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Assessment of the Surface and Groundwater Quality in Ismailia Canal and its Adjacent Area

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Abstract

Ismailia Canal, one of the main branches of the Nile River in Egypt, is considered as one of the most important irrigations and drinking water source for Ismailia, Port Said and Suez governorates. The aim of the present study is to determine the water quality in the area of investigation to follow up on the long-term changes in the physical and chemical characteristic of water to find out the present status of the water quality of Ismailia Canal.In order to achieve effluent concentration regulations, the study advises improving the control of garbage dumped into the channel. Set in Law 48/ 1982 for the protection of the Nile River and its waterways against pollution.The widely applied solution to this problem is based on keeping heavy metals below the permissible limits in soil and agricultural crops. The outcome of this study can provide key information on heavy metals, which is useful in achieving sustainable agricultural management. So, water samples were collected from different dimensions and directions from Ismailia Canal, and chemical properties of the collected Surface and groundwater were determined the appropriateness of water for irrigation using various parameters like pH, electrical conductivity, sodium absorption ratio, and water quality index were assessed. The results of samples analysis showed that pH values ranged from 7.1 to 8.1, and electrical conductivity values fluctuated between 0.334 and 0.447 mS/cm. Moreover, the sodium adsorption ratio of the water samples ranges between 0.55 and 3.01, While the water quality index showed that all water samples, both surface and groundwater, are excellent for irrigation. The most pressing challenge facing water resources development in Egypt are rapid growth and unbalanced distribution of the population, rapid urbanization, water quality deterioration, government's policy to reclaim new land, and unsustainable water use practices. Now Egypt is reaching its limits of available water and this will not be possible anymore and Egypt will have to face variable supply conditions.

keywords: Groundwater, Surface water, Water quality index and Ismailia Canal.

Introduction

Egypt, a dry nation, has an unfavorable water balance. Egypt receives 55.5 BCM of water annually from the Nile River, but this supply is constrained recycling bridges the gap between water availability and demand. **(MWRI, Egypt, 2013).** Groundwater quality in Egypt has received a massive attention in some regions, especially in arid and semi-arid areas since groundwater is considered as a substantial source of water for domestic and irrigation purposes **(Redwan and Abdel Mokhney, 2015)**. Groundwater plays an essential role in the global drinking and irrigation water supply. In Egypt, fresh groundwater resources contribute to less than 20% of the total potential of water resources. Groundwater resources management provides a solution against the decline in other water sources, especially in areas where aridity is increasing. The local geological formation of the area has a considerable impact on the quality of the groundwater (physicochemical and biological properties). Since groundwater is regarded as a significant supply of water for home and agricultural use, groundwater quality in some parts of Egypt has attracted a great deal of interest, particularly in dry and semi-arid regions, (**El Osta, et al., 2020).** Accordingly, the water quality of water bodies can be tested through changes in physical, chemical and biological characteristics related to anthropogenic or natural phenomena **(Britton et al. 2018).**Also Evaluation of groundwater quality for agricultural under different conditions using water quality indices, partial least squares regression models, and GIS approaches) Moreover theses parameters are applied for different areas such Makah Al-Mukarramah **(Masoud et al., 2022)**, Algeria **(Gaagai et al., 2023)** and Tunsia **(Salem et al., 2023).** A thorough understanding of the various physic-chemical factors used to test the quality of water, including color, pH, temperature, electrical conductivity, total carbon dioxide, chloride content, carbonate content, and bicarbonate content, as well as total alkalinity, is required. For comparing the value of an actual water sample, standards set by the World Health Organization (WHO) and (Food and Agriculture Organization FAO) for various physic-chemical characteristics have also been provided. WQI makes use of data on water quality and aids in the alteration of regulations are created by a variety of environmental observing organizations **(Behailu et al., 2017).** Also, the present work focuses on applying the multivariate statistics using factor analysis of surface and groundwater chemistry data to identify the most influential factors that control the surface and groundwater evolution, with a particular emphasis on the spatial distribution of the contaminants and the various quality parameters and sources.

Materials and Methods

study area

Depiction of the study region Ismailia Trench is one of the most significant irrigation canals in Egypt. It was built to move new water from Stream Nile in north Cairo (El-Mazola) to Ismailia, Port Said, and Suez governorates (Fig. 1). It is 128 km long, 2.1m top to bottom, and 18 m in width. The water channel's stream rate is 433.56 m^3/s. Around 108 to 200 feed is covered by the canal, which gives water for drinking and horticulture and is utilized in modern cycles **(Gopher et al., 2014).** This research was carried out in the Ismailia Canal. We chose three wells to study groundwater around Ismailia canal (after 4, 6, 10 km from the main source) and five surface water locations from the canal (Fig. 1) because they were characterized by industrial pollution with heavy metals due to discharge from nearby factories.

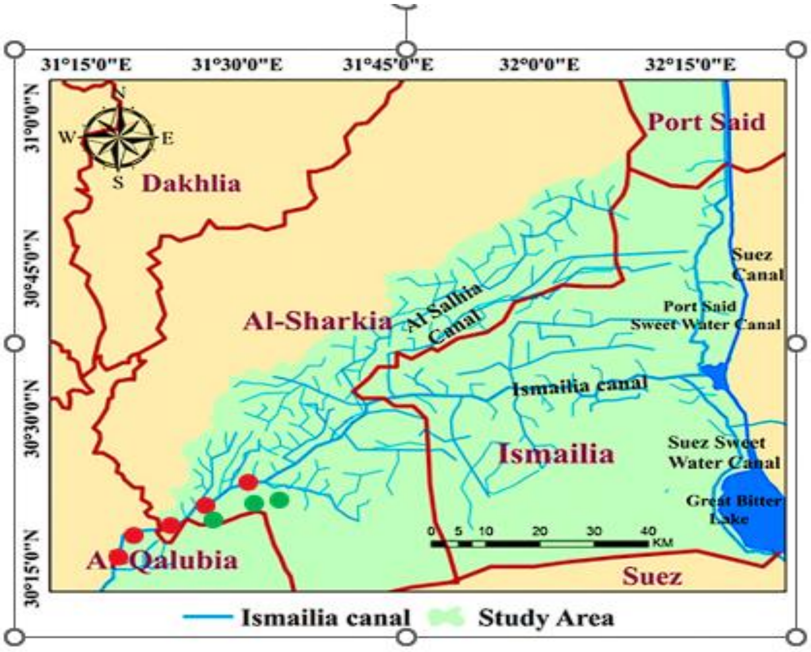

Fig. 1. Location map of the study area

Sampling, Preservation, and Preparation.

Systematic sampling of surface water and groundwater was performed in 8 representative areas Including 5 representative samples of surface water from 5 areas around the Ismailia Canal, and 3 representative samples of groundwater from surface water pumps (depth 10-20 m) at 3 different areas around the Ismailia Canal. The samples were collected after 10 minutes of pumping and stored in polyethylene bottles. Then samples were carried to the laboratory and preserved at4˚C prior to laboratory analysis.

Water quality characterization
Laboratory measurements

Immediately after sampling, pH and electrical conductivity (EC) were measured in the field.Cations (calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), and Potassium (K^{+}), anions (Chloride (Cl^{-}), Sulfate (SO_4^{2-}), Bicarbonate (HCO_3^{-}), and Carbonate (CO_3^{--}), heavy metals (Zn^{2+}, and Fe^{2+}), were analyzed in the laboratory using American Public Health Association (APHA) standard procedures (APHA 2017) at the Central Laboratory for Environmental Quality Monitoring (CLEQM), National Water Research Center (NWRC), Cairo, Egypt, The anions were measured by ion chromatography (IC), model DX-500 chromatography system. In addition, the cations and heavy metals were measured by ICP-OES instrument (Inductively Coupled Argon Plasma-Optical Emission Spectroscopy) (Perkin Elmer Optima 3000 Redial, USA).

Irrigation water quality criteria

The presence of undesired elements determines thewater's appropriateness for irrigation. To assess thequality and irrigation suitability of these waters, themost frequently calculated irrigation criteria havebeen used. The following formulas were used to calculate the sodium adsorption ratio (SAR), residualsodium carbonate (RSC), sodium percentage (Na%), Permeability index (PI%), Magnesium hazard percentage (MH%), and Kelly's index (KI), and their categories are described in Table 4.

- Sodium adsorption ratio (SAR)=Na^+ / √(Ca^{2+}+Mg^{2+}) / 2) (Richards, 1954).
- Residual sodium carbonate (RSC) mmole L^{-1}=[CO_3^{--}+HCO_3^-]-[Ca^{2+} +Mg^{2+}] (Murtaza et al., 2021).
- Residual Sodium Bicarbonate (RSCB) = (HCO_3^- - Ca^{2+}) (Gupta and Gupta (1987)
- Sodium percentage (Na%)=(Na^+ +K^+) / (Na^+ +Ca^{2+} +Mg^{2+} +K^+)×100 (Ravikumar et al., 2011).
- Permeability index (PI%)=(Na^++√HCO_3^-) / (Ca^{2+}+Mg^{2+}+Na+)×100 (Eyankware et al., 2018).
- Magnesium hazard percentage (MH%)= Mg^{2+} /(Ca^{2+} + Mg^{2+})×100 (Zhang et al., 2021).
- Kelly's index (KI)=Na^+ / (Ca^{2+}+Mg^{2+}) (Shil et al., 2019).

Sodium Adsorption Ratio (SAR)

SAR communicates the general movement of sodium particles in return responses with soil and is a proportion of evaluating the suitability of water for water system as for the saltiness or sodium peril (Sundry et al. ,2009, Tiara and Manor, 1988, andHaritash et al. ,2008). The course of invasion is impacted by higher SAR and EC as recommended by FAO-UN (FAO, 2008). Soil scattering and underlying harms may be happened because of the presence of abundance sodium particles in water system water and cause obstructing and ruin penetration by topping off a considerable lot of the more modest pore spaces in better soil particles **(FAO, 1985 and Singh et al., 2008)**. The water system water with a high extent of sodium expands the trade of sodium content of the dirt supplanting calcium and magnesium and influences the dirt penetrability making it reduced and impenetrable which is unsatisfactory for seedling development.

SAR can be computed as follow:

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+}+Mg^{2+})/2}}$$

Where both ionic concentrations are measured in mill equivalents per liter (me/l).

Residual sodium carbonate (RSC)

The residual sodium carbonate (RSC) value represents the amount of bicarbonate present in the water. An elevated concentration of bicarbonate in water results in an elevation of the pH level of the water. An elevation in the RSC (Residual Sodium Carbonate) value in the water also results in the deposition of calcium and magnesium, which might subsequently lead to an augmentation in the sodium content in the soil that is irrigated with this water. The elevated concentration of bicarbonate ions in irrigation water leads to plant toxicity and disrupts the mineral nutrition of plants. Eaton introduced the categorization of irrigation water quality based on the Residual Sodium Carbonate (RSC) index was proposed by Eaton, (1950).

Residual Sodium Bicarbonate (RSCB)

Gupta and Gupta (1987) defined RSBC as RSBC = (HCO_3^- - Ca^{2+}) According to Gupta and Gupta (1987) waters are satisfactory for agricultural practice if the RSBC < 5 meq/L.

Sodium percentage (Na%) (Soluble Sodium Percentage (SSP)

Wilcox (1955) assessed the appropriateness of groundwater for irrigation by analyzing its sodium percentage and specific conductance. The sodium percentage is a measure of the proportion of sodium concentration relative to the combined concentration of sodium, potassium, calcium, and magnesium cations. The concentration levels are provided in moles per liter.

Permeability index (PI%)

The long-term usage of irrigation water affects the permeability of the soil, as it is influenced by the presence of Na^+ Ca^{2+}, Mg_2^+, and HCO_3^- in the soil (Ramesh &Elango, 2012). The World Health Organization (WHO) utilizes a criterion to evaluate the appropriateness of water for irrigation, employing the permeability index (PI) as a basis. The necessary ion concentrations are specified by this criterion.

Magnesium hazard percentage (MH%)

In 1964, Szabolcs and Darab introduced a magnesium hazard (MH) measure for evaluating irrigation water. Groundwater with a magnesium ratio exceeding 50 is deemed detrimental and unsuitable for irrigation purposes. This would have a detrimental impact on the crop output, as the soils grow increasingly alkaline.

Kelly's index (KI)

Kelley et al. (1963) proposed that the issue of sodium in irrigation water might be effectively resolved by considering the values of Kelley's ratio. Groundwater with a Kelley's ratio exceeding one is typically deemed unsuitable for irrigation.

Weighted Arithmetic Water Quality Index Method (WAWQI)

Water quality to surface and groundwater appraisal can be characterized as the assessment of the physical, synthetic and organic nature of water according to normal quality, human impacts and planned utilizes. In this study the water quality record (WQI) created helps with the appraisal of water quality for public purposes (consumable water supply, entertainment, and so on.) furthermore, need to address areas of strength for the activities of the water source. It very well may be utilized to further develop appreciation of general water quality issues, impart water quality status and show the adequacy of defensive practice. The data collected can be used to estimate the proportion of the intake that comes from food and the proportion that comes from drinking water. However, for most contaminants, data from the various exposure sources, most notably food and drinking water, are available only from developed countries.

Water Quality Index

Calculation of IWQI

Standards for irrigation water quality have been used to calculate the IWQI. Each physical and chemical parameters standard at (mg/L or me/L) according to the guidelines of the (Food and Agriculture Organization, FAO, 2008).

The relative weight (We) was allotted for water quality boundaries in light of their general significance on water quality for drinking water. The water quality order in light of calculation of IWQI using the following equations:

$WQI = \Sigma QiWi / \Sigma Wi$

The quality rating scale (I) for each parameter is calculated by using this expression:

We = we / Nib=1 (1)

Where:

We is the relative weight.

we is the weight of each parameter.

N is the number of parameters.

$$q_i = \frac{Ci - v_o}{S_i - v_o} \times 100 \qquad (2)$$

Where qi is the quality rating and Ci is the concentration of each chemical parameter in each sample in meq/l.

Sii = Wi × qi (3)

IWQI = ∑Sii(4)

For computing the final stage of IWQI, the SI is the determined for each parameter. (3), (4) Where, Sii is the Sub index of each parameter,

qi is the rating based on concentration of each parameter and

n is the number of parameters.

Results and Discussion

Physiochemical, cations and anions parameters of surface and groundwater around Ismailia canal.

Hydrogen ion concentration (pH)

Water pH is typically not problematic on its own, but it serves as a signal for other issues, such as the presence of sodium and carbonates. The pH level of a water source indicates its degree of acidity or alkalinity. The pH level of a water supply can impact plant growth, irrigation equipment, and pesticide effectiveness. Alkaline water typically contains elevated levels of bicarbonates (typically at a pH of 8 or higher) and carbonates (typically at a pH of 9 or higher). The presence of this substance can induce the precipitation of calcium and magnesium from the soil, hence impacting plant development. Under these circumstances, certain trace metals such as copper and zinc will be less accessible to plants. The optimal pH range for irrigation water typically falls between 6.5 and 8.4.In the study zone, the pH of the examined samples in surface water ranges from 8.1 at sample No. 4 to 7.1 at sample No.1 with a mean value of 7.78, indicating an alkaline character, while the groundwater the range between 7.95 at samples 8 and 7.64 at samples No. 7 (Table 1). All of the collected samples have pH values that were below duo to maximum permitted limits **(Food and Agriculture Organization, FAO, 2008).**

Electrical Conductivity (EC)

The EC values research range as surface water between 0.344 ms/cm as a minimum value in

Table1. Calculated weight (We) for each water quality parameter for irrigation water.

Samples No.	**Surface water**					**Groundwater**			**FAO (Si) 2008**	**1/Si**	**wi**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**			
pH	7.1	7.2	7.5	8.1	8.0	7.76	7.64	7.95	8.5	0.1176	0.1204
E.C (mS/cm)	0.450	0.490	0.450	0.460	0.460	0.334	0.346	0.477	3	0.3333	0.3413
SAR	0.56	0.56	0.56	0.55	0.55	2.98	3.01	2.95	15	0.0666	0.0682
Ca^{2+}(meq/L)	3.41	3.091	3.071	3.057	3.062	1.596	1.52	0.85	20	0.05	0.0512
Mg^{2+}(meq/L)	1.28	1.25	1.29	1.39	1.40	0.879	0.855	0.645	5	0.2	0.2048
Na^{+}(meq/L)	0.82	0.87	0.86	0.84	0.89	0.87	0.86	2.87	40	0.025	0.0256
CO_3^{2-} (meq/L)	-	-	-	-	-	-	-	-	-	-	-
HCO_3^{-} (meq/L)	1.65	1.68	1.59	1.73	1.69	0.227	0.237	0.311	1000	0.1	0.1024
Cl^{-}(meq/L)	1.347	1.355	1.360	1.388	1.357	0.44	0.388	0.563	30	0.0333	0.0341
SO_4^{2-} (meq/L)	2.29	2.23	2.27	2.33	2.43	2.91	3.10	3.16	20	0.05	0.051
Fe^{2+}(µg/L)	90.50	99.70	76	71.4	65.22	95.35	97.69	94.22	5000	0.0002	0.0002
Zn^{2+} (µg/L)	3.27	5.26	2.28	2.31	1.90	4.02	3.25	3.89	2000	0.0005	0.0005
Sum										0.9765	1

sample No. 6 in Table 1. The EC maximum values of the entire research zone are found 0.490mS/cm in samples No. 2. These results are suitable for irrigation and drinking water in all wells according to Food and Agriculture Organization **(FAO, 2008).** The higher EC may be because at the sampling site, there was a normal of salinity and mineral content **(Vend et al., 2009)** and may be because to effect Ismailia canal at the research zone.

Total Hardness (TH)

Ragunath (1987) categorized water into different hardness levels, as illustrated in the TH values, along with their associated classes listed in Table 4, which are utilized to understand depicting the overall hardness of the research area. The TH-values of the water samples in the research area vary from 74.81 to 234.69 mg/L, as shown in Table 3. Based on Raghunath's classification (7), the groundwater samples in the research area are categorized as.

Sodium Adsorption Ratio (SAR)

In Table 1 the Sodium Adsorption Ratio (SAR) is used to evaluate the hazard in irrigation waters caused by sodium (Na^+). The SAR relates the concentration of sodium ions to the concentration of magnesium (Mg^{2+}) and calcium (Ca^{2+}) ions.

The SAR is defined as equation:

$$\mathrm{SAR} = \frac{\mathrm{Na}^+}{\sqrt{(\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+})/2}}$$

According to the results of sodality hazard Table 1 could be used for irrigation on nearly all soils and for all crops except those are very sensitive to sodium. The maximum range to minimum range was 3.01 for sample No.7 and 0.55 for sample No. 4 and 5.

Major ions in surface and groundwater

Calcium (Ca^{2+})

The seasonal distribution of Ca^{2+}concentration in surface water to Ismailia canal water showed in Table1, it recorded high results was 3.091meq/l in sample No.2 and 3.071meq/l in sample No.3respectively, and the spatial distribution of Ca^{2+}concentration. The minimum result was 3.041in sample No. 1while the maximum value in groundwater was 1.569 me/l in sample No. 6 but the minimum value was 0.853meq/l in sample No.8 and these results agree with that obtained by **(Elmo's et al. 2017)** and annual average value Ca^{2+}in water can be used in agriculture.

Magnesium (Mg^{2+})

As shown in Table 1 the maximum value Mg^{2+} 1.40 meq/l was recorded atsample5 as a surface water and minimum value recorded 1.25 meq/l at sample No. 2 but the high value was 0.879 meq/l and low value was 0.645 meq/l as groundwater generally Ca^{++} and Mg^{++} fixations are in balance. The alkalinity is phenomenon happens through water is blocked and crop yields are decreased when Mg++ions present in high focuses **(Omar et al., 2019).**

Sodium (Na^+)

Results in Table 1 showed the maximum value of Na^+ was 0.89meq/l in sample No.5 and minimum value was 0.82meq/l in sample 1 as a surface water but the maximum value for Na^+ in groundwater sample was 2.87meq/l in sample No.8 and minimum value was 0.86 meq/l in sample No.7while it is not widely between results but the highest value in sample 5 because it's the nearest from treatment station.

Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-)

CO_3^{2-} concentration in the surface and ground water recorded zero but HCO_3^{2-} in surface water is ranging between high and law value were 1.73 meq/l at sample No. 4 to 1.59 meq/l sample No. 3, respectively but the troth the content of HCO_3^{2-} has no reported negative health consequences, and all water samples are the recommended level. Objectives have been taken from maximum desirable limit of **(FAO, 2008).**

Chloride (Cl^-) and sulfate (SO_4^{--})

Data in Table 1 recorded that the maximum value for Cl^- in surface water was 1.388 me/l for sample No. 4 and the minimum value was 1.347 meq/L, for sample No.1. In potable water, the desirable limit for chloride Cl^- is 2.50 meq/L (FAO 2008), all of the samples the surface and groundwater don't exceed the desirable limit, in the research zone. For $SO_4^{2-}$of the surface water of the study area the maximum and minimum value were 2.43 meq/l and 2.23 meq/l, respectively but groundwater research zone in Table 1 recorded the maximum value was 3.16 meq/l with the minimum value was 2.91 meq/l, and we noticed the maximum allowed concentration to use irrigation water. The all samples contain suitable amounts of chloride Cal^- and sulfate SO_4^{2-}because this zone is near at treatment station of agricultural irrigation (**FAO, 2008).**

Heavy metals in surface and groundwater

Iron (Fe^{2+})

The average values of dissolved Fe^{2+}concentrations varied from the maximum value of 99.70 µg/l at samples 2 and a minimum value was 65.22µg/l atsample5 in table1.The iron concentration imparts a noticeable bitter surface water for irrigation (**Davis, 2010**).Data showed that Groundwater Iron (Fe^{2+}) content of the research zone maximum value recorded that to97.69 µg/l in sample No. 7 with minimum value recorded 94.22 µg/l in sample No. 8, and all the samples of the groundwater contains low from the uppermost limit that can be used as irrigation water in the research zone (**FAO, 2008).**

Zinc (Zn^{2+})

Zinc (Zn^{2+}) is essential for growth of marine organisms and its concentration affected by plankton communities. The toxicity of zinc to aquatic life is dependent on the hardness of the water and it decreases with rising hardness (**FAO, 2008).** Data in Table 1 showed the variations of total zinc in Ismailia canal surface water show that maximum and a minimum concentration were 5.26 µg/l at sample No.2 and 1.90 µg/latsampleNo.5, respectively. While the maximum and minimum value as groundwater samples were 4.02 µg/l sample No.6 and 3.25 µg/l sample No. 7, respectively. These results revealed that the concentrations of Zn^{2+}at the canal were matched requirements according (**FAO, 2008**).

Water Quality Index

Objectives have been taken from maximum desirable limit of **(FAO, 2008**). To accomplish the last score of WQI, many elements connected with water quality are considered. It is one of the best approaches to spreading data with respect to water quality. With the assistance of WQI, the overall population, legislators, and different appointed authorities can rapidly and effectively find out about water quality in their space of interest. Thusly, this exploration intends to examine Ismailia Channel water quality for irrigation based on the local and occasional inconstancy of physicochemical boundaries, irrigation criteria, and the water system water quality file (IWQI). Tables 1, 2a, 2b , 3 and 4 showed that water quality in surface water (samples No.1, 2, 3, 4, and

5) are excellent for irrigation. Also, water quality in groundwater (samples No. 6,7 and 8) are excellent for irrigation.

Table 2 (a). Calculated weighted arithmetic water quality index (WAWQI) for irrigation (a).

Samples No.	**1**		**2**		**3**		**4**	
	Qi	**Qi*Wi**	**Qi**	**Qi*Wi**	**Qi**	**Qi*Wi**	**Qi**	**Qi*Wi**
pH	83.529	10.056	84.70	10.197	88.235	10.623	95.29	11.472
E.C (mS/cm)	15	5.119	16.333	5.574	15	5.119	15.333	5.233
SAR	3.733	0.254	3.733	0.254	3.733	0.254	3.666	0.25
Ca^{2+}(meq/L)	15.15	0.775	15.15	0.775	15.15	0.775	15.15	0.775
Mg^{2+}(meq/L)	25.2	5.16	25.2	5.16	25.2	5.16	27.8	5.69
Na^{+}(meq/L)	0.82	0.020	0.82	0.020	0.82	0.020	0.82	0.020
CO_3^{2-} (meq/L)	-	-	-	-	-	-	-	-
HCO_3^{-} (meq/L)	0.16	0.016	0.16	0.016	0.16	0.016	0.16	0.016
Cl^{-}(meq/L)	4.533	0.154	4.533	0.154	4.533	0.154	4.533	0.154
SO_4^{2-} (meq/L)	11	1.080	11	0.9613	11	1.130	11.65	1.109
Fe^{2+}(µg/L)	1.81	0.0003	1.98	0.0003	1.52	0.0003	1.428	0.0002
Zn^{2+} (µg/L)	0.1635	0.000	0.263	0.0001	0.114	0.000	0.115	0.000
WAWQI	22.634		23.111		23.251		24.719	

Simi: the sub-index for each parameter and I: the quality rating scale for each parameter,WAWQI: weighted arithmetic water quality index

From all the previous data and in relation to **(Elsayed et al., 2020)** and all the parameters listed in **(El Osta et al., 2022)** for the suitability of this water for drinking and irrigation also according to **(Eid et al., 2023)** in using multi parameter evaluation the water in Ismail canal is assessed using various parameters such as pH, electrical conductivity, sodium absorption ratio, and different water quality indices. While the water quality results showed that all water tests, both surface and groundwater, are suitable for irrigation and drinking.

Conclusions

The current study's goal is to assess the water quality in the investigation region in order to track long-term changes in the physical and chemical characteristics of water in order to determine the current state of the Ismailia Canal's water quality. So, water samples were collected from Ismailia Canal in various dimensions and directions, and the chemical properties of the collected surface and groundwater were determined. The appropriateness of water for irrigation use was assessed using various parameters such as pH, electrical conductivity, sodium absorption ratio, and water quality index. The pH values in the samples ranged from 7.1 to 8.1, and the electrical conductivity values varied between 0.334 and 0.447 mS/cm. Additionally, the sodium adsorption proportion of the water tests ranges somewhere in the range of 0.55 and 3.01, While the water quality file showed that all water tests, both surface and groundwater, are suitable for irrigation.

Table 2(b). Calculated weighted arithmetic water quality index (WAWQI) for irrigation.

Sample No.	**5**		**6**		**7**		**8**	
	Qi	**Qi*Wi**	**Qi**	**Qi*Wi**	**Qi**	**Qi*Wi**	**Qi**	**Qi*Wi**
pH	94.117	11.331	91.294	10.991	89.88	10.821	93.529	11.260
E.C (mS/cm)	15.333	5.033	11.466	3.913	11.533	3.936	15.9	5.426
SAR	3.733	0.254	19.866	1.354	20.066	1.368	19.666	1.341
Ca^{2+}(meq/L)	15.15	0.775	7.98	0.402	7.6	0.389	4.25	0.222
Mg^{2+}(meq/L)	27.8	5.69	17.58	3.60	17.1	3.50	12.9	2.64
Na^{+}(meq/L)	0.82	0.020	2.17	0.055	2.15	0.055	7.17	0.183
CO_3^{2-} (meq/L)	-	-	-	-	-	-	-	-
HCO_3^- (meq/L)	0.16	0.016	0.227	0.023	0.023	0.002	0.031	0.003
Cl^-(meq/L)	4.533	0.154	1.466	0.048	1.293	0.044	1.876	1.945
SO_4^{2-} (meq/L)	11.65	1.077	14.55	0.741	15.5	0.786	15.8	0.538
Fe^{2+}(µg/L)	1.304	0.0002	1.907	0.0003	1.953	0.0003	1.884	0.0003
Zn^{2+} (µg/L)	0.095	0.000	0.201	0.000	0.162	0.000	0.194	0.000
WAWQI	24.35		21.127		20.90		23.558	

SIi : the sub-index for each parameter and Qi : the quality rating scale for each parameter

Table 3. Calculated irrigation water quality criteria.

Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
pH	7.1	7.2	7.5	8.1	8.0	7.76	7.64	7.95
Hardness (mg/l) as $CaCO_3$	234.69	217.23	218.23	222.53	223.28	123.85	118.85	74.81
Sodium adsorption ratio (SAR)	0.56	0.56	0.56	0.55	0.55	2.98	3.01	2.95
Residual sodium carbonate (RSC) mmole L^{-1}	-3.040	-2.661	-2.771	-2.717	-2.772	-2.248	-2.138	-1.184
Residual Sodium Bicarbonate (RSCB)	-1.760	-1.411	-1.481	-1.327	-1.372	-1.369	-1.283	-0.539
Sodium percentage (Na%)	15.80	17.64	17.42	16.83	17.55	28.30	29.00	66.37
Permeability index (PI%)	28.209	30.728	29.774	30.417	30.025	20.120	21.358	40.173
Magnesium hazard percentage (MH %)	27.292	28.795	29.580	31.257	31.376	35.515	36.000	43.144
Kelly's index (KI)	0.175	0.200	0.197	0.189	0.199	0.352	0.362	1.920
Irrigation water quality index (IWQI)	24.719	23.251	23.111	22.634	23.558	20.90	21.127	24.35

Table 4. Classification of water quality criteria and IWQI (Amer& Mohamed 2022, El-Amier et al., 2021).

Criteria	**Range**	**Class**	**References**
pH Value	> 6.5 6.5 - 8.5 < 8.5	Not Acceptable Acceptable Not Acceptable	Abdalazem, et al., 2020
Hardness (mg/l) as $CaCO_3$	00 – 55 56 – 100 101 – 200 201 – 500 more than 500	Soft water Slightly hard water Moderately hard water Very hard water Excessively hard wate	Ragunath, 1987
Sodium adsorption ratio (SAR)	<10 10–18 19–26 >26	Excellent Good Fair Poor Unsuitable	(Oster &Sposito, 1980)
Residual sodium carbonate (RSC) mmole L^{-1}	<1.25 1.25–2.50 >2.50	Good Medium Unsuitable	(Murtaza et al., 2021)
Residual Sodium Bicarbonate (RSCB) meq/L	< 5 > 5	Satisfactory unsatisfactory	Gupta and Gupta (1987)
Sodium percentage (Na%)	<20% 20%–40% 40%–60% 60%–80% 80%	Excellent Good Permissible/Safe Doubtful Unsuitable	(Ravikumar et al., 2011)
Permeability index (PI%)	>75% 25–75% <25%	Suitable Moderate Unsuitable	(Das & Nag, 2015)
Magnesium hazard percentage (MH%)	<50% >50%	Suitable Unsuitable	(Zhang et al., 2021)
Kelly’s index (KI)	<1 >1	Suitable Unsuitable	(Shah et al., 2019)
Irrigation water quality index (IWQI)	0–25 26–50 51–75 76–100 >100	Excellent Good Poor Very poor Unsuitable	(Şener et al., 2017)

Table 5. Classification of water sites for irrigation deployment based on water quality criteria.

Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
pH	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
Hardness	Moderately hard water	Moderately hard water	Moderately hard water	Moderately hard water	Moderately hard water	Moderately hard water	Moderately hard water	Slightly hard water
(SAR)	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
(RSC)	Good	Good	Good	Good	Good	Good	Good	Good
(RSBC)	satisfactory	satisfactory	satisfactory	satisfactory	satisfactory	satisfactory	satisfactory	satisfactory
(Na%)	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Good	Doubtful
(PI%)	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
(MH%)	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
(KI)	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
(IWQI)	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent

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