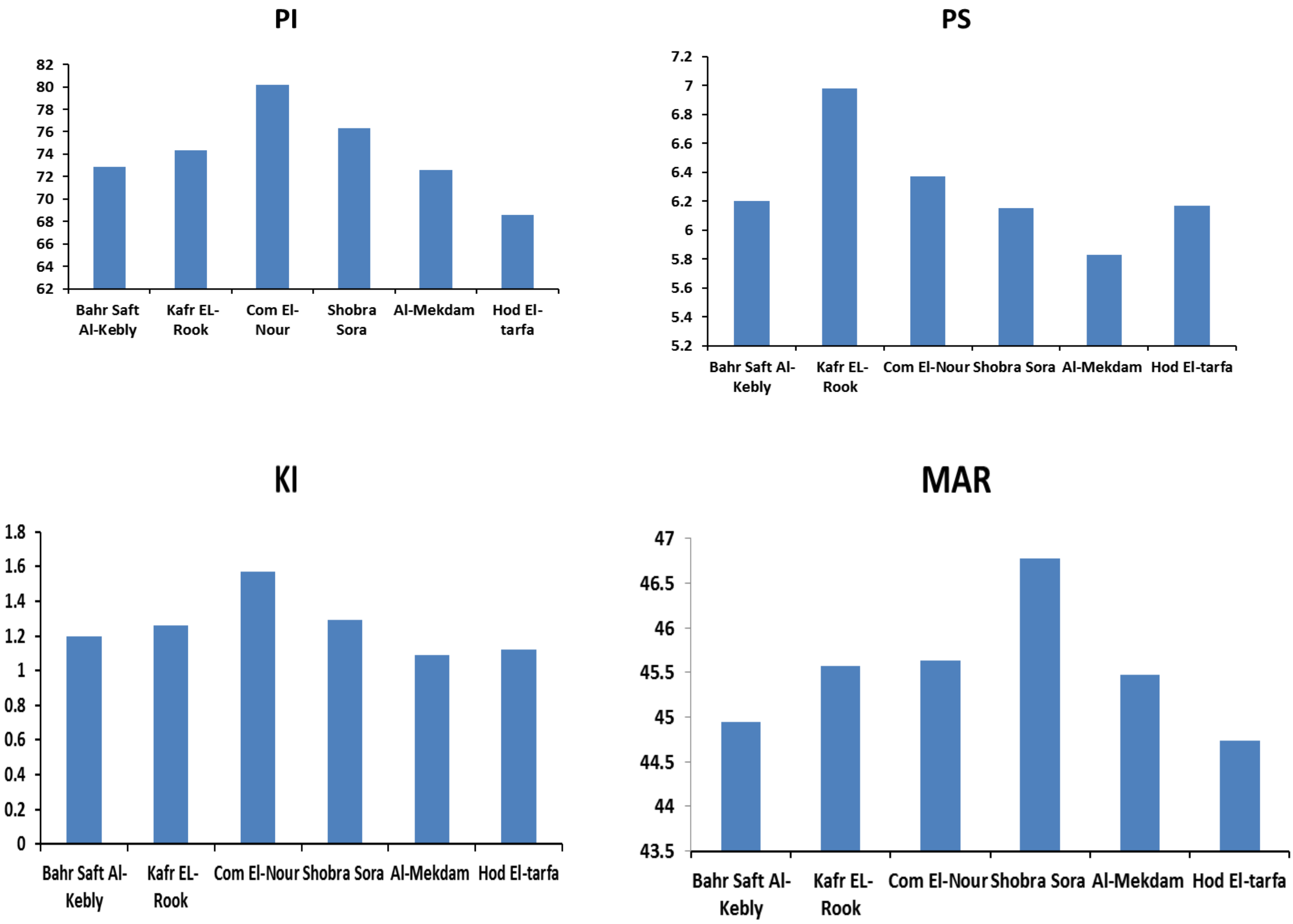

Fig.2: Permeability Index (PI), Potential Salinity (PS), Kelly Index (KI)and Magnesium Adsorption Ratio (MAR) of different drains in south of Dakahlia Governorate, Egypt

Table 5: Turbidity, BOD, COD, DO, B and NO_3-N, (mg L^{-1}) of different drains in south of Dakahlia Governorate Egypt

Name of Drains	Turbidity	BOD	COD	DO	B, mg l^{-1}	NO_3-N. mg l^{-}
Hod El-tarfa	70.67	54.29	104	7.54	0.040	8.23
Al-Mekdam	94.87	80.22	151	9.21	0.045	10.24
Shobra Sora	81.23	73.09	132	8.25	0.044	9.56
Com El-Nour	103	93.84	163	10.67	0.060	12.12
Kafr EL-Rook	122	105	207	14.08	0.068	15.33
Bahr Saft Al-Kebly	115	101	185	12.11	0.065	13.09
LSD 0.05%	2.35	1.285	1.673	0.982	0.021	2.431

Note: BDO= Biological Oxygen Demand, COD= Chemical Oxygen Demand and DO= Dissolved Oxygen

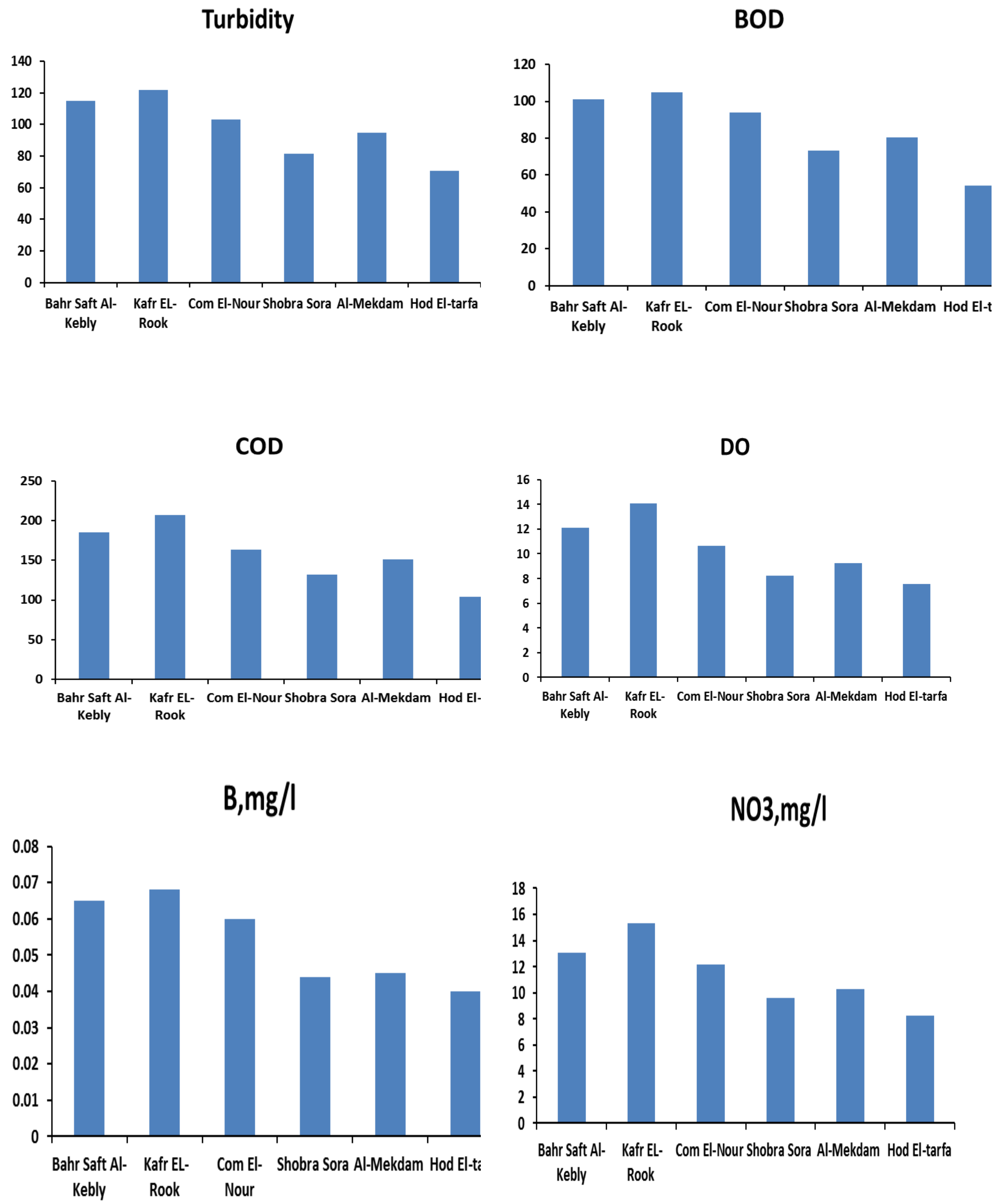

Fig. 3: Turbidity, BOD, COD, DO, B and NO_3-N, (mg L^{-1}) of different drains in south of Dakahlia Governorate Egypt.

4. Micro nutrients and heavy metals (mg L^{-1}) of different drains in south of Dakahlia Governorate, Egypt

Data in Table 6, shows values of micro nutrients *i.e.,* Fe, Zn, Mn and Cu and heavy metals *i.e,* Co, Cd, Ni and Pb, (mg L^{-1}) of different drains in south of Dakahlia Governorate. The highest values of Fe, Mn, Zn and Cu were obtained in Kafr EL-Rook drain (0.061,0.306, 0.024 and 0.037mg L^{-1}, respectively), while the lowest values were found in Hod El-tarfa drain (0.030, 0.140, 0.010 and 0.011 mg L^{-1}, respectively). These results are agreement with those obtained by who [61] reported that the highest values of Pb was 1.27 mg l^{-1} in Autumn , Ni (1.587 mg l^{-1}) and Cd (0.13 ppm) in summer in El-Mansoura El- Mostagad drain in Dakahlia Governorate, Egypt. [12] found that the concentration of heavy metals in the beginning of different drains is lower compared to the end of those drains, and also that the concentration is lower in the summer compared to the winter in Dakahlia Governorate. 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 [53]. [50] found that in Bahr El-Baqar wastewater, the concentration of heavy metals in water drain followed the order: Fe> Zn> Mn> Cu> Pb> Ni> Cd. The highest concentrations for all the studied elements were mostly found in Baher El-Baqar drainage water. The variations encountered in the concentrations of heavy metals in the irrigation canals are mainly rendered to the contaminated sources, which varied from one location to another.

Data in Table 6**,** shows values of heavy metals *i.e,* Co, Cd, Ni and Pb (mg L^{-1}) of different drains in south of Dakahlia Governorate. The highest values of Co, Cd, Ni and Pb were obtained in Kafr EL-Rook drain (0.075, 0.066, 0.045 and 0.103 mg L^{-1}, respectively), while the lowest values were found in Hod El-tarfa drain (0.027, 0.008, 0.014and 0.040 mg L^{-1}, respectively). These results are agreement with those obtained by [47,50,53,54]. [40] that The EL-Gharbia main drain's overall mean content of micronutrients (Fe, Mn, Zn, Cu, and B) and heavy metals (Cd, Co, Cr, Ni, and Pb) exceeded the permissible limit in both study seasons; however, the pollution grade was higher during the summer. Research conducted by [62] indicates that drainage water pollution has led to increased concentrations of heavy metals, including zinc (Zn), iron (Fe), copper (Cu), cadmium (Cd), and lead (Pb), particularly on the southern shores of the lake compared to the northern shores. According to [63], improvements in water quality indicators were observed significantly in the lake inlet and eastern section, where dredging operations were implemented, while less improvement was noted in the western area. The drainage area surrounding Lake Burullus is a primary factor contributing to the deterioration of its water quality. Therefore, it is imperative to devise solutions addressing the drainage area to positively impact the lake's water quality. The initial step toward remediating the water body involves assessing its current condition. [63] found that concentrations of bicarbonate, boron, ammonium nitrate and heavy metals (Fe, Zn, Mn, Cu, CO, Ni, Cd and Pb) in water of El-Salam canal and some drains were less than the critical levels. They recommended that the water of EL-Salam canal and its drains contributors can be used for irrigation of most of the tolerant and semi-tolerant crops on light and medium textured soils without problems in the short run but not recommended to heavy textured unless proper management practices are adopted. [64] reported that heavy metals contents (Fe, Mn, Zn, and Pb) in El-Salam canal water was much lower than those of maximum permissible limits for irrigation water. [65] indicated that all drains or mixing water in both areas of Bahr El-Bakr drain and Bahr Hadous have a content of Fe, Zn, Mn, Pb and B below the critical limits, except for boron and manganese, which have concentrations exceed the critical limits.

Table 6: Micro nutrients and heavy metals (mg L^{-1}) of different drains in south of Dakahlia Governorate, Egypt

Name of Drain	Fe	Mn	Zn	Cu	Co	Cd	Ni	Pb
Hod El-tarfa	0.030	0.140	0.010	0.011	0.027	0.008	0.014	0.040
Al-Mekdam	0.034	0.201	0.013	0.014	0.035	0.009	0.043	0.052
Shobra Sora	0.034	0.240	0.017	0.017	0.030	0.010	0.017	0.103
Com El-Nour	0.041	0.222	0.016	0.030	0.071	0.009	0.016	0.074
Kafr EL-Rook	0.061	0.306	0.024	0.037	0.075	0.066	0.045	0.103
Bahr Saft Al-Kebly	0.050	0.214	0.021	0.015	0.028	0.011	0.022	0.077
LSD 0.05%	0.0256	0.0767	0.037	0.026	0.062	0.043	0.010	0.047

4. Conclusions

Water quality monitoring is an important exercise, aids in determining the water quality trends, ordering pollution control effort, assessing the extent and nature of pollution as well as efficiency of pollution control measures, specifics in case of little water quality (drainage water reused in agriculture and blending freshwater with agriculture drainage wastewater. Therefore, the aim of this study was to evaluate some drains in the south of Dakahlia Governorate through the chemical properties of the water, its heavy metal content, and to assess its quality and suitability for irrigation and reuse. The pH value is ranged from 7.52 (in Bahr Saft Al-Kebly drain) to 7.63 (in Shobra Sora drain). Bahr Saft Al-Kebly drain showed the highest values of EC (highly saline category). The lowest value of EC was obtained in Hod El-tarfa drain (highly salinity). The classification of waters indicates that all drains have waters of high salinity-low sodicity (C3S1) According to USDA (1954). The highest concentration of BOD, COD, NO3-, Fe, Mn, Z, Cu and heavy metals i.e., Co, Cd, Ni and Pb were obtained in the Kafr EL-Rook drain and the lowest value were found in the Hod El-tarfa drain.

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