Egypt. J. Soil Sci. **Vol. 65**, No. 1, pp: 371 – 386 (2025)

Egyptian Journal of Soil Science

http://ejss.journals.ekb.eg/

Environmental Studies on Some Irrigation and Drainage Water in Egypt

Zienab H. Abd El-Aziz, Mohamed El-Ghannam, Ominia F. Amin and **Saffaa S. M. Abd El-Al**

Soils, Water and Environment Research Institute, Agricultural Research Center, Egypt

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. Present study aims to assessment water quality of some fresh and drainage water sources in Kafr El-Sheik, El-Qalyubia and El-Fayoum Governorates, Egypt for use in irrigation of agricultural concurring to FAO guidelines for irrigation and drainage water. This was performed during summer 2023 and winter 2023/2024. Data revealed that pH of water sources was within the permissible limit (6.5 - 8.5). Salinity and sodicity values varied from 0.226 to 0.672 dS m^{-1} and 3.78 to 20.53 % for fresh water and from 0.26 to 3.04 dS m^{-1} and 2.67 to 21.51% for drainage water, respectively. Corresponding to USDA diagram (1954), the investigated samples are in class C_1S_1 to C_4S_4. Nitrate (NO_3^-) and ammonia (NH_4^+) concentration exceed the critical limits FAO (1985). In most samples, nitrogen (N) is outside the recommended limits values, but phosphor (P) and potassium (K) are in permissible limits for irrigation water. Biological oxygen demand, chemical oxygen demand and heavy metals concentrations in most samples were blow the allowable FAO irrigation limits and Egyptian water quality standards. Adjusted sodium adsorption ratios (adj.SAR) in most of samples were above 9. According to USDA (1954), the soluble sodium percent (SSP) over maximum limits (60%) in most water samples. Permeability index (PI), Residual Sodium Carbonate (RSC) and Magnesium Adsorption Ratio (MAR) values in most samples > 75%, < 1.25 mmolc L^{-1} and < 50 %, i.e. no permeability, good and safe for irrigation, respectively. Potential salinity (PS) varied from classified as good, moderate and unsuitable. Kelly Ratio (KR), for all water sources were above the acceptable limit of 1.0 except End Bilibies drain (D6) and Middle Bilibies drain (D5) values are below the acceptable limit. These findings support the idea that drainage water in the study locations shouldn't be utilized for farming before being treated to prevent soil, agricultural, food security, and health protection from deteriorating.

Key word: Water quality, Drainage water, Freshwater, Suitability index, Heavy metals.

1. Introduction

One of Egypt's most dangerous threats is water contamination which the main stream, canals, and drains of the Nile River have become more polluted in recent years due to industrial development, population growth, a number of new irrigated agriculture projects, and other activities along the Nile **(Al-Afify and Aly 2019).** Unregulated wastewater discharges have a negative impact on the aquatic ecosystem and environment, as well as the health of the flora and fauna **(Oyekanmi et al., 2021; Amer and Mohamed, 2022). Soliman et al., (2024)** reported that the occurrence of the heavy metals in the wastewater samples can case possible environmental and health risks, so, wastewater treatment and management strategies is value of active to lessen their influence on ecosystems and human health when used for irrigation uses. High levels of heavy metals in water can spread to plants, animals, and even people, causing a variety of health issues such immune system dysfunction, cancer, and neurological damage **(ElGhannam et al., 2019; Lian et al., 2020; Nour et al., 2022).** Before releasing these metals into the environment, wastewater must be cleaned of them in order to create a healthy ecosystem **(Adeleke et al., 2017 and Amer and Mohamed, 2022).**

Water quality is defined by the physical, chemical, and biological characteristics of the water that affect its acceptability for a given use. Additionally, it is a reliable determinant for agricultural yield **(Mukiza et al., 2021; Kijne, 2003).** Completely like any other source of water, drainage water within certain superiority parameters is constantly suitable for some purposes. Drainage water outside these limits must be treated before usage **(Al-**

*Corresponding author e-mail: khattab.ph7@gmail.com
Received: 29/10/2024; Accepted: 18/12/2024
DOI: 10.21608/EJSS.2024.332185.1903

humairia and Rahal 2023). Irrigation water quality had an operative influence on the physical and chemical properties of the soil (Saffan et al., 2024). 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 according to **Sultana and Kala, (2012) and Al-Afify and Aly (2019).** Water sources should be regularly reassessed by taking into account a number of water properties, such as sodicity and salinity hazards **(Abbas et al., 2020),** magnesium hazards, chloride content **(Abdelhafez et al., 2021),** pH **(Hegazi et al., 2019 and Abosena et al., 2021),** BOD and COD (**Farid et al., 2019 and Abosena et al., 2021**), and their toxic element contents **(Bassouny et al., 2020 and Abosena et al., 2021)** in order to ensure that they are safe for use in domestic, industrial, agricultural, and agricultural settings as well as for food production and ecosystem health **(Nabwi et al., 2018; Sheta and Fayed., 2021; Abosena et al. 2022**).

In the Kafr El Sheikh Governorate, the Meet Yized, El-Bahr El-Saidy, and El-Manaifa canals serve as freshwater resources, while the Gharbia, Nashart, and Drain No. 1 drains serve as drainage water resources. The Middle Delta's largest drainage system is the Gharbia drain. According to **Khalifa and Mossa (2017)** and **El-Amier et al. (2023),** its main purpose was to gather and move water from surface and subsurface drains in agricultural settings (75%), industrial wastewater (23%), and urban wastewater (2%). According to **Abosena et al. (2021),** the chemical properties of the EL-Gharbia main drain water samples that were analyzed were appropriate for use in agriculture (irrigation). However, biologically speaking, the waters are unsuitable for agricultural usage. 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 **(Abuzaid and Jahin. 2021; Abd El-Razik et al. 2023).** Nashart drain water's BOD, COD, TSS, TDS, NO_3, NH_4, TP, pH, and salinity did not meet the requirements for direct drainage water reuse in the study area for irrigation, according to **Allam and Negm (2013).** According to the findings, reusing drainage water could preserve freshwater and boost farmer revenue. In El-Manaifa canal, the concentration of common metals does not reach the rate that could cause problems to plant and soil **(El-Ganzori et al., 2000).** However, BOD and COD concentrations in the monitored canal do not comply with the national standards. Rayah EL-Tawfiki, Ismailia Canal and Qalyubia Canal are the main Nile River branches for fresh water in Qalyubia Governrate (South eastern Delta), Egypt. They are represents the lifeblood of numerous millions of people as it transferences freshwater to several drinking water purifying stations and agricultural fields. Their water qualities are subject to various sources of contamination. **Amer and Mohamed (2022)** observed that the physicochemical parameters of Ismailia canal were inside the acceptable FAO irrigation limits, except the potassium (K^+) concentrations were over the permitted irrigation limits. Bilbies drain, in El-Qalyubia Governorate, is the one of Eastern Delta starting from Qaha and El-Khanka towards Mediterranean Sea. According to the findings of **Abdel-Fattah and Helmy (2015),** the El-Qalyubia and Bilbies drains are classified as normal water with non-sodic (C1S0) and can be used for irrigation of most crops on most soils, with the exception of those that are sensitive to salt and those that have very heavy textures and impeded drainage. The wastewater from Bilbies, Bahr El-Baqar, and El Qalyubia drains is deemed to have mild to moderate salinity **(Abd El-Al et al., 2022; Mahmoud 2022).** As a result, special management for salinity control may be required, and plants with high tolerance should be chosen together with proper drainage. While El-Bates, El-Gatea Al-Sharky, and Abd El-Azim drains are the primary sources of drinking and irrigation water, Bahr Yusuf, Hassan Wasif, and Bahr El-Zidia are among the most important branches of the River Nile in the El-Fayuom region. The concentrations of the main water quality parameters in Bahr Yusuf are typically low and are below the recommended ranges for agricultural and drinking use **(Al-Afify and Aly, 2019). Ghieth et al. (2019)** demonstrated that heavy elements were below the allowable limits at all locations in the El-Bats, Bahr Wahby, and El-Gharaq drains in the Fayoum Governorate; however, crops that can withstand salinity could be grown in all locations with high salinity and medium sodicity water hazards.

The current study aims to evaluate the water quality of certain freshwater and drainage resources in the El-Fayoum and Delta (Kafr El-Sheikh and Qalyubia) regions . To achieve this work, eighteen monitoring sites (F1 through F9 fresh water and D1 to D9 drains water) were selected for water sampling. In summer 2023 and winter 2023/2024, water samples from these sites were taken, examined, evaluated, and compared to FAO, (1985) guidelines and Egyptian standards of irrigation water quality for reusing in agriculture and to refect the WQI.

2. Materials and Methods

2.1 Sampling collection

Fresh and drainage water samples (eighteen, 18) were collected using GPS device (eTrex series, Garmin, Romsey, UK) including nine samples (tiplicate) of each water from Kafr El-Sheikh, El-Qalyubia and El-Fayoum Governorates, Egypt between 29.20343 to 31.423194 N latitude and 30.49 06 to 31.60316 E longitude (Table 1). About 20 cm below the water surface by Nansen bottle water samples were taken during summer 2023 and winter 2023/2024 and poured into polyethylene containers (2 Liter). Water samples were collected from Meet Yazeed (F1), El-Manaifa (F2), El-Bahr El-Saidy (F3), Rayah EL-Tawfiki (F4), Ismailia Canal (F5), Qalyubia Canal (F6), Bahr Yousef (F7), Bahr Hasan Wasef (F8) and Bahr El-Zidia (F9) as freshwater sources and Gharbia main drain (D1), Nashart drain (D2), Drain No. l1 (D3), Beginning Bilbies (D4), middle Bilbies (D5), End Bilbies (D6), El-Bates (D7), El-Qatea El-Shargy (D8) and Abd El-Azim (D9) drains as drainage water sources in Kafr El-Sheikh, Qalyubia and El-Fayoum region, respectively. Water samples were brought into the laboratory in ice tanks and kept at 4° C until they were analyzed. To evaluate freshwater and drainage sources' water quality for use in agricultural irrigation. Certain locations are exposed to both direct and indirect discharge of agricultural drainage and industrial effluent.

Table 1. The studied fresh and drainage water sources locations.

Governorate	Water sources	Latitude	Longitude
	Freshwater sources		
Kafr El-Sheikh	Meet Yazeed (F1)	31.124066	30.954514
	El-Manaifa (F2)	31.137094	30.799576
	El-Bahr El-Saidy (F3)	31.26931	30.686212
El-Qalyubia	RayahEL-Tawfiki (F4)	30.60912	31.27609
	Ismailia Canal (F5)	30.38451	31.51319
	Qalyubia Canal (F6)	30.2561	31.14002
El- Fayoum	Bahr Yousef (F7)	29.20348	30.97115
	Bahr Hasan Wasef (F8)	29.20343	30.96955
	Bahr El-Zidia (F9)	29.45715	30.71229
	Drainage water sources		
Kafr El-Sheikh	Gharbia drain (D1)	31.423194	31.176532
	Nashart drain (D2)	31.301548	30.791317
	Drain No. l1 (D3)	31.353467	30.536909
El-Qalyubia	Beginning Bilbies drain (D4)	30.16439	31.37988
	Middle Bilibies drain (D5)	30.36299	31.46102
	End Bilibies drain (D6)	30.56029	31.60316
El- Fayoum	El-Bates drain (D7)	29. 29 55	30.51 41
	El-Qatea El-Shargy drain (D8)	29. 28 56	30.49 06
	Abd El-Azim drain (D9)	29.49336	30.8555

2.2 Physical and chemical analysis

In plastic bottles samples were stored and filtrated using filter paper No.1 then analyzed immediately after arrival to the laboratory for EC and pH were determined as described by **(Rowell, 1995).** Anions and cations were determined according to procedures of ICARDA, **(2013). Clesceri et al. (2005)** evaluated the soluble levels of Zn, Cu, Ni, Cd, and Pb. Inductively coupled plasma was used to identify the water-soluble components (ICP-JYULTIMA). The five-day incubation method was used to measure the biological oxygen demand (BOD). The potassium dichromate method was used to determine the chemical oxygen demand (COD) **(APHA, 2005).** The Kjeldahl method was used to measure the levels of nitrogen, ammonia, and nitrate in water samples **(Cottenie et al., 1982).**

Assessment water quality

The Food and Agriculture Organisation **(FAO, 1985)** and Egyptian regulations (Law 48/1982) provide guidelines and criteria for irrigation water quality that can be reused in agriculture (Table 2).

Table 2. Food and Agriculture Organization (FAO, 1985) guidelines and Egyptian standards of irrigation water quality for reusing in agriculture.

pH	EC_w	SAR	Adj SAR	NO_3	NH_4	P	K	BOD	COD	Pb	Ni	Cd	Cu	Zn
	dS m^{-1}	-	-	mg L^{-1}										
According to FAO*														
6.5–8.5	< 0.7	15	< 6.0	< 5	10	2	20	20	40	5	0.2	0.01	0.2	2
According to Egyptian standards														
7.0–8.5	≤ 1		9	≤45	≤50	1		30	50	0.	0.2	0.05	1	2

* Degree of problem "No Problem"

Evaluate the water quality and suitability for irrigation; the most frequently computed irrigation criteria were the soluble sodium percentage (SSP), magnesium adsorption ratio (MAR), permeability index (PI), residual sodium carbonate (RSC), sodium adsorption ratio (SAR), adjusted sodium adsorption ratio (adj.SAR), potential salinity (PS), and Kelly ratio (KR). Additionally, graphical representations such as those from the United States Salinity Laboratory (USSL) were used to clarify the analysis results.

Sodium adsorption ratio (SAR) is a measure of the sodicity of the water.

$SAR = Na^{+} / ([Ca^{2+} + Mg^{2+}]/2)^{1/2}$ **(Richards, 1954).**

Adjusted sodium adsorption ratio (adj.SAR)

$adj.SAR = Na^{+} / ([Ca^{2+} + Mg^{2+}]/2)^{1/2}\,(1 + (8.4 - pHc))$ **(USDA, 1954).**

Adjusted SAR classes are No problem (< 6.0), increasing problem (6-9) and severe problem (> 9.0) (**FAO, 1985).**

Soluble Sodium Percentage (SSP)

SSP= $Na\,\% = (Na^{1+} + K^{1+}) / (Na^{1+} + Ca^{2+} + Mg^{2+} + K^{1+}) \times 100$ **Ayres and Westcot, (1994).**

Water less than 60 SSP is safe with modest sodium accumulations that will cause a breakdown of the soil's physical properties **(Fipps, 1998).**

Permeability index (PI %)

$PI\,\% = (Na^{1+} + \sqrt{HCO_3^{1-}}) / (Ca^{2+} + Mg^{2+} + Na^{1+}) \times 100$ **Doneen (1964).**

The PI categorization is: excellent (>75%), good (25-75 %) and unsuitable (< 25 %) **(Al-Amry, 2008).**

Residual sodium carbonate (RSC)

$RSC = (CO_3^{2-} + HCO_3^{1-}) - (Ca^{2+} + Mg^{2+})$ **Richards (1954) and Adimalla&Venkatayogi (2018).**

RSC classes are good (< 1.25), medium (1.25-2.25) and unsuitable (> 2.5) **(Murtaza et al., 2021).**

Magnesium adsorption ratio (MAR)

$MAR = Mg^{2+} / (Ca^{2+} + Mg^{2+}) \times 100$ **Ravikumar et al. (2011).**

MAR organization is: (< 50) suitable and (>50) unsuitable **(Zhang et al., 2021).**

Potential salinity (PS)

$PS = Cl^{1-} + 1/2\,SO_4^{2-}$ **Doneen (1964) and Ravikumar et al. (2011).**

The PS ordering is: < 3, 3-15 and >15, for soils of good, moderate and not recommended, respectively **(Delgado et al. (2010).**

Kelly ratio KR

$KI = Na^{1+} / (Ca^{2+} + Mg^{2+})$ **(Shil et al., 2019).**

A KI (>1) indicates an excess level of sodium in waters (**Kelly, 1940).** Therefore, waters with a KI (< 1) is suitable for irrigation, while those with (>1) are unsuitable **(Shah et al., 2019).**

1. Results

3.1 Water pH

Data indicated that, the water sources were slightly alkaline. Table (3) shows that mean annual of pH values varied from 6.41 (F9) to 8.10 (F2) for fresh water sources, while, in drainage water sources varied from 6.52 (D7) to 8.08 (D4). The pH of water samples were within the range of the allowable limits (6.5 – 8.5), revealing its appropriateness for irrigation.

3.2 Salinity (EC)

In the study areas, the annual average EC were varied from of 0.226 dS/m (F9) to 0.672 dS/m (F6) for fresh water and 0.26 dS/m (D5) to 3.04 dS/m (D8) for drainage water (Table 3). For the freshwater sources salinity were low the permissible limits, while drainage water sources exceeded the permissible limits except (D3), (D4) and (D5) were in the permissible limits.

Table 3. Mean annual of pH and EC for fresh and drainage water sources.

Governorate	Water sources	pH	EC
		Fresh water sources	
	F1	7.51± 0.07	0.278± 0.004
Kafr El-Sheikh	F2	8.10± 0.065	0.254±0.005
	F3	7.57± 0.055	0.35± 0.010
	F4	7.75± 0.071	0.243± 0.003
El-Qalyubia	F5	7.93± 0.070	0.281± 0.003
	F6	7.55±0.071	0.672± 0.010
	F7	6.93± 0.065	0.36± 0.001
El- Fayoum	F8	6.64± 0.065	0.353±0.003
	F9	6.41± 0.065	0.226± 0.025
		Drainage water sources	
	D1	8.01± 0.067	0.85± 0.030
Kafr El-Sheikh	D2	7.00± 0.068	0.88± 0.025
	D3	7.02± 0.065	0.72± 0.015
	D4	8.08 ±0.066	0.38± 0.010
El-Qalyubia	D5	8.03± 0.071	0.26± 0.021
	D6	7.56± 0.065	1.02± 0.050
	D7	6.52± 0.061	2.00± 0.050
El- Fayoum	D8	6.65± 0.068	3.04± 0.015
	D9	6.76± 0.067	2.82± 0.010

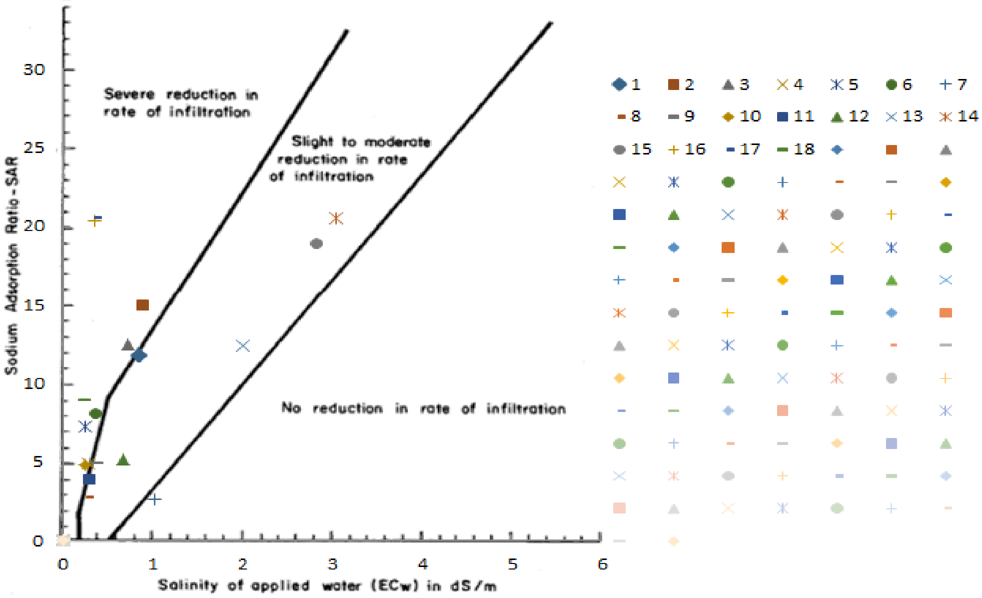

Fig. 1. The relation between SAR and salinity of water in the studied locations.

3.3 Nitrate and ammonia

In fresh and drainage water sources, the mean annual nitrate concentrations of samples taken from the Governorates under study ranged from 49.98 to 78.54 mg l^{-1} and 54.74 to 85.68 mg l^{-1}, respectively (Table 4). All fresh and drainage water sources in every Governorate have nitrate nitrogen concentrations that are higher than the standards limits for irrigation water quality for reusing in agriculture (10 mg l^{-1}). There were minor geographical variations in the ammonia concentrations. In fresh and drainage water sources, the range of NH_4-N was 27.37 to 32.13 mg l^{-1} and 24.99 to 33.32 mg l^{-1}, respectively. Both fresh and drainage water sources have NH_4-N levels beyond the permissible limits (less than 10 mg l^{-1}) for irrigation.

3.4 Nutrients (N, P and K)

The maximum values of measured mean annual total nitrogen (N) in fresh and drainage water sources are 109.48 mg l^{-1} (F4) and 117.8 mg l^{-1} (D6), respectively. While the minimal (N) in fresh and drainage water sources were measured 77.35 mg l^{1-} (F3) and 84.49 mg l^{-1} (D3), respectively. In comparison with maximum standards the concentrations of nitrogen is outside the limits for irrigation water (Table 4).

Mean annual Phosphorus were found to be in the ranges of 0.96 to 3.02 and 1.31 to 4.24 mg l^{1-} for fresh and drainage water sources, respectively. According FAO guidelines phosphate-phosphorus (2 mg l^{-1}) is in permissible limits in (D2), (D3) and (D9) as drainage water and all fresh water except (F8) and (F9). Mean annual potassium varied from 3.90 to 27.69 mg l^{-1} and from 8.81 to 26.21 mg l^{-1} in fresh and drainage water sources respectively. Based on maximum limit for potassium (20 mg l^{-1}) all water samples in permissible limits except (F1) in fresh water and (D6) at drainage water (Table 4).

Table 4. Mean annual of ammonia, nitrate, nitrogen, phosphors and potassium values (mg l^{-1}) fresh and drainage water sources.

Governorate	Water sources	NH_4	NO_3	N	P	K
		Fresh water sources				
Kafr El-Sheikh	F1	27.37±1.2	58.31±2.6	85.68±4.5	0.96±0.35	27.69±1.50
	F2	28.56±1.4	57.12±2.5	85.68±5.0	1.32±0.25	9.75±0.75
	F3	27.37±1.25	49.98±2.3	77.35±4.1	1.21±0.40	16.38±0.85
El-Qalyubia	F4	30.94±1.3	78.54±2.1	109.48±5.5	1.46±0.55	7.80±0.80
	F5	28.56±1.7	64.26±2.9	92.82±5.2	1.89±0.35	3.90±0.70
	F6	32.13±1.8	55.93±3.1	88.06±4.2	1.64±0.25	3.90±0.80
El- Fayoum	F7	30.94±1.5	59.5±2.6	90.44±5.1	1.54±0.26	5.85±0.95
	F8	28.56±2.1	54.74±2.5	83.3±4.5	2.01±0.45	7.80±1.15
	F9	28.56±2.2	59.5±2.3	88.06±4.5	3.02±0.25	4.29±0.45
		Drainage water sources				
Kafr El-Sheikh	D1	33.32±1.25	66.64±3.5	99.96±5.2	2.29±0.35	10.84±1.50
	D2	30.94±2.5	69.02±3.2	99.96±5.3	1.75±0.25	9.91±1.45
	D3	24.99±2.3	59.5±3.2	84.49±5.1	1.31±0.26	13.65±1.35
El-Qalyubia	D4	30.94±2.1	64.26±2.3	95.2±5.25	3.77±0.35	9.48±1.46
	D5	27.37±2.6	60.69±3.5	88.06±5.6	2.55±0.25	10.96±1.45
	D6	32.13±2.8	85.68±3.5	117.8±5.1	4.24±0.45	26.21±2.10
El- Fayoum	D7	35.7±2.3	54.74±3.2	90.44±5.0	2.62±0.45	14.04±1.95
	D8	29.75±2.6	59.5±3.3	89.25±5.3	1.39±0.35	13.77±2.50
	D9	27.37±2.0	69.02±3.5	96.39±5.1	2.69±0.45	8.81±1.15

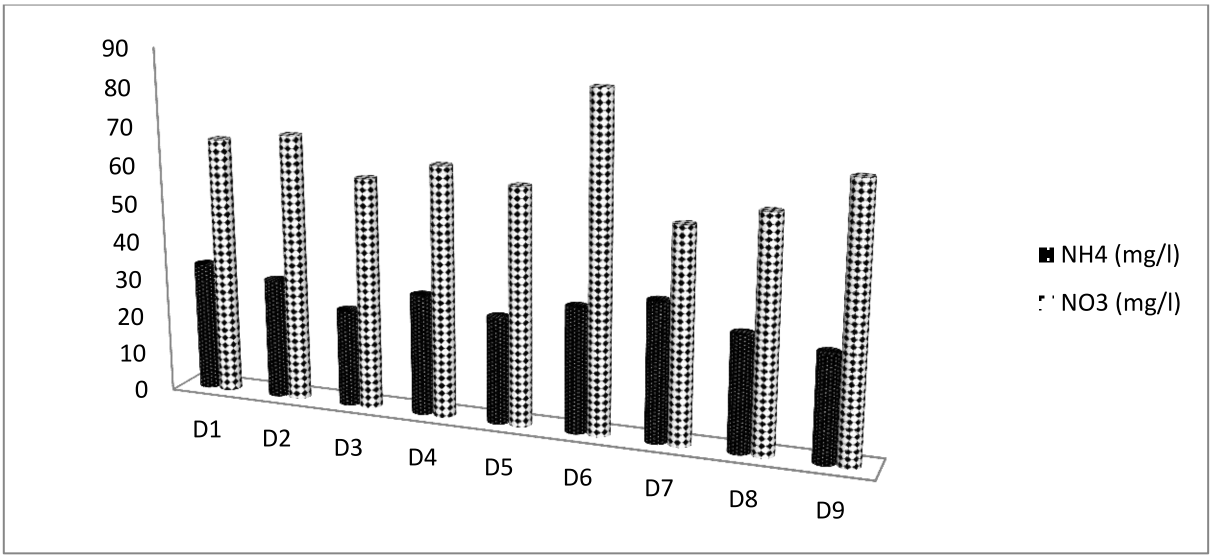

Fig. 2. NH^{4+}N and NO^{3-}N in drainage water samples in the studied area.

3.5 Organic Matters

The highest mean annual BOD and COD values in fresh and drainage water were (20.72 and 28 mg l^{-1}) (F1) and (72 and 96 mg l^{-1}) (D7), respectively. While, the lowest values were (3 and 4 mg l^{-1}) (F5 and F6) and (26.6 and 36 mg l^{-1}) (D3), for fresh and drainage water, respectively (Table 5). So, according to these results and based on guideline standard all water samples BOD and COD were below the standard limit except ((F1) and all drainage water sources) for BOD and (all drainage water sources except (D3) was blow limit) for COD were above limit. The BOD and COD of water samples were within the range of the permissible limits for fresh water except ((D1), (D6), (D7), (D8) and (D9)) for BOD and (D7) for COD, reflecting its suitability of all fresh and some drainage water sources for irrigation.

Table 5. Mean annual of BOD and COD levels in fresh and drainage water sources.

Governorate	Water sources	COD (mg l^{1-})	BOD (mg l^{1-})
		Fresh water sources	
	F1	28±2.50	20.72±2.45
Kafr El-Sheikh	F2	24±2.45	17.76±1.45
	F3	08±1.50	06.08±0.45
	F4	08±1.25	06.00±0.75
El-Qalyubia	F5	04±0.55	03.00±0.25
	F6	04±0.45	03.04±0.45
	F7	24±2.45	18.24±2.10
El- Fayoum	F8	08±1.15	06.08±0.25
	F9	08±1.15	06.00±0.35
		Drainage water sources	
	D1	76±3.55	57.00±4.5
Kafr El-Sheikh	D2	76±4.10	27.00±3.15
	D3	36±3.50	26.60±3.75
	D4	64±4.10	48.00±3.55
El-Qalyubia	D5	56±3.45	42.00±3.45
	D6	76±4.15	57.76±4.15
	D7	96±5.14	72.00±5.15
El- Fayoum	D8	80±3.75	60.00±5.45
	D9	80±3.80	59.20±3.45

3.6 Micronutrients and heavy metals

The determined heavy metals of Zn, Cu, Cd, Ni and Pb in the fresh and drainage water sources of the studied areas (Table 6). Their concentrations in fresh water sources were ranged from 0.024 to 0.3659, 0.0012 to 0.212, 0.00 to 0.0024, 0.0184 to 0.2294 and 0.0002 to 0.015 mg l^{1-}, respectively. Comparable values in drainage water sources were ranged from 0.00 to 0.2418, 0.00 to 0.0806, 0.00 to 0.0028, 0.0174 to 0.098 and 0.00 to 0.0126 mg l^{1-}, respectively. Thus, with the exception of Cu and Ni at (F6), which were above the permitted limits, the quantities of heavy metals in fresh and drainage water sources exceeded the irrigation limits water quality standards. All water sources in the areas under study can be classified as "No problem," indicating high water quality, with the exception of those that have surpassed allowable limits.

Table 6. Mean annual of heavy metal concentrations (mg l^{-1}) for fresh and drainage water sources.

Governorate	Water sources	Zn	Cu	Cd	Ni	Pb
				Fresh water sources		
	F1	0.067±0.1	0.002±0.2	0.00002±0.1	0.0186±0.1	0.0032±0.1
Kafr El-Sheikh	F2	0.024±0.1	0.008±0.3	ND	0.0254±0.2	0.0002±0.2
	F3	0.105±0.2	0.012±0.2	0.0002±0.1	0.0292±0.2	0.0038±0.1
	F4	0.365±0.15	0.157±0.2	0.0024±0.1	0.1742±0.2	0.015±0.3
El-Qalyubia	F5	0.024±0.1	0.015±0.2	0.0002±0.1	0.032±0.20	0.0052±0.3
	F6	0.061±0.2	0.212±0.3	ND	0.2294±0.2	0.004±0.3
El- Fayoum	F7	0.027±0.1	0.033±0.2	0.0002±0.1	0.0504±0.2	0.0052±0.1
	F8	0.027±0.1	0.058±0.2	ND	0.0754±0.3	0.004±0.1
	F9	0.030±0.1	0.030±0.1	0.00004±0.1	0.0478±0.3	0.0024±0.2
				Drainage water sources		
	D1	0.091±0.1	0.021±0.1	0.0002±0.1	0.0384±0.2	0.0064±0.1
Kafr El-Sheikh	D2	0.014±0.2	0.005±0.1	ND	0.0222±0.2	0.0014±0.2
	D3	0.017±0.2	ND	0.0002±0.1	0.0174±0.3	0.003±0.2
	D4	0.050±0.1	0.020±0.2	0.0002±0.1	0.0372±0.2	0.0054±0.1
El-Qalyubia	D5	0.109±0.2	0.081±0.3	0.0028±0.2	0.098±0.1	0.0126±0.1
	D6	0.241±0.3	0.049±0.2	0.0008±0.2	0.0668±0.1	0.0054±0.2
	D7	0.086±0.2	0.042±0.2	0.0012±0.2	0.0592±0.2	0.0068±0.1
El- Fayoum	D8	0.007±0.1	0.019±0.1	0.0004±0.2	0.0366±0.3	ND
	D9	ND	0.009±0.1	0.0002±0.2	0.0268±0.2	0.0014±0.1

ND: Not detected.

3.7 Calculated irrigation water quality criteria and categorization

Results showed that, mean annual SAR in fresh water varied from 3.98 (F5) to 20.53 (F8) and in drainage water ranged from 2.67 (D6) to 21.51 (D8) for all the studied areas (Table 7). All SAR results are within standard limits (<15) except (F7) and (F8) in fresh water and (D8) and (D9) in drainage water sources exceeds the standard limit. SAR results show that 77.78% of these samples are excellent and appropriate for irrigation. All sources of water Adj SAR content based on standard limits (6) were above the limit except sample (F5) in fresh water sources and ((D5) and (D6)) in drainage water sources were blow (no –problem). Most of the studied samples severe problems (Table 8) since values of Adj SAR were above (9).

Sodium soluble percentage (SSP)

Because the maximum limit should be less than 60%, the allowable sodium percentage permits the use of the water for irrigation. When water contains more than 60% salt, Na^+ can build up and cause soil damage. In drainage and fresh water resources, the soluble sodium percentages in the current study varied from 39.98 to 81.97% and 54.66 to 89.57%, respectively (Table 7). Water samples in our investigation are therefore classified as safe, questionable, and inappropriate for irrigation (Table 8).

Permeability index (PI)

PI varied between 67.42 (F5) to 101.34 meq/L (F3) for fresh and from 55.92 (D6) to 103.10 meq/L (D3) for drainage sources (Table 7). Therefore, based on PI values, all water samples in the study area were excellent except (D5 and D6) as drainage water and (F4 and F5) as fresh water were considered to be good for irrigation purposes (Table 8).

Residual sodium carbonate (RSC)

Results in Table (7) reveal that the majority of RSC was less than 1.25 mmolc l^{-1}. While, other above limit (1.25) were (F1), (F2), (F3) and (F9) as fresh sources and (D1), (D2) and (D3) as drainage sources therefore, most water samples is good for irrigation except the sources above limit were unsuitable for irrigation (Table 8).

Magnesium adsorption ratio (MAR)

According to Table (7), the mean annual MAR for fresh and drainage water sources in the study locations varied from 35.12 (F4) to 72.68 percent (F1) and 32.51 (D2) to 60.67 percent (D9), respectively. With the exception of (F1), (F8), and (D9), which are inappropriate fresh and drainage water sources, respectively, the majority of the areas under consideration have fresh and drainage water quality of less than 50%, indicating that they are suitable for irrigation (Table 8).

Potential salinity (PS).

In this study (Table 7), the PS values varied from 1.75 (F2) to 13.13 (F8) and from 3.28 (D5) to 32.44 (D9) for fresh and drainage water sources, respectively. So, according to standards of irrigation water quality based on PS, all water sources in study areas are classified as moderate except fresh water in Kafr El-Sheikh Governorate were good and drainage water sources in El-Faoum Governorate were low permeability (Table 8).

Kelly ratio (KR)

In Table (7), KR values are varying from 1.23 to 9.1meq/l and from 0.68 to 5.13 meq/l for fresh and drainage water sources, respectively. The present study illustrating that, all water sources were above the permissible limit of 1.0 except (D5) and (D6) values are lower the acceptable limit. Therefore, water of (D5) and (D6) considered appropriate and other samples were unsuitable for irrigation purposes (Table 8).

Table 7. Mean annual of some calculated irrigation water quality criteria for both fresh and drainage water sources.

Water sources	SAR	Adj.SAR	RSC	SSP	PI	PS	KR	MAR
				Fresh water sources				
F1	4.89±0.55	10.19±1.5	4.14±0.25	60.88±3.5	92.66±3.1	2.05±0.5	1.89±0.2	72.68±5.4
F2	7.31±0.75	15.47±1.4	6.27±0.45	73.42±4.2	100.1±4.3	1.75±0.3	2.99±0.3	38.59±4.5
F3	8.16±1.50	16.05±2.1	5.01±0.45	75.77±4.1	101.3±6.5	2.96±0.5	3.65±0.6	47.39±3.5
F4	4.82±0.45	8.79±1.2	-2.93±0.2	57.83±4.5	70.19±5.6	8.67±1.5	1.42±0.1	35.12±3.1
F5	3.98±0.25	6.78±0.65	-3.00±0.3	54.66±3.5	67.22±5.4	5.53±1.1	1.23±0.2	42.86±3.1
F6	5.20±0.35	11.13±1.2	1.12±0.2	61.10±3.5	79.68±4.1	5.32±1.5	1.60±0.6	43.18±4.1
F7	20.35±2.1	31.74±2.5	0.90±0.1	89.57±2.6	97.40±4.5	12.1±1.8	9.10±1.5	37.20±4.2
F8	20.53±2.2	33.35±2.8	0.50±0.1	88.71±5.4	95.99±3.5	13.1±2.0	8.38±1.1	60.00±5.4
F9	8.96±1.15	20.58±2.1	3.25±0.2	71.83±6.5	86.37±3.6	7.56±1.5	2.60±0.5	36.13±5.6
				Drainage water sources				
D1	11.82±1.1	24.32±2.1	4.20±0.4	79.47±5.4	95.80±3.5	8.16±1.5	4.44±0.5	40.85±4.5
D2	15.07±2.3	35.99±3.2	10.54±0.5	81.88±5.6	97.82±4.5	8.24±1.0	5.04±0.6	32.51±4.6
D3	12.51±2.2	27.63±2.5	9.53±0.5	81.46±5.8	103.1±5.6	5.31±1.4	5.13±0.4	47.14±4.5
D4	4.95±0.65	9.82±1.25	0.25±0.1	60.98±5.4	79.71±4.6	5.23±1.1	1.63±0.4	43.48±5.6
D5	2.76±0.25	5.17±0.45	-1.30±0.1	46.20±4.5	67.10±4.5	3.28±0.9	0.89±0.2	45.26±4.8
D6	2.67±0.35	5.58±0.55	-3.50±0.6	39.98±5.4	55.92±4.5	7.69±1.1	0.68±0.2	45.45±4.8
D7	12.39±1.5	26.37±2.5	-1.90±0.1	74.95±6.4	83.70±6.4	18.8±2.1	3.20±0.2	38.93±4.6
D8	20.51±2.0	46.45±3.45	-0.59±0.2	81.97±4.5	88.89±4.5	28.7±3.1	5.01±0.3	37.54±4.5
D9	18.96±2.4	44.37±3.15	-0.10±0.1	81.17±5.6	87.87±4.5	32.4±3.2	4.49±0.6	60.67±5.4

EC: Electrical conductivity, SAR: Sodium adsorption ratio, adj.SAR: adjusted sodium adsorption ratio, RSC: Residual Sodium, SSP: Sodium Soluble Percentage, PS: Potential salinity, MAR: Magnesium Adsorption Ratio, PI: Permeability Index, KR: Kelly ratio.

Table 8. Classification of irrigation fresh and drainage water sources in accordance with guidelines for various water quality factors.

Water sources	EC	SAR	USSL Index	USSL Class	Adj.SAR	RSC	SSP	PI	PS	KR	MAR
Fresh water sources											
F1	C2	S1	C2S1	G.	S. P.	Uns.	V.P	E.	G.	Uns.	Uns.
F2	C2	S1	C2S1	G.	S. P.	Uns.	V.P	E.	G.	Uns.	Su.
F3	C2	S2	C2S2	G.	S. P.	Uns.	V.P	E.	G.	Uns.	Su.
F4	C1	S1	C1S1	E.	S. P.	G.	S.	G.	M.	Uns.	Su.
F5	C2	S1	C2S1	G.	S. P.	G.	S.	G.	M.	Uns.	Su.
F6	C2	S1	C2S1	G.	S. P.	G.	V.P	E.	M.	Uns.	Su.
F7	C2	S3	C2S3	A.	S. P.	G.	Uns.	E.	M.	Uns.	Su.
F8	C2	S3	C2S3	A.	S. P.	G.	Uns.	E.	M.	Uns.	Uns.
F9	C1	S2	C1S2	G.	S. P.	Uns.	V.P	E.	M.	Uns.	Su.
Drainage water sources											
D1	C3	S3	C3S3	A.	S. P.	Uns.	V.P	E.	M.	Uns.	Su.
D2	C3	S3	C3S3	A.	S. P.	Uns.	Uns.	E.	M.	Uns.	Su.
D3	C2	S3	C2S3	A.	S. P.	Uns.	Uns.	E.	M.	Uns.	Su.
D4	C2	S1	C2S1	G.	S. P.	G.	V.P	E.	M.	Uns.	Su.
D5	C2	S1	C2S1	G.	S. P.	G.	S.	G.	M.	Su.	Su.
D6	C3	S1	C3S1	Ap.	S. P.	G.	S.	G.	M.	Su.	Su.
D7	C3	S3	C3S3	A.	S. P.	G.	D.	E.	L.P.	Uns.	S.
D8	C4	S4	C4S4	V.P	S. P.	G.	Uns.	E.	L.P.	Uns.	S.
D9	C4	S4	C4S4	V.P	S. P.	G.	Uns.	E.	L.P.	Uns.	Uns.

Water quality class according to USDA (1954); C1, C2, C3, C4 are low, medium, high and very high salinity; S1 , S2 , S3 , S4 are low, medium, high and very high sodicity, respectively. EC: Electrical conductivity, SAR: Sodium adsorption ratio, adj.SAR: adjusted sodium adsorption ratio, RSC: Residual Sodium, SSP: Sodium Soluble Percentage, PS: Potential salinity, MAR: Magnesium Adsorption Ratio, PI: Permeability Index, KR: Kelly ratio. G: Good, E: Excellent, A: Acceptable, V.P: Very poor, S.P.: Severe problem, Uns.: Unsuitable, D.: Doubtful, S.: Safe, M.: Moderate, L.P.: Low permeability, Su. Suitable, Ap.: Appropriate.

2. Discussion

Worsening of water quality can happen due to industrial, municipal and agricultural activities. Consistent assessment water quality of water resources is essential to evaluation water quality for ecosystem health, industrial, domestic and agricultural usage. Traditional methods for evaluating water quality are centred on comparing values of the tested determined variable with current guidelines.

The pH values of each water sample are within the permissible parameters given by FAO recommendations and Egyptian regulations, revealing its appropriateness for irrigation. Some sources may experience a small increase in pH due to intrusions of industrial effluent. Changes in pH are associated with variations in conductivity and bicarbonate content (Roy and Rhim, 2021). The electrical conductivity (EC) of water is directly related to the amounts of ions dissolved in it (Wu et al., 2017 and Ghieth et al., 2019). The growth of soil salinity to the point where crop yields are adversely affected serves as the primary basis for categorizing irrigation water based on salinity threat. The incapacity of the plant to compete with ions in the soil solution for water (physiological drought) is a significant element influencing the impact of high EC on crop productivity when it comes to irrigation water (**Temesgen et al., 2023).**

The lowest value of EC in fresh water sources in our investigation was 0.226 dS/m (F9). However, in drainage water sources, the greatest EC value was 3.04 dS/m (D8). According to the FAO's Guidelines for Irrigation Water (**FAO, 1985),** all fresh water samples falls into the C1 class, or "No Problem," which indicates that the water quality is in good condition. The fact that (D8) was in the C4 class, however, suggests a serious issue, whereas other drainage water sources in the C2 class "i.e. increasing problem"

In water bodies, nitrate (NO_3^--N) can be created by oxidizing and reducing other forms of nitrogen, such as nitrite, ammonia, and organic nitrogen compounds like amino acids. It can also enter water directly from fertilizer runoff that contains nitrate **(Kidd, 2011 and Ashoura et al., 2021).** Excessive NO_3^-in irrigation water delays crop maturity by overstimulating vegetation growth, which lowers crop output quality and quantity.

Furthermore, nitrate poses serious health problems due to its easy leaching from the soil and potential for groundwater contamination **(Elgallal et al., 2016 and Abbas et al., 2020).**

A quantity of more than 2.5 mg/l of ammonia can be toxic to aquatic life, and an excess of 1 mg l^{-1} is indicative of organic pollution **(Reid, 1961).** The concentrations of NO_3^- and NH_4^+ in all of the water samples from our investigation are found to be higher above the essential limits for irrigation. According to the **FAO (1985),** the degree of restriction in usage for irrigation is categorized as "Moderate to high" for NH_4^+ and "Severe problem" for NO_3^-. Runoff from agricultural fields, particularly those with significant inputs of mineral fertilizers, animal dung, and urban waste water, may be the cause of these rising nutrient concentrations (NPK), which would result in eutrophication **(Afify et al., 2019 and Abdo et al., 2022).** BOD and COD provide the organic matter indicator. When BOD levels are high, aerobic bacteria use the dissolved oxygen to finish decomposing organic materials and create an anaerobic condition. The quantity of oxygen consumed by the biotic organisms during biodegradation is known as BOD. However, according to **El-Bourie (2008) and Abd El-Razik et al. (2023**), COD is a sign of the oxidation of both organic and inorganic elements in water. High BOD and COD in the current study could be the result of home wastewater pollution. Increasing BOD and COD levels are typically signs of increased microbial activity. NH_4^+ and NO_3^- values were shown to rise as a result **(Masoud et al., 2020 and Abdo et al., 2022).** To improve the water quality for BOD and COD, a basic wastewater treatment plant should be feasible to install on the study regions' drains. Water sources may become contaminated by heavy metals, which would affect the quality of the water **(Krishna et al., 2009 and Ghieth et al., 2019).** Because of their toxicity, durability, and bioaccumulative nature in the environment, they are considered serious pollutants **(Pekey et al., 2004).** With the exception of Cu and Ni at Qalyubia Canal (F6), which were within acceptable limits, the majority of the fresh and drainage water samples in our investigation were below the FAO irrigation limits and Egyptian water quality criteria for drainage water. The behaviour of the heavy metals, which are deposited at the water pathway's bottom, could be the cause of this **(Sherif, 2019).** 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.

Under specific soil texture circumstances, applying water with an imbalance in salt can further reduce yield. Water infiltration may decrease when irrigation water has a high salt content in comparison to its calcium and magnesium content **(Hamid et al., 2012).** The USDA proposed the "sodium adsorption ratio" (SAR) in 1954. Water samples investigated in this study range from those with no sodicity hazard to those with sodicity hazard. The high number, which reflects inappropriate water quality, particularly in the El-Fayoum Governorate, suggests a sodicity threat. With the exception of the samples of F5 in fresh water sources and D5 and D6 in drainage water sources, all water sources had a SAR concentration above the FAO regulatory limits (6). Since levels of Adj SAR were above (9) according to Egyptian norms (Law 48/1982), which might produce permeability issues for the soil, the majority of the studied samples had serious issues (Table 8). SSP is the primary criterion used to classify irrigation water quality. According to Table 7, the lowest SSP value in drainage water sources is 39.98 (D6), while the highest value is 89.57 (F7) in fresh water sources. According to the findings, samples (F4), (F5), (D5), and (D6) had lower maximum limits, indicating that their water was safe or acceptable for use in agricultural irrigation throughout the study period. The lower Na^+ abundance in certain water sources may be the cause of this **(Temesgen et al., 2023).** Other water sources, such as drainage and fresh water sources were above the upper limit. As a result, their water quality was questionable and inappropriate **(Wilcox 195**5). When soil and water sodium react, the sodium builds up in the pore space and reduces soil permeability **(Hem, 1991).** According to **Akhtar et al. (2015) and Khalil et al. (2019),** too much Na^+ in irrigation water also causes issues with crop water uptake, lack of aeration, poor seedling emergence, plant and root reductions, etc. The lowest PI recorded in command areas was 55.92 meq/L (D6), and the highest was 103.1 meq/L (D3). Water quality is excellent with a PI > 75 and no issues with permeability or infiltration **(Al-Amry, 2008).** According to PI category, every water sample in this study is of excellent and good irrigation quality, demonstrating its appropriateness for irrigation. The findings of Wong et al. (2020), who recommended using exceptional and good PI water quality for irrigation, are supported by this research. Sodium carbonate buildup can render irrigated soils with high RSC water content unproductive **(Khalid, 2019 and Amer and Mohamed, 2022).** Additionally, raising the RSC in irrigation water poses harm to plant growth. The majority of the water samples in our study had RSC levels below the maximum limit (1.25 meq/l), making them safe for irrigation; those that above the limit were deemed unsuitable **(Murtaza et al., 2021). Singh et al.'s (2020)** which used RSC levels to categorize high-quality water for irrigation aims, provided support for this work. High magnesium levels in irrigation water reduce agricultural productivity **(Grattan, 2002 and Temesgen et al., 2023).** The water samples in our study had the highest average MAR level of 72.68% (F1) and the lowest level of 32.51% (D2). Accordingly, the command regions' fresh water and drainage quality are less than 50%, indicating that they are suitable, with the exception of F1, F8, and D9, which exceed the limit and are therefore unsuitable **(Zhang et al., 2021).** This might be because most samples have low Mg^{2+} levels **(Temesgen et al., 2023).** PS in this study ranged from 32.44 (D9) in El- Fayoum Governorate to 1.75 (F2) in Kafr El-Sheikh Governorate. Accordingly, samples are classified as having good to low permeability based on PS of irrigation water quality criteria **(Delgado et al., 2010).** The somewhat reduced Cl^- and SO_4^{-2} levels in fresh water samples from the Kafr El-Sheikh Governorate and the slightly higher values in other samples may be due to **Giri et al. (2022) and Temesgen et al. (2023)**.

In agriculture, the Kelly Ratio/Kelly index is used to determine if irrigation water is suitable. Higher sodium irrigation water affects soil structure by slowing the rate at which water enters the soil **(Grattan, 2002).** KI had the greatest value of 9.10 (F7) and the lowest value of 0.68 (D6) in the current study. The findings show that, with the exception of D5 and D6, the majority of samples are deemed unsuitable for irrigation based on Kelly's values **(Shah et al., 2019).** This might be because the water samples from D5 and D6 had higher concentrations of Ca^{2+} and Mg^{2+} **(Kelly 1940 and Giri et al., 2022),** and they concluded that the water was suitable based on the KI result of 0.74–0.94.

3. Conclusion

Assessing the water quality of fresh and drainage water sources is essential for public health and food security since irrigation canals and drains pick up contaminants from agriculture, industry, and municipalities. Our results for fresh water sources, classified as class excellent (C1S1) to acceptable (C2S3) while drainage water sources varied from good (C2S1) to very poor (C4S4) in El- Fayoum Governorate, which could had negative outcomes on soil and plant health. Additionally, the PI, MAR, SSP and RSC indexes in both water resources ranked as good to excellent, suitable to unsuitable, safe to unsuitable and good to unsuitable, respectively. But, PS index ranked as good to moderate for fresh water sources and moderate to Low permeability for drainage water sources. Based on the findings of physicochemical analyses and irrigation criteria of all fresh water resources are appropriate for irrigation. But, most drainage water sources have large obstacles and inappropriate for irrigation, especially in El- Fayoum Governorate drainage water are very poor. Therefore, this study recommended conducting regular and continuous studies on these areas in future works to monitor any change in water quality therefore avoid pollution and clarify its suitability for irrigation. In addition, drainage water sources must be properly treated before using in agriculture irrigation.

Ethics approval and consent to participate: None of the writers of this essay has ever conducted any research on humans or animals.
Consent for publication: All authors declare their consent for publication.
Funding: There is no external funding.
Conflicts of Interest: The author declares no conflict of interest.
Contribution of Authors: All authors shared in writing, editing and revising the MS and agree to its publication.

References

Abbas, H. H.; Abuzaid, A. S.; Jahin, H. S. and Kasem D.S. (2020).Assessing the quality of untraditional water sources for irrigation purposes in Al-Qalubiya Governorate, Egypt. Egypt. J. Soil. Sci. Vol. 60, No. 2, P. 157-166.

Abd El-Al, Saffaa S.; Abd El-Aziz, Zienab M. H. and El-sayed Suzan, A. (2022). Monitoring of some chemical and biological pollutants in wastewater of Bahr ElBaqar, Bilbies and El-Qalyubia drains in east Delta, Egypt for irrigation purposes.J. of Basic and Env. Sci., 9, 12- 19.

Abd El-Razik, Eman M.; El Tohamy, S. A. and Khafagy, Dalia H. (2023).A qualitative and quantitative study on El-Gharbia main drain wastewater. J. of Soil Sciences and Agri. Eng., Mansoura Univ., Vol. 14 (6):163 – 169.

Abdel-Fattah, M.K. and Helmy, A.M. (2015). Assessmentof water quality of Wastewaters of Bahr El-Baqar, Bilbies and El-Qalyubia Drains in East Delta, Egypt for irrigation purposes. Egypt. J. Soil Sci. Vol. 55, No. 3, P.287-302.

Abdelhafez, A.A..; Abbas, M.H.H.; Kenawy, M.H.K.; Ewis, A.M.G. and Hamed, M.H. (2021).Evaluation of underground water quality for drinking and irrigation purposes in New Valley Governorate, Egypt, Env.Tech. & Innovation, 101486.

Abdo, M.H.; Ahmed, H.B.; Helal, M.H.; Fekry, M.M. and Abd El-hamid, A.E. (2022).Water quality Index and environmental assessment of Rosetta Branch aquatic system, Nile River, Egypt. Egypt. J. Chem. Vol. 65, No. 4, P. 321 – 331.

Abosena, A.; Abbas, H.; Farid, I. and El-Kholy, M. (2021). Environmental assessment of El-Gharbia main drain water.Env.Biodiv.Soil Security Vol. 5 P. 185 – 203.

Abuzaid, A.S and Jahin. H.S.(2021) Changes in Alluvial Soil Quality under Long-Term Irrigation with two Marginal Water Sources in an Arid Environment. Egypt. J. Soil. Sci. Vol. 61, No. 1, pp. 113-128 (2021)

Adeleke, A. R. O.; Abdul Latif, A. A.; Daud, Z.; Mat Daud, N. F. and Aliyu, M. K. (2017). Heavy metal removal from wastewater of palm oil mill using developed activated carbon from coconut shell and cow bones.Key Engineering Materials.

Adimalla, N. and Venkatayogi, S. (2018). Geochemical characterization and evaluation of groundwater suitability for domestic and agricultural utility in semi-arid region of Basara, Telangana State, South India.Appl. Water Sci. 8, 44. https://doi.org/10. 1007/s13201-018-0682-1

Afify D. G. Al-Afify; Usama M. Tahoun and Mohammed H.Abdo (2019). Water quality index and microbial assessment of lake Qarun, El-Batts and El-Wadi drains, Fayoum Province, Egypt. Egypt. J. Aquat. Biol. Fish. 23: 341–357.

Akhtar, S.; Andersen M. and Liu F. (2015). Residual effects of biochar on improving growth, physiology and yield of wheat under salt stress. Agric. Water Manag., 158 : 61– 68.

Al-Afify, A. D.G. and Aly, M. Y. M. (2019). Application of Nile chemical pollution index to evaluate the quality of water for drinking and agricultural purposes on Bahr Yusuf Branch, River Nile, Egypt. Egyptian J. of Aq. Bio. &Fis.Zo.De., Fac. of Sci., Ain Shams Uni., Cairo, Egypt. ISSN 1110 – 6131 Vol. 23(1): 367 -379.

Al-Amry, A.S. (2008). Hydro geochemistry and groundwater quality assessment in an arid region: A case study from al Salameh area, Shabwah, Yemen. The 3rd Inter. Conf. on water resources and arid environments and the 1 st Arab Water Forum.

Al-humairia, Basima A. J., and Rahal, Nadhum S. (2023).Assessing drainage water quality for irrigation using the water quality index and Data Fit software. Water Supply Vol 23 No 6, 2349 doi: 10.2166/ws.131.

Allam, A. E. and Negm, A. M. (2013). Agricultural drainage water quality analysis and its suitability for direct reuse in irrigation: case study: Kafr El-Sheikh Governorate, Egypt. Seventeenth Inter. Water Tech. Conf., IWTC17 Istanbul, 5-7 November.

Amer, Amany S. and Mohamed, Walaa S. (2022). Assessment of Ismailia Canal for irrigation purposes by water quality indices. Environ Monit. Assess. 194: 862.

APHA, AWWA and WEF (2005). Standard methods for the examination of water and wastewater, XX Edn., American Public Health Association, Washington, DC.

Ashoura, Eman; Zeidana, Bakenaz and Elshemy, M. (2021). Assessment of agricultural drainage water reuse for irrigation in El-Behira Governorate, Egypt. Water Science, Vol. 35, NO. 1, 135–153. https://doi.org/10.1080/23570008.2021.1982336.

Ayres, R.S and Westcot, D.W. (1994), "Water quality for agriculture", Irrigation and Drainage paper No. 29, FAO, Rome, Italy.

Bassouny, M.A. and Abbas, M.H.H. (2020).Monitoring environmental pathways of trace elements in the northern east area of Egypt. Environment, Biodiversity and Soil Security 4, 103-121. doi:10.21608/jenvbs.2020.29403.1094.

Clesceri, L. S.; Greenberg, A. E.; Eaton, A. D.; Rice, E. W. and Franson, M. A. H. (2005). Standard methods for the examination of water and wastewater.American Public Health Association, (No. 628.161 S7/2005).

Cottenie, A.; ver Loo, M.; Mjkiekens, L.; Velghe G. and Comertynck, R. (1982).Chemical analysis of plant and soil. Lab. Anal. And Agrochem. State Univ., Gent., Belgium, Chapter 2 and 3, pp. 14-54.

Delgado, C.; Pacheco, J.; Cabrea, A.; Baltlori, E.; Orellana R. and Baustista F. (2010). Quality of groundwater for irrigation in tropical karst environment; the case of Yucatan, Mexico, Agric. Water Manag., 97: 1423–1433.

Doneen, L. D. (1964). Notes on water quality in agriculture.Department of Water Science and Engineering, University of California, Oakland, CA, USA.

Egyptian Law (48/1982) The Implementer Regulations for Law 48/1982 Regarding the Protection of the River Nile and Water Ways from Pollution (in Arabic). https://www.mwri.gov.eg/ index.php/ministry/ministry-17/12-1984.

El-Amier, Y.A.; Bonanomi, G. and Abd-ElGawad, A.M. (2023). Pollution risk assessment of heavy metals along Kitchener drain sediment, Nile Delta. Soil Syst. 7, 85. https:// doi.org/10.3390/soilsystems7040085.

El-Bourie, M. M. Y. (2008).Evaluation of organic pollutants in Rosetta branch water-river Nile, M.Sc. Thesis.faculty of science, Tanta University, Egypt environ. Res. our. 35: 109-136.

Elgallal, M.; Fletcher, L. and Evans, B. (2016). Assessment of potential risks associated with chemicals in wastewater used for irrigation in arid and semiarid zones: A review. Agric. Water Manag.177, 419-431.

El-Ganzori, A.; Abdel Gawad, T.; El-Sayed, A. and Hashim, A. (2000).Assessment of the drainage water reuse in the irrigation improvement areas, Kafr El Sheikh Governorate of Egypt. ICEHM2000, Cairo University, Egypt, page 333-344.

Elghannam, Kh.M ; Mona K. Abdel-Razek and Hesham Aboelsoud. Quality Assessment of Some Water Sources and Soil under Sea Water Intrusion Conditions in North Nile Delta, Egypt. Env. Biodiv. Soil Security Vol. 3 pp. 179 - 192 (2019).

FAO (1985). Guidelines: Land evaluation for irrigated agriculture - FAO Soils Bulletin 55. Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy.

Farid, I.; Abbas, M.; Bassouny, M.; Gameel, A. and Abbas, H. (2019). Indirect impacts of irrigation with low quality water on the environmental safety. Egyptian J. of Soil Science. doi: 10.21608/ ejss.2019.15434.1294.

Fipps, G. (1998) “Irrigation Water Quality Standards and Salinity Management”. The Texas A & M University System.

Ghieth, M. I.T.; Soliman, K.G. and Abu-Hashim, M.S. (2019). Quality of surface water in some selected drains and canals in Fayoum Governorate. Zagazig J. Agric. Res., Vol. 46 No. (6B).

Giri, A.; Bharti, V. K;,Kalia, S.; Kumar, K. and Khansu, M. (2022). Hydro chemical and quality assessment of irrigation water at the trans-himalayan high-altitude regions of Leh, Ladakh, India. Appl. Water Sci. 12, 197.https://doi.org/10.1007/s13201-022- 01716-1.

Grattan, S. (2002). Irrigation water salinity and crop production.University of California, Division of Agriculture and Natural Resources. http://anrcatalog.ucdavis.edu https://doi.org/10.3733/ucanr.8066.

Hamid I. T.; Bakhtiyar, Y.; Ahmad F. and Inam A. (2012). Effluent quality parameters for safe use in agriculture, water quality, soil and managing irrigation of crops, Dr. TeangShui Lee (Ed.), ISBN: 978-953-51-0426-1, In Tech., Available from: http://www.intechopen.com.

Hegazi, I.M.; Abbas, M.H.H and Ismaeil, A.O. (2019). Groundwater quality assessment for irrigation purposes in the West of Minia Governorate, Egypt. J. Soil Sci. and Agric. Eng., Mansoura Univ. 9(12, 809-916.

Hem, J. D. (1991).Study and interpretation of the chemical characteristics of natural water.Scientific Publishers.

ICARDA (2013) “International Center for Agricultural Research in the Dry Areas”. Methods of soil, Plant, and water analysis: A manual for the West Asia and North Africa region. Estefan, G., Sommer, R. and Ryan, J. 3th edition. Box 114/5055, Beirut, Lebanon.

Kelly, W.P. (1940). Permissible composition and concentration of irrigation water. Proc. Amer. Soc. Civ. Engin. 66, P: 607-613.

Khalid, S. (2019). An assessment of groundwater quality for irrigation and drinking purposes around brick kilns in three districts of Balochistan province, Pakistan, through water quality index and multivariate statistical approaches. Journal of Geochemical Exploration, 197, 14–26.

Khalifa, H. and Moussa, H. (2017).Soil and agriculture after the Aswan High Dam. In Irrigated Agriculture in Egypt; Satoh, M., Aboulroos, S., Eds.; Springer: Cham, Switzerland, 2017; P: 81–124.

Khalil, M. A.A.; El-Sherbieny, A.E.; Dahdouh, S.M. and Sherif, M.M. (2019). Evaluation of Belbais drain water quality and the possibility of using in agricultural irrigation purposes in Sharkia Governorate, Egypt. Zagazig J. Agric. Res., Vol. 46 No. (6B).

Kidd, S. (2011). Summary of standard parameter ranges for salmonid habitat and general stream water quality. Water Quality Monitoring Grant Report, Oregon Watershed Enhancement Board, Salem, Oregon.Published July 2011.

Kijne, J. W. (2003). Water productivity under saline conditions.In J. W. Kijne, R. Bark er, & D. Molden (Eds.), Water Productivity in Agriculture: Limits and Opportunities for Improvement (P: 89-102).CABI.https://doi.org/10.1079/9780851996691.0000.

Krishna, A.K.; Satyanarayanan, A. and Govil, P.K. (2009). Assessment of heavy metal pollution in water using multivariate statistical techniques in an industrial area: A case study from Patancheru, Medak District, Andhra Pradesh, India. J. Hazard. Mater., 167: 366-373.

Kumar, M., and Kumar, R. (2012).Assessment of Physicochemical properties of ground water in granite mining areas in Jhansi, U.P. Inter. J. of Engineering Res. and Tech., 1, 1-9.

Lian, J.; Wu, J.; Zeb, A.; Zheng, S.; Ma, T.; Peng, F.; Tang, J. and Liu, W. (2020). Do polystyrene nanoplasties affect the toxicity of cadmium tp wheat (Triticum awstivum L.). Environ. Pollut. Volume 263, Part A, August, 114498.

Mahmoud, E. (2022). 'Effect of nanomaterials on Soil Quality and Yield of Canola (Brassica napus) Grown in Heavy Clayey Soils Asmaa El-shahawy a,', *Egyptian Journal of Soil Science*, 62(4), pp. 361-371. doi: 10.21608/ejss.2022.152942.1522

Masoud, M.S.; Ismail, A.M.; Kamel, H.M.; ElKholany, A.S. and ElKasas, A.A.M. (2020).Physico chemical studies for water at Rosetta Branch of River Nile, Egypt, IOP Conf. Ser. Mater. Sci. Eng. 975 (2020).https://doi.org/10.1088/1757-899X/975/1/012010.

Mohamed H. Sheta and Mostafa H. Fayed (2021) Productivity and Water Use Efficiency of Summer Squash Crop under Two Methods of Irrigation Water Application. Egypt. J. Soil. Sci. Vol. 61, No. 1, pp. 1-11 (2021)

Mukiza, P.; Bazimenyera, J. D. D.; Nkundabose, J. P.; Niyon kuru, R. and Bapfakurera, N. E. (2021). As sessment of Irrigation Water Quality Parameters of Nyandungu Wetlands. Journal of Geoscience and Environ. Protection, 9, 151-160.

Murtaza, G.; Rehman, M.; Qadir, M.; Shehzad, M.; Zeeshan, N.; Ahmad, H.; Farooqi, Z. and Naidu, R. (2021). High residual sodium carbonate water in the Indian subcontinent: Concerns, challenges and remediation. Inter. J. of Environ. Sci. and Technology, 18(10), 3257–3272.

Nabwi, M.F.; Abbas, H.H.; Salem, H.M. and Abbas, M.H.H. (2018) Feasibility of reclamation of low quality waters from different sources in Egypt. Egypt J. Appl. Sci. 3(5), 105-128.

Nour, H.E.; Alshehri, F.; Sahour, H. and El-Sorogy A.S. (2022). Evaluation of sediment and water quality of Ismailia Canal for heavy metal contamination, Eastern Nile Delta, Egypt. Regional Studies in Marine Science. Vol. 56,102714.

Oyekanmi, A.; Ahmad, A.; MohdSetapar, S. H.; Alshammari, M. B.; Jawaid, M.; Hanafah, M. M.; Abdul Khalil, H. and Vaseashta, A. (2021). Sustainable duriozibethinus derived biosorbents for congo red removal from aqueous solution: Statistical optimization, isotherms and mechanism studies. Sustainability, 13(23), 13264.

Pekey, H.; Karakas D. and Bakoglu, M. (2004). Source apportionment of trace metals in surface water of a polluted stream using multivariate statistical analyses. Mar. Pollut. Bull., 49: 809-818.

Ravikumar, P.; Somashekar, R. and Angami, M. (2011).Hydrochemistry and evaluation of groundwater suitability for irrigation and drinking purposes in the Markandeya River basin, Belgaum District, Karnataka State, India. Environ. Monit. Assess. 173, 459–487.

Reid, K. G. (1961). Ecology of Inland Waters and Estuaries. Text book VNR, New York, 375 p. Richards, L.A. (1954). Diagnosis and improvement of saline and alkaline soils" U.S. Dep. Agric. Hand book 60. U.S.A.

Rowell, D. L. (1995).Soil sciences methods and applications.Library of congress cataglogin in publication data, New York. USA.

Roy, S., and Rhim, J.W. (2021). Anthocyanin food colorant and its application in pH-responsive color change indicator flms. Critical Reviews in Food Science and Nutrition, 61(14), 2297–2325.

Saffan, M. M.; El-Henawy, A. S. ; Agazo, Nesma. A. and El-Mahdy. Shimaa. M. (2024). Effect of irrigation water quality on chemical and physical properties of soils. Egypt. J. Soil Sci. Vol. 64, No. 4, pp: 1407 – 1417.

Shah, B.; Kansara, B.; Shankar, J.; Soni, M.; Bhimjiyani, P.; Bhanushali, T.; Shah, M. and Sircar, A. (2019). Reckoning of water quality for irrigation and drinking purposes in the konkan geothermal provinces, Maharashtra. India. Groundwater for Sustainable Development, 9, 100247.

Sherif, A.E.A. (2019). Environmental assessment for soils and plants irrigated from canal Bani Ghalib Assiut Governorate Egypt. Inter. J. of Envi. Vol.: 08 | Issue : 04| Oct. - Dec. P.: 189-209.

Shil, S.; Singh, U. K. and Mehta, P. (2019).Water quality assessment of a tropical river using water quality index (WQI), multivariate statistical techniques and GIS.Applied Water Science, 9(7), 1–21.

Singh, K.; Tewari, G. and Kumar, S. (2020). Evaluation of groundwater quality for suitability of irrigation purposes: a case study in the Udham Singh Nagar, Uttarakhand. J. Chem. 2020, 1–15. https://doi.org/10.1155/2020/6924026.

Soliman, M. A.; Abdullah, Amal Sh. A. and El-Sherpiny, M. A. (2024). Assessing the Efficacy of Agro-Waste Biochar-Derived Nanoparticles for Purification of Municipal Wastewater, Agricultural Drainage Water and Industrial Effluents. Egypt. J. Soil Sci. Vol. 64, No. 3, pp: 885 – 896.

Sultana, R. and Kala, D. S. (2012). Water body quality analysis by benthic macro invertebrates, ijpbs, 2(1): 269 - 279.

Temesgen, E.; Gulie, G. and Akili, D. (2023). Evaluation of drainage water quality for irrigation reuse in Kulfo and Hare irrigation command areas, southern Ethiopia.Water Practice & Technology Vol 18 No 10, 2329 doi: 10.2166/wpt.2023.146.

USDA (1954).“Diagnosis and Improvement of Saline and Alkali Soils”.Agriculture Handbook 60, US Gov. Printing Office, Washington, DC, USA.

Wilcox, L. (1955). Classification and use of irrigation waters. United States Deparment of Agri., Washington, DC, USA.

Wong, Y.J.; Shimizu, Y.; He, K. and Nik Sulaiman, N.M. (2020). Comparison among different ASEAN water quality indices for the assessment of the spatial variation of surface water quality in the Selangor river basin, Malaysia. Environ. Monit. Assess 192, 644.

Wu, T.; Li, X.; Yang, T.; Sun, X.; Mielke, H.W.; Cai, Y.; Ai, Y.; Zhao, Y.; Liu, D. and Zhang X. (2017). Elements in source water (Drinking and Surfaces Water) within Five Cities from the Semi-Arid and Arid Region, NW China: Occurrence, Spatial Distribution and Risk Assessment. Int. J. Environ. Res. Public Health, 14: 1168.

Zhang, Q.; Qian, H.; Xu, P.; Hou, K. and Yang, F. (2021).Groundwater quality assessment using a new integrated weight water quality index (IWQI) and driver analysis in the Jiaokou Irrigation District, China. Ecotoxicology and Environmental Safety, 212, 111992.