Egypt. J. of Appl. Sci., 37 (9-10) 2022 *104-127*

ASSESSMENT OF GROUNDWATER QUALITY IN WEST MALLAWI DISTRICT, SOUTH MINYA GOVERNORATE, EGYPT, USING WATER QUALITY INDEX (WQI) AND IRRIGATION PARAMETERS

El-Fakharany, M.A.[1] ; I.E. Mussa[2] and Nehad M. Mansour[1]
1 Department of Geology, Faculty of Science, Benha University, Cairo, Egypt.
2 Savola Food Group Alexandria United Company For Land Reclamation (AUCR)
***E-mail- nehad.mansour@fsc.bu.edu.eg**

ABSTRACT

The current study used the WQI index and various irrigation quality parameters to evaluate the groundwater quality of the Oligocene and M. Eocene aquifers in the west Mallawi District, south Minya Governorate for drinking and irrigation uses. To do that, twenty-seven groundwater samples representing both aquifers were chemically examined for major cation, anion, pH, TDS, EC, and trace elements. The water quality index and irrigation water parameters like Na%, SAR, RSC, KR, MH, and PI were computed and used for irrigation suitability assessment. In addition to creating and interpreting the spatial variation maps of major ions and WQI for the Oligocene and M. Eocene aquifers.

Results of the spatial distributions of TDS, major ions, and WQI values of the groundwater samples of both aquifers indicated that the groundwater is acceptable for consumption, except in the eastern portions of the Oligocene aquifer, where the values of TDS, Na^+, SO_4^{-2}, and Cl^- exceeds the permissible limits and the groundwater samples fall under the poor water classification (WQI > 50). The concentrations of trace elements (Fe, Mn, Li, V, Zn, and Al) in the groundwater of both aquifers were within acceptable limits for drinking. The areal distributions of EC, TDS, $SO4^{-2}$, and Cl^-, as well as Kelly's ratios, plotting of Na% and SAR versus EC revealed that the groundwater of the M. Eocene aquifer and 87.5% of water samples of the Oligocene aquifer were categorized as good to a permissible for irrigation, while 12.5 % of water samples of the Oligocene aquifer are deemed unfit for the same purpose. According to the computed RSC, PI, and MH values, the groundwater of the M. Eocene and Oligocene aquifers show values below the recommended limits for irrigation.

Key Words: Groundwater, water quality index, water quality.

INTRODUCTION

Egypt's water demand is increasing at present due to uncontrolled growth of the population and in light of limited water resources, particularly since the construction of the Ethiopian Renaissance Dam and the shortage of surface water coming from the Nile, which is not enough to meet water demands, as the per capita share of water decreased to reach about 600 m^3/year which is less than the water poverty level of about 1000 m^3/year, which is the minimum per capita share in the world. Consequently, dependence on groundwater as a second source to supply water has become inevitable. The government's project to develop 1.5 million acres of land, is considered a starting signal for the launch of the modern agricultural revolution, in which the political will unite extensive efforts and scientific research to achieve development goals, not only to achieve agriculture, sufficiency, and food security but also to build new societies and create parallel industries.

The area west Minya Governorate has received Governmental attention and represents itself as one of the land reclamation projects (300 thousand acres) that has been accelerated during the twenty years. Groundwater plays a significant role in satisfying requirements for different purposes. **Salim, (2015)** investigate the shallow aquifers' hydrogeology in the Minya Governorate region west of Samalut to determine the water's appropriateness for livestock and agricultural uses. He stated that the salinity increases due east coinciding with the direction of flow. All water samples are appropriate for agricultural and livestock purposes. According to **Ismail *et al.*, (2017)**, the salinity of the water generally decreases from west to east, and the groundwater from both aquifers is regarded as appropriate for many uses. According to **Yousif *et al.*, (2018)**, the limestone aquifer's groundwater has a salinity range of 560 to 930 mg/l, which is reasonably low. Groundwater displays an isotopic profile like that of current Nile water with a little amount of paleo-water from Nubian sandstone, according to stable isotope values. According to **Gedamy *et al.*, (2019),** 54% of the Eocene groundwater samples are appropriate for human, animal, and bird consumption, and 47% of the samples are suitable for irrigation of virtually all soils, given a reasonable amount of leaching processes occurs.

One of the most effective ways to determine if water is fit for consumption is the water quality index (WQI) **(Subba-Rao, 1997 and Magesh *et al.*, 2013)**. It offers a single number to evaluate the general water quality at a specific time and place. Several water quality indicators are included in a mathematical equation that assesses the suitability of water for drinking **(Al-Mohammed and Mustasher, 2013 ; Ochuko *et al.*, 2014 ; Boateng *et al.*, 2016 and Akter *et al.*, 2016)**. Many studies, including **(Wilcox, 1955 ; Ayers and Westcot, 1985 ; Hem, 1989)** have used the irrigation quality parameters (MH, RSC, KR, SAR, Na%, and PI) to assess the quality of groundwater for agricultural use.

The increase in salinity in irrigation water results in an excessive rise in the amount of TDS in the soil, which harms plant growth and output. TDS should typically not exceed 1000 mg/l, although it has been discovered that this limit is weakly imposed when salts in the form of carbonates and bicarbonates are present. A decrease in soil permeability and hardening of the soil are both caused by an increase in sodium ions in irrigation water. Both effects are a result of sodium ions exchanging cations with calcium and magnesium on clay minerals and colloids **(Hamill and Bell, 1986)**. Increased chloride ions in irrigation water prevent plants from absorbing phosphates and phosphoric acid, and excessive absorption can be harmful to particular plants **Ayers, (1975)**.

The area west of Minya Governorate is currently experiencing rapid agricultural growth at uncontrolled rates. There is an urgent need for extensive studies to evaluate the quality of the groundwater to reclaim desert lands and conserve water to fulfill the rising demand for crops. The water must be of good quality to satisfy the requirements of both agriculture and human use. The water's quality and quantity are almost equally significant factors in any assessment of groundwater resources. Most human activities directly and typically negatively affect the quality of water **(Hamill and Bell, 1986)**. Although much has been written about groundwater occurrences in the west Minya Governorate, limited studies are available on the groundwater quality in the studied area. Therefore, the main goal of the present study was to (1) evaluate the physicochemical characteristics of the groundwater of Oligocene and M. Eocene aquifers. (2) create spatial variation maps of the parameters affecting water quality to illustrate their distribution in the investigated aquifers. (3) determine whether groundwater is suitable for drinking using the WQI index. (4) determine if groundwater is viable for irrigation based on a range of irrigation quality factors.

MATERIAL AND METHODS

Study area

The area under consideration lies west of Mallawi City south of Minya governorate at km 128 Asyut desert road. It represents one of the land reclamation projects carried out now. It is bounded by 27^0 42^-, 27^0 51^- latitudes N and 30^0 15^-, 30^0 35^- longitudes E. (Fig 1). The study area (630 Km^2) is shaped like a long strip of land, extending along the E-W direction for more than 40 km west of Asyut desert road and stretching to more than 15.5 km north-south (Fig 1).

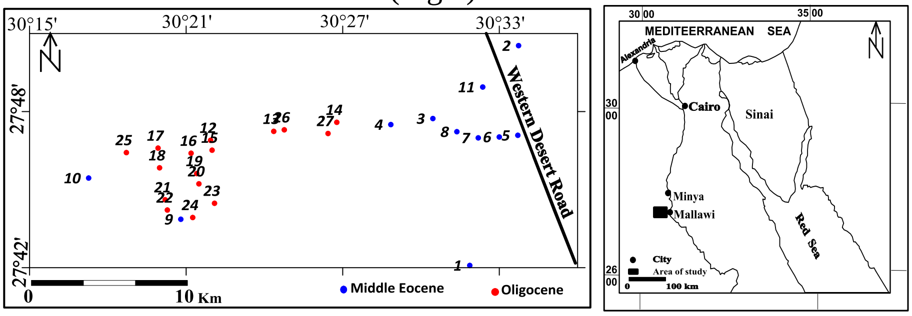

Fig 1: Map of the study region with sample locations.

The investigated area has a dry climate with infrequent winter precipitation. The annual average precipitation in the past 15 years ranged between 23.05 and 33.15 mm/year. The rate of evaporation is 4897.91 mm per year. While the lowest temperature fluctuates from 4.5 to 20.5°C in January and August, respectively, the maximum temperatures vary from 20.7° to 37.5°C in both months. The monthly average relative humidity in daylight varies between 36% and 62% in May and December, respectively **(Korany *et al.*, 2008)**.

Geologic and hydrogeologic setting

The limestone plateau, which separates the Nile Valley from the east and west, is one of the three primary geomorphic units that make up the western El Minya Governorate. The second unit, the old alluvial plains, rises above the young alluvial plains in the form of terraces and stretches from the eastward edges of the young alluvial plains to the western edge of the Eocene plateau. The third element is the Nile's young alluvial plains, which are located in the east and contribute to the Nile Valley's agricultural land **(Abdel Moneim *et al.*, 2016)**. According to **Conoco Coral, 1987** (Fig 2) a sedimentary succession ranging in age from the Middle Eocene to the Quaternary is exposed in the west Minya area. The Eocene rocks include Minya and Samalut Formations and are composed mainly of fractured carbonate rocks. Qatrani Formation consists mainly of a series of clastic deposits that belongs to the Oligocene age **(EGSMA, 2005)**. The Oligocene- Pleistocene Sand, gravel, and limestone fragment cover a large area and is regarded as a reliable local aquifer. The dunes, Nile silt, proto-Nile, and pre-Nile deposits are among the Quaternary alluvial deposits **(Klitzsch *et al.*, 1987)**. The considered area is affected by a series of normal faults that make a hydraulic connection between the M. Eocene and the Oligocene aquifers (Fig 3).

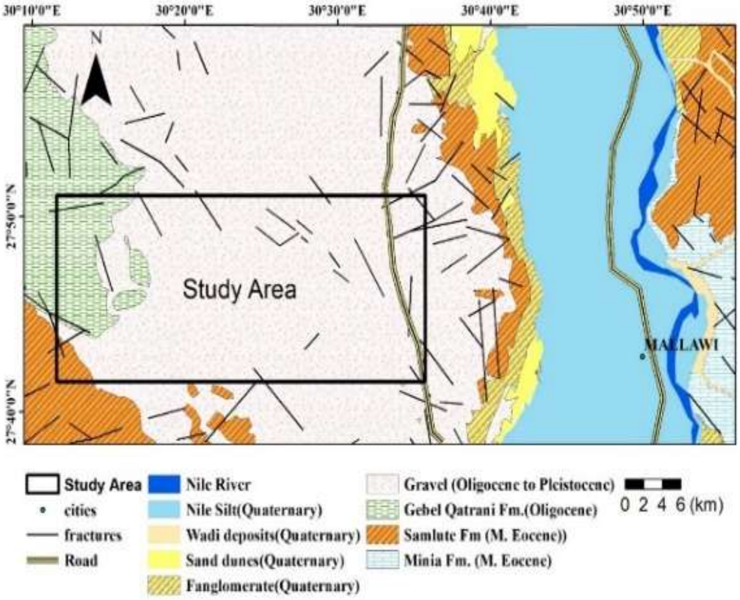

Fig 2: Geological map of the study area

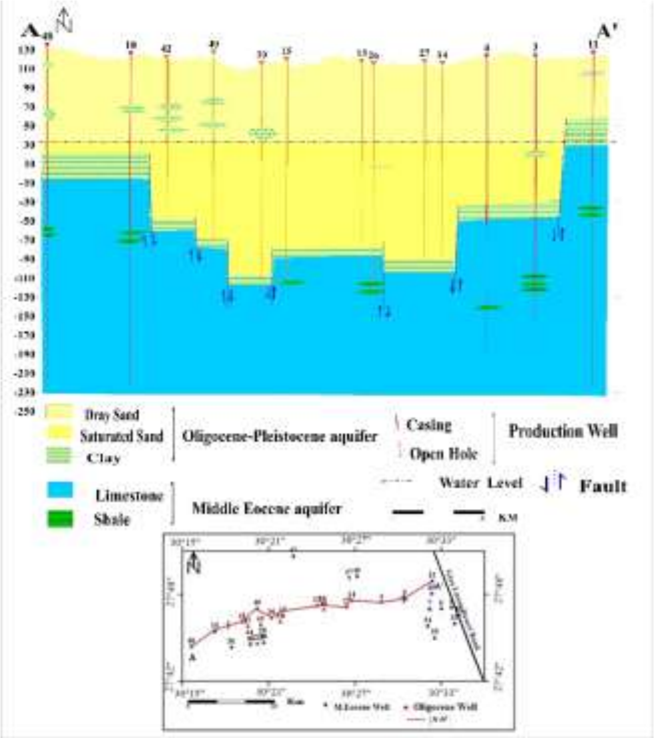

Fig 3: Hydrogeologic cross-section E-W

Generally, in the studied area, the Oligocene and M. Eocene aquifers play a significant role in satisfying water requirements for different uses. The Oligocene aquifer is primarily made up of sand and gravel with intercalations of shale and limestone, the penetrated thickness ranging between 200 and 254m. The Middle Eocene aquifer is made up of fractured limestone rocks and is characterized by its great thickness, the penetrated thickness ranging between 216 and 205m. The well-field comprises 27 wells, 16 of which are designed to tap the Oligocene aquifer, their depth range between 200 and 254m and the discharge rate ranges from 190 to 215 m^3 /hr. 11 wells are designed to tap the M. Eocene aquifer, their depth varies from 165 to 360m, the discharge rate ranges from145 to 220 m^3.

Groundwater Sampling and analysis

Twenty-seven groundwater samples were gathered during June 2021, with 16 wells tapping the Oligocene aquifer and 11 wells representing the M. Eocene aquifer. The water samples were filtered to remove suspended material which could dissolve when acid is added. Two samples from each site were collected in clean plastic bottles (High-Density Polythene, HDPE). A bottle content was used for physicochemical analysis, and the another was used for metal analysis and acidified by adding 65% HNO_3 acid until the pH reached <

2. Determinations of electric conductivity and pH values were directly measured in the field. For identifying the precise water quality characteristics, all samples were immediately stored in an icebox and carried to the lab. According to the procedures recommended by the standard methods of **APHA (2005)**, chemical analyses were performed to measure the concentrations of Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, CO_3^{-2}, HCO_3^{-}, SO_4^{-2}, and Cl. The trace elements were identified using the atomic-absorption device. Electro neutrality was performed for the analytical data considering ionic charge balance error within 5%. The spatial distribution maps of the chemical constituents of both Oligocene and M. Eocene aquifers were constructed using Surfer 16 software.

Water quality index (WQI).

In the present study, seventeen significant parameters were picked to calculate the water quality index. The drinking water guidelines established by **WHO (2017)**, were used to determine the WQI. The following formula was used to generate the weighted arithmetic water quality index, which was first introduced by **Horton (1965)** and developed by **Brown *et al.*, (1972)**:

$$WQI=\Sigma QnWn/\Sigma Wn$$

Where:

Qn =Quality rating for the n^{th} Water quality parameter

Wn = Unit weight for the n^{th} parameters

The unit weight (Wn) is calculated using the formula:

$$Wn = K/Vs$$

Where:

K = the constant of proportionality, and it is calculated using the equation:

$k = [1/\Sigma\ 1/Vs_{1, 2, . . .n}]$.

Vs = the standard allowable value for the n^{th} water quality parameter.

The quality rating scale (Qn) for each parameter was also calculated using the following equation, according to **Brown *et al.*, (1972)**:

$$Qn = 100\ \{(Vn-Vi)/\ (Vs-Vi)\}$$

where,

Vn= actual value of the water quality indicator as determined by lab testing.

Vi = Ideal value of n^{th} parameter in pure water, (i.e.,0 for all other parameters except the parameter pH and Dissolved Oxygen (7.0 and 14.6 mg/l respectively). The arial distribution maps of WQI of both Oligocene and M. Eocene aquifers were constructed using Surfer 16 software.

Quality of irrigation water

The main factors of irrigation water, which help to determine the suitability of the studied Oligocene and M. Eocene aquifers for irrigation, are EC, TDS, chloride, and sulfate **(Ayers and Wescot, 1985)**. Using the formulae in the Table (1), certain computed indicators that are crucial for figuring out whether water is suitable for irrigation were calculated.

Table (1): The parameters of irrigation water quality.

Parameter	Equation (All ions in meq/L)	Reference
SAR	SAR = $\frac{Na}{\sqrt{Ca+Mg/2}}$ ions in meq/L	Richard (1954)
Na%	Na% =$Na^{+}\times100/(Ca^{2+}+Mg^{2+}+Na^{+}+K^{+})$	Wilcox (1955)
RSC	RSC = (CO3 + HCO3) − ($Ca+^{2}$ + Mg^{+2})	Richard (1954)
KR	KR = Na+ /Ca^{2+} + Mg^{2+}	Kelly (1940)
MH	MH = $\frac{mg}{ca+mg}$*100	Paliwal (1972)
PI	PI=$(Na^{+}+\sqrt{HCO_3^{-}})\times100/(Ca^{+2}+Mg^{+2}+Na^{+}+K^{+})$	Doneen (1964)

The results of calculated parameters such as Na% and SAR are plotted against **EC** and investigated using **Wilcox (1955) and USSL Staff, (1954)** diagrams. The spatial distribution maps of irrigation parameters (Na%, SAR, RSC, KR, MH, and PI) of both Oligocene and M. Eocene aquifers were constructed using Surfer 16 software.

RESULTS AND DISCUSSION

The results of statistical calculations of the groundwater parameters of the examined Oligocene and M. Eocene aquifers are shown in Table (2). The data were compared to WHO-recommended criteria (2017).

Table (2): Statistical calculations of the groundwater parameters and WHO criteria

Aquifer	Middle Eocene			Oligocene			WHO criteria (2017)
Parameter	Max	Min	Average	Max	Min	Average	
pH	8.2	7.5	7.9	8	7.5	7.8	6.5-8.5
Hardness	406.4	235.2	320.8	778.6	207.0	492.8	100
ECµS/cm	1648	1084	1366	4110	922	2516	2000
TDS	920	545	732.5	2596	505	1551	500 -1000
Ca++	103.8	49.37	76.585	196.4	45	121	75
Mg++	40	27.19	33.595	74.5	20	47	50
Na+	180	110	145	650	70	360	200
K+	12	5	8.5	9	5	7	10-12
HCO3-	305	146.4	225.7	201	20	111	120-200
SO4--	141	37	89	535	32	284	250
Cl-	360	175	267.5	1036	105	571	250
Sr	4.199	1.156	2.6775	3.851	1.252	2.5515	4
Al	0.19	0.02	0.105	0.19	0.13	0.16	0.2
Fe	0.13	0.021	0.0755	0.29	0.023	0.20755	0.3
Li	0.0215	0.006	0.01375	0.234	0.0093	0.12165	0.7
Mn	0.42	0.0049	0.21245	0.49	0.0013	0.29065	0.4
V	0.034	0.01	0.022	0.08	0.01	0.045	0.1
Zn	0.58	0.0086	0.2943	0.2	0.0098	0.1049	3

Spatial variations of groundwater parameters

The pH values of the Oligocene aquifer range from 7.5 to 8 with an average of 7.8 and vary from 7.5 to 8.2 with an average of 7.9 for the M. Eocene aquifers (Table 2), this indicating that the groundwater was alkaline in reaction. The Oligocene aquifer's electrical conductivity varied from 922 to 4110 µS/cm with an average of 2516, whereas the M. Eocene aquifer's ranged from 1084 to 1648 µS/cm with a median of 1366 µS/cm. TDS values in the Oligocene aquifer vary from 505 mg/l to 2596 mg/l with an average 1551 mg/l, while they were 545 mg/l to 920 mg/l with an average of 732.5 mg/l in the M. Eocene aquifer (Table 2). In the eastern and northeastern parts of the investigated area, there was a noticeable increase in TDS levels in the groundwater (Figs 4 & 5) that is above-permitted limits in the Oligocene aquifer (> 1000mg/l. Numerous sodium compounds found in rocks and soils readily dissolve to release sodium into groundwater. In the Oligocene aquifer, Na ions range from 70 to 650 mg/l, with an average of 360 mg/l, and in the M. Eocene aquifer varied from 110 to 180 mg/l (Table 2). The content of Na^+ in groundwater increased toward the eastern and the northeastern portion of both aquifers (Figs 6 & 7) and exceeds the permitted level (> 200 mg/l) in the Oligocene aquifer. Leaching of calcium-containing minerals results in the entry of calcium (Ca^{+2}) into the aquifer system. Ca^{+2} contents vary from 45 to 196 mg/l with a 121 mg/l average in the Oligocene aquifer, while the Eocene aquifer has a mean of 76.6 mg/l and a range between 49.37 and 103.8 mg/l. The aerial distribution of Ca^{+2} is illustrated in Figs (8 &9) for the Oligocene and M. Eocene aquifers. Ca^{+2} concentration in the research area was below the upper limits for human consumption (200 mg/l). Magnesium (Mg^{+2}) is a significant element that affects the water's hardness. In the Oligocene aquifer, Mg^{+2} concentrations range from 20 mg/l to 74.5 mg/l, with an average of 47 mg/l, while in the M. Eocene aquifer, it ranges from 27.19 mg/l to 40 mg/l, with an average of mean of 33.6 mg/l. The aerial distribution of Mg^{+2} (Figs 10 &11) for the Oligocene and M. Eocene aquifers indicate that their concentrations are below the acceptable limits for human consumption (100 mg/l). The K^+ contents were low in both aquifers. It ranges from 5 to 9 mg/l with an average of 7mg/l in the Oligocene aquifer and varies from 5 to 12 mg/l in the M. Eocene aquifer (Figs. 12 &13). The Sulfate content ($SO4^{-2}$) in the Oligocene aquifer varies between 32 and 535mg/l with an average of 284 mg/l, while in the M. Eocene aquifer. It ranges between 37 and 141mg/l with a mean of 89mg/l (Table 2). The spatial variation of sulphate in groundwater (Fig 14 &15) shows the presence of high concentrations above the standard limits (>250 mg/l) recorded at the eastern and northeastern portions of the Oligocene aquifer and the groundwater is unfit for consumption. The Chloride (Cl^-) content fluctuates between 105 and 1036mg/l with an average of 571 mg/l average in the Oligocene aquifer, while it averages 267.5 mg/l in the Eocene aquifer, ranging from 175 to 360 mg/l (Table 2). High concentrations of Chloride (>250mg/l) were recorded in the northern portions of the Oligocene and M. Eocene aquifer (Figs 16&17) and the groundwater is unacceptable for drinking. Bicarbonate HCO_3^- contents were low in both aquifers. It was fluctuating between 20 and 201 mg/l. with a mean of 111mg/l in the Oligocene aquifer and between 146 to 305 mg/l with an average of 225.7mg/l in the M. Eocene aquifer (Figs 18 & 19).

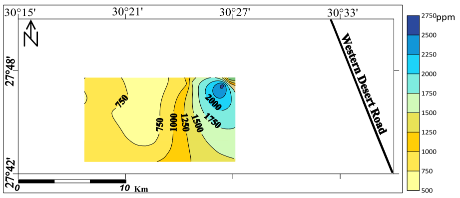

Fig 4: Spatial variations of TDS in the Oligocene aquifer

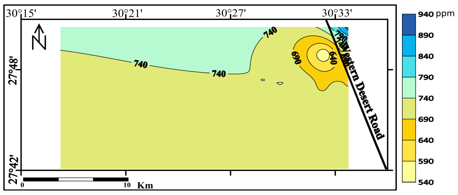

Fig 5: Spatial variations of TDS in the M. Eocene aquifer

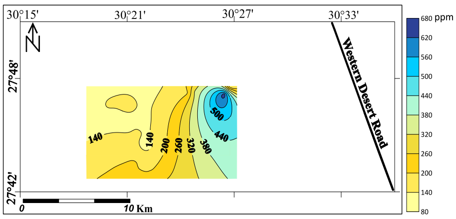

Fig 6: Spatial variations of sodium in the Oligocene aquifer

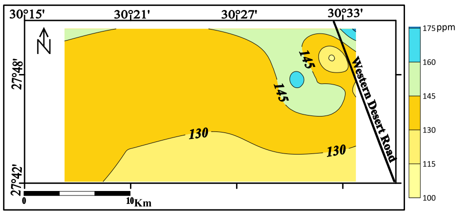

Fig 7: Spatial variations of sodium in the M. Eocene aquifer

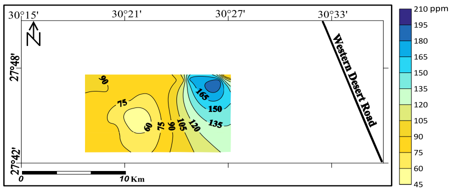

Fig 8: Spatial variations of Calcium in the Oligocene aquifer

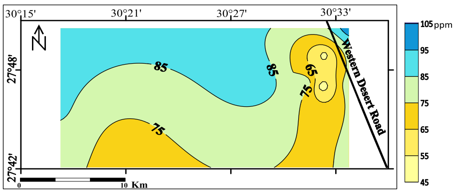

Fig 9: Spatial variations of Calcium in the M. Eocene aquifer

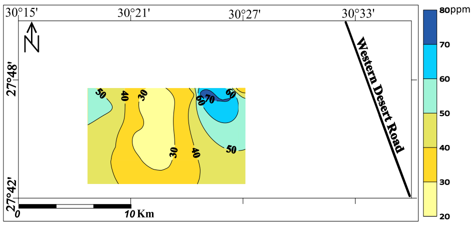

Fig 10: Spatial variations of Magnesium in the Oligocene aquifer

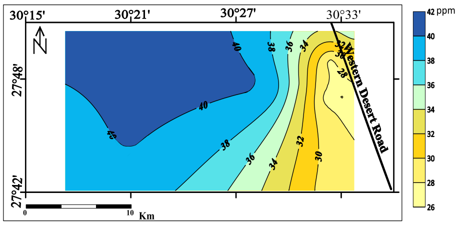

Fig 11: Spatial variations of Magnesium in the M. Eocene aquifer

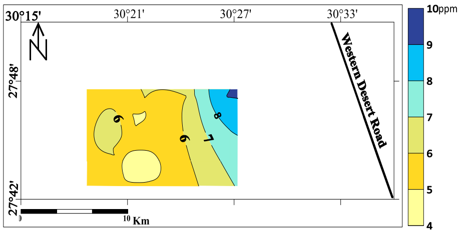

Fig 12: Spatial variations of Potassium in the Oligocene aquifer

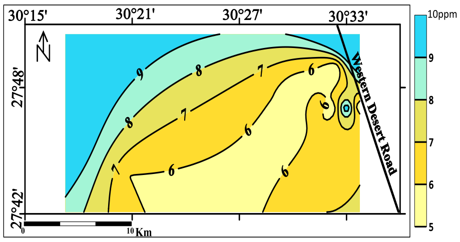

Fig 13: Spatial variations of Potassium in the M. Eocene aquifer

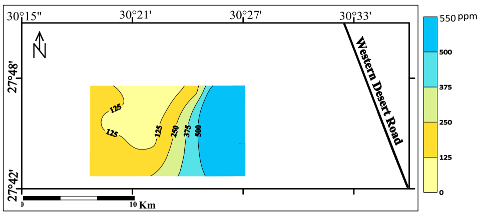

Fig 14: Spatial variations of Sulphate in the Oligocene aquifer

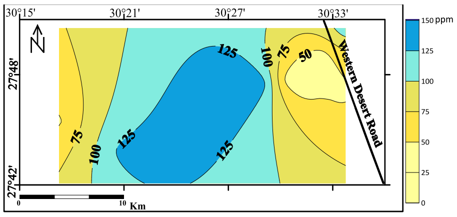

Fig 15: Spatial variations of Sulphate in the M. Eocene aquifer

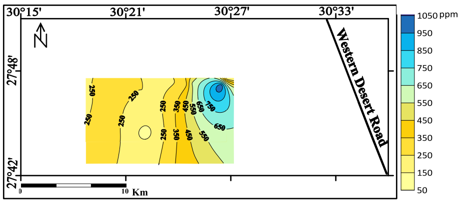

Fig 16: Spatial variations of Chloride in the Oligocene aquifer

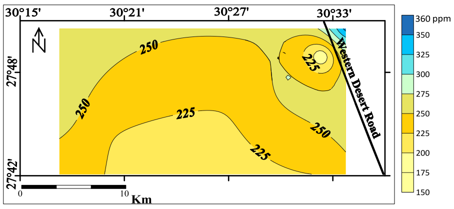

Fig 17: Spatial variations of Chloride in the M. Eocene aquifer

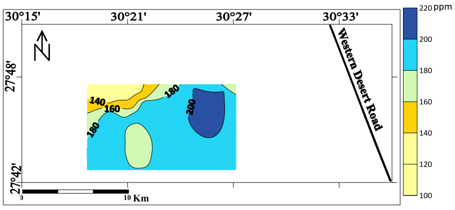

Fig 18: Spatial variations of Bicarbonate in the Oligocene aquifer

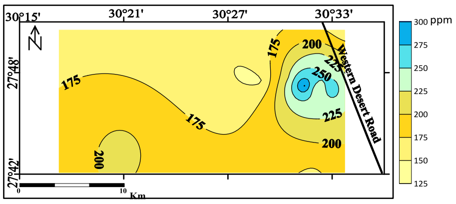

Fig 19: Spatial variations of Bicarbonate in the M. Eocene aquifer

Trace elements

In groundwater samples, iron concentrations range between 0.023 and 0.29 mg/l, with an average of 0.21 mg/l in the Oligocene aquifer. and from 0.021 to 0.13 mg/l in the M. Eocene aquifer (Table 2). Manganese contents in groundwater samples range from 0.0013 and 0.49mg/l 0.29 mg/l in the Oligocene aquifer and the M. Eocene aquifer between 0.005 and 0.42 mg/l, with an average of 0.21 mg/l. (Table 2). Aluminum contents in groundwater samples range from 0.13 and 0.19mg/l in the Oligocene aquifer and between 0.02 and 0.19mg/l with an average of 0.105 mg/l in the M. Eocene aquifer. Al concentrations were below the recommended limits (0.2) in both aquifers indicating that groundwater suitability for drinking. Lithium contents in groundwater samples range from 0.009 and 0.23mg/l with an average of 0.12 mg/l in the Oligocene aquifer and between 0.006 and 0.02mg/l with an average of 0.014mg/l in the M. Eocene aquifer (Table 2). Vanadium contents in groundwater samples were ranged from 0.01 to 0.08mg/l with an average of 0.045

mg/l in the Oligocene aquifer and between 0.01 and 0.034mg/l with an average of 0.022mg/l in the M. Eocene aquifer (Table 2). Zinc contents in groundwater samples range from 0.01 and 0.2 mg/l with an average of 0.11 mg/l in the Oligocene aquifer and from 0.009 to 0.58 mg/l in the M. Eocene aquifer (Table 2). Based on the limits presented by **WHO (2017)** in Table (2), the concentrations of trace elements (Fe, Mn, Li, V, Zn, and Al) in groundwater of the Oligocene and M. Eocene aquifers (Table 2) were within the acceptable limits for drinking.

Water quality index

Many researchers have utilized the water quality index (WQI) to evaluate the quality of groundwater **(Balan *et al.*, 2012 ; Al-Mohammed and Mustasher 2013 ; Tyagi *et al.*, 2013 ; Eslami *et al.*, 2017 ; Wagh, *et al.*, 2017 ; Abdulhady, 2018 ; Rabeiy, 2018 ; Gaber *et al.*, 2021 and Ismail *et al.*, 2021)**. The water quality index (WQI) is one of the finest indices for assessing and monitoring the water quality of groundwater supplies **(Eslami *et al.*, 2017)**. According to **Wagh *et al.*, (2017)**, the WQI is a valuable tool for determining the quality of groundwater and communicating water's health to multiple users. It provides exact data and reports on the quality of the water to policy and decision-makers more easily. Using the Water Quality Index, **Abdulhady, (2018)** evaluated the groundwater quality of the Quaternary aquifer in the western El Minya Governorate. Using WQI and Geographic information system (GIS). **Rabeiy, (2018)** evaluated and simulated groundwater quality in the Upper Egypt region. In urban areas west of the Ibrahimmia Canal, **Gaber *et al.*, (2021)** discovered that the (WQI) readings indicated poor groundwater quality for drinking. The east of the Ibrahimmia Canal, on the other hand, has good (WQI) ratings but still needs to be cleaned up before it can be used. **Ismail *et al.*, (2021)** evaluated the aquifers' groundwater quality in the northwest Assiut area. They concluded that the Pleistocene aquifer was appropriate for irrigation and drinking, whereas nearly half of the Eocene water samples were unsafe for consumption and irrigation. According to the quality index created by **Brown *et al.*, (1972) and Chatterji and Raziuddin (2002),** water quality is categorized in the following Table (3).

Table (3): Rating Water quality indices.

Water Quality Index	Water Quality Status
0 - 25	Excellent
26 - 50	Good
51 - 75	Poor
76 - 100	Very Poor
> 100	Unfit For Consumption

Table 4 and Figs 20 & 21 show the WQI values for all water samples from the Oligocene and M. Eocene aquifers. The results showed that out of a total of 16 samples representing the Oligocene aquifer, there were 2 (12.5%) excellent samples (WQI<25) and 12 (75%) good samples for drinking (WQI ranges from 26 to 50). While there were two water samples (12.5%) fall under the poor water category (WQI varies from 51 to 75). The highest WQI values (51 - 75) were noticed in the eastern portions of the investigated area (Fig 20) and they are considered unfit for human use. As a result, they must be treated before being used to prevent infections associated with water. Of a total of 11 samples representing the M. Eocene aquifer, there were 3 samples (27.3%) that showed excellent water for drinking (WQI<25), while 8 samples (72.7%) were good for drinking (WQI ranges from 26 to 50). The WQI values increase toward the northeast of the investigated area (Fig, 21)

Table 4: Computed (WQI) values for groundwater samples and their suitability for drinking

Sample No.		WQI	Water quality	Sample No.		WQI	Water quality
1	Middle Eocene aquifer	38.5	Good	15	Oligocene aquifer	29.2	Good
2		36.8	Good	16		33.47	Good
3		30.36	Good	17		33.9	Good
4		40.1	Good	18		44.5	Good
5		33.4	Good	19		39.3	Good
6		24.6	Excellent	20		27.5	Good
7		31.8	Good	21		23.1	Excellent
8		30.64	Good	22		42.22	Good
9		23.6	Excellent	23		18.7	Excellent
10		23.5	Excellent	24		28.97	Good
11		36.44	Good	25		27.18	Good
12	Oligocene	27.33	Good	26		71.18	Poor
13		32.77	Good	27		73.52	Poor
14		40.18	Good				

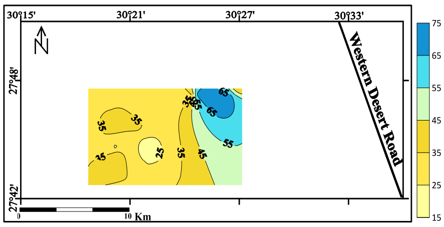

Fig 20: Spatial variations of WQI in the Oligocene aquifer

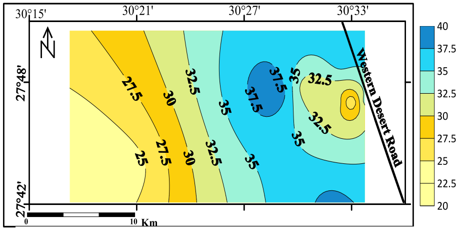

Fig 21: Spatial variations of WQI in the M. Eocene aquifer

Irrigation water quality parameters

The effect of the water's components on plants and soil governs whether groundwater is suitable for agricultural use. Chemical impacts interrupt plant metabolism, while physical factors reduce soil permeability and osmotic pressure in the plant cell composition, thus stopping water from entering the leaves and branches **(Sahinci, 1991)**. The quality of irrigation water has an impact on productivity because it may have an impact on plant development, which would lower agricultural production levels **(Yesilnacar and Gulluoglu, 2008; Deshpande and Aher, 2012)**. Therefore, evaluating the groundwater quality for irrigation is required. Some key hydrochemical indicators used to assess the research area's irrigation water quality such as EC, TDS, Cl, and sulphate were used. Some important factors were also calculated in evaluating the suitability of water for irrigation such as the ratio of sodium absorption, the sodium percentage, the residual sodium carbonate, the Kelly index, magnesium hazard, and the permeability index. The results obtained are shown in Tables (2,5).

Table 5: Irrigation quality parameters (epm) of groundwater of the Oligocene and M. Eocene aquifers

Well No	aquifer	KR	PI	SAR	RSC	Na%	MH%	Well No	aquifer	KR	PI	SAR	RSC	Na%	MH%
1	M. Eocene aquifer	0.9	60.2	3	-1.40	46	40.5	12	Oligocene aquifer	1.0	62.0	3	-2.22	49	33.9
2		1.0	57.8	4	-4.62	48	36.2	13		1.1	62.1	4	-4.04	51	39.3
3		1.1	65.8	4	-2.18	52	43.0	14		1.0	62.3	4	-2.64	50	42.8
4		0.7	53.4	3	-4.68	42	41.7	15		1.0	64.6	3	-1.86	50	35.1
5		0.8	61.2	3	-2.14	45	34.7	16		1.0	61.2	4	-3.08	50	40.7
6		1.2	70.4	4	-0.20	53	42.0	17		0.7	51.1	3	-5.78	41	48.2
7		1.4	74.7	4	-0.30	58	47.6	18		0.7	53.3	3	-3.34	40	47.8
8		1.0	65.3	3	-1.01	48	38.0	19		0.6	53.9	2	-2.07	37	45.0
9		0.8	59.5	3	-2.79	45	48.5	20		1.6	76.3	5	-0.74	61	45.7
10		0.8	56.0	3	-3.04	44	42.7	21		1.0	62.1	4	-3.29	50	47.8
11		1.0	68.9	3	-0.26	49	46.7	22		1.0	61.6	4	-3.57	50	42.4
								23		1.2	72.4	4	-0.64	54	39.7
								24		1.3	68.3	5	-1.95	56	47.0
								25		0.5	46.3	2	-5.17	35	48.8
								26		1.0	54.9	5	-10.7	49	42.1
								27		1.8	68.3	10	-12.3	64	37.0

Electric conductivity (EC)

Electric conductivity (EC) is a significant factor controlling whether water is proper for irrigation since it indirectly exposes the concentration of salt content in the water. In general, water below 3000 µm/cm is acceptable for irrigation uses **(Ayers 1977 and FAO 2008),** with few exceptions, for example highly sensitive crops and very clay soils **(Haritash *et al.,* 2016)**. In the Oligocene aquifer, the electrical conductivity ranged from 922 to 4110 µS/cm, while in the M. Eocene aquifer, it ranged from 1084 to 1648 µS/cm (Table .2). Except for some samples (well No. 26 and 27 in the Oligocene aquifer), all water samples' EC values were below 2000 µS/cm, which is acceptable for irrigation according to **Ayers (1977) ; FAO (2008) and WHO, (2017)**, rules.

Salinity hazard

The water is naturally evaporated, and the dissolved salts remain in the soil complex. Salinity risks and toxicity are brought on within a few years by the slow salt deposition in the soil causing salinity risk and toxicity **(Srinivasamoorthy *et al.*, 2014)**. Furthermore, excessive salt modifies the soil's permeability and structure, which indirectly affects plant development. Plant growth may be physically harmed by the uptake of excessive soluble salts of groundwater through alteration of osmotic pressure or may be harmed chemically by metabolic effects, such manners those produced by toxic elements. According to the groundwater quality standards for irrigation which were recommended by **Ayers (1977)** in Table (6), the TDS should not generally exceed 2000 mg/l, consequently, the majority of the groundwater entrapped in the Oligocene aquifer is appropriate for agriculture., except for a local zone at the northeastern of the studied aquifer (Fig. 4) is categorized as unfit for the same purpose (TDS >2000 mg/l). The groundwater of the M. Eocene aquifer is recommended for irrigation (where TDS is less than 1000 mg/l) as shown in Figure (5).

Table 6: Recommended values for irrigation water quality (Ayers, 1977)

Constituent	Unit	Suitability for irrigation			Specific crops affected
		Suitable	marginal	Unsuitable	
EC	µ mhos	<750	750-3000	>3000	
TDS	mg/l	<500	500-2000	>2000	
Cl^-	mg/l	<142	142-355	>355	Tree crops and ornamentals-root adsorption field and vegetable crops foliar damage at >106 mg/l
SAR		<3	3-9	>9	Tree crops root adsorption
SO_4^{2-}	mg/l	<350	350-600	>600	

Chloride hazard

Very little amounts of chloride are necessary for plants, but larger amounts can be hazardous to sensitive crops. An increase of chloride ions in irrigation water prevents plants from absorbing phosphates and phosphoric acid, and excessive absorption can be hazardous to some plants. The Cl concentrations in most groundwater samples of both the Oligocene and M. Eocene aquifers were below the recommended limits for irrigation purposes (<355mg/l) (Figs 17&18), while high concentrations of Chloride (>355mg/l) were recorded in the northeastern portions in the Oligocene aquifer (Fig 18). According to the limits published by **Ayers, (1975) and ASAM, (1990)**, the groundwater samples of the Oligocene and M. Eocene aquifers are appropriate for irrigation uses except for the northeastern portions of the Oligocene aquifer are classified as unsuitable for the same purpose and may cause severe problem.

Sulphate hazard

All groundwater samples from the Oligocene and M. Eocene aquifers are appropriate for irrigation according to **Ayers, (1975)** established standards, except for sample No. 27, whose sulphate concentrations were (535) (Fig14). Therefore, the groundwater sample is classified as marginal and may cause problems.

EC and Na% classification of irrigation water

A decrease in soil permeability and hardening of the soil are both brought on by an increase in sodium ions in irrigation water. These effects are a result of sodium ions exchanging cations with calcium and magnesium on clay minerals and colloids **(Hamill and Bell, 1986)**. Typically, sodium is expressed as a percentage (Na %). It is common practice to measure the Na+ content of water to see if it is suitable for irrigation **(Wilcox 1955)**. The relative quantity of cations in water is utilized to compute the Na% using the following equation:

$$\text{Na\%} = \text{Na}^+ \times 100 / (\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^{+} + \text{K}^{+})$$

The units of measurement for all concentrations are meq/l.

Wilcox's diagram (Fig 22) shows the computed Na % and EC values, which show that all groundwater samples from the M. Eocene aquifer fall within the good to a permitted category of irrigation water class. 87.5 % of the water samples taken from the Oligocene aquifer are rated outstanding to acceptable or good to permissible, 12.5 %, however, are rated inappropriate for irrigation.

EC and (SAR) classifications of irrigation water quality

The USSL of agriculture recommends SAR owing to its direct relationship to the adsorption of Na by soil. **(Richard, 1954)**. The formula for SAR is as follows:

$$\textbf{SAR} = \frac{Na}{\sqrt{Ca+Mg/2}} \qquad \textbf{Eq1}$$

The units of measurement for all concentrations are meq/l.

The U.S. S. L Staff diagram is used to plot the results of the estimated SAR and EC (Tables 1 & 3 and Fig 23). The findings showed that all groundwater samples from the M. Eocene aquifer and 87.5% of those from the Oligocene aquifer fall into the (C3-S1) class (Fig 23), which was usually regarded as a medium category for irrigation. C 3, had high salt water (750 < EC<2250 µ mhos/ cm) and cannot be used on soils with poor drainage. S_1 can be used in any type of soil and is distinguished by its low sodium concentration in the water. 12.5 % of water samples of the Oligocene aquifer fall in (C_4–S_2 and C_4–S_3) classes (Fig 23) which is generally considered bad and very bad for irrigation. C_4 S_2 & C_4 S_3 (Bad and very bad water category). C_4 is characterized by extremely high water salinity (EC >2250 µ mhos/ cm), the permeable soil and sufficient drainage are necessary. Additionally, it is advisable to select plants that can tolerate salinity. S_2 and S_3 are distinguished by water with medium and high salt contents, respectively. Most soils may create hazardous quantities of exchangeable sodium as a result, and particular soil management practices like adding gypsum and organic matter to the soil would be needed. **(USSL Staff, 1954 and Alavi. *et al.*, 2010)**.

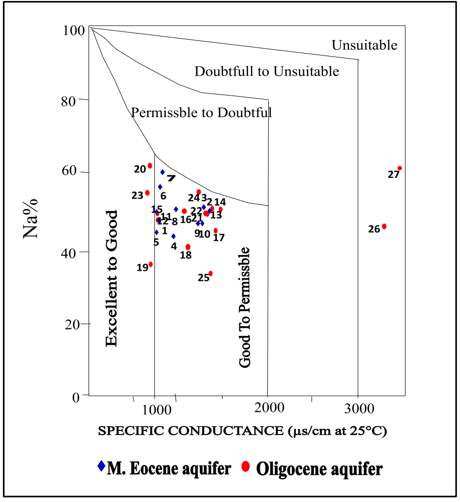

Fig 22: Representation of the waters of the aquifers according to the Wilcox diagram

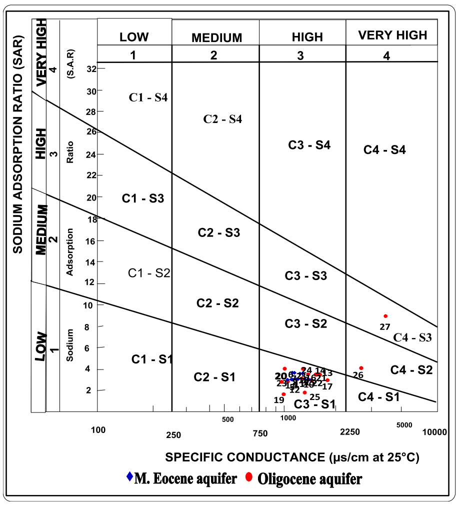

Fig 23: USSL diagram for waters of classification of irrigation aquifers

Kelly's Ratio (KR)

According to Kelly's ratio (KR), the harmful impact of sodium on the irrigation water quality was identified, where sodium was compared with calcium and magnesium **(Kelly, 1940 ; Wilcox, 1955 and Srinivasamoorthy *et al.*, 2014)**. Kelly's index is computed with the following equation:

$$\mathbf{KI = Na^{+} /Ca^{2+} + Mg^{2+}}$$

Ion concentrations are measured in meq/l.

Kelly's ratio of less than 1 indicates that the water is ideal for irrigation, whereas a ratio of >1 is improper, indicating excessive sodium content in the water **(Karanth 1987 and Ramesh and Elango 2012)**. In the current study, the calculated Kelly’s ratios of groundwater samples vary from 0.3 to 1.6 in the Oligocene aquifer, and in the M. Eocene aquifer. They fluctuate between 0.7 and 1.4. (Table 5). Kelly's ratios indicate that 75 and 72.3% of the groundwater samples from the Oligocene and M. Eocene aquifers, respectively, which acceptable for irrigation, whereas 25 and 27.3% of the groundwater samples from the aquifers are, according to Kelly's ratios, unsuitable for irrigation.

Residual sodium carbonate (RSC)

When irrigation water contains carbonates and bicarbonates at concentrations larger than those of calcium and magnesium, it might resulted in deflocculation of the soil as a result of sodium carbonates formation **(Palacios and Aceves, 1970; Aguilera and Martinez, 1996)**, affecting agriculture unfavorably **(Eaton, 1950 and Richard,1954)** and the agricultural land becomes infertile **(Rifat *et al.*, 2014)**. The following equation is used to calculate the residual sodium carbonate:

$$\mathbf{RSC = (CO3^{-2} + HCO3^{-}) - (Ca+^{2} + Mg^{+2})}$$

where meq/l is used to express all cation and anion values.

The values of calculated RSC in (Table 5) show that the maximum and minimum values are – 12.3 RSC (well No 27) and - 0.2 (well No. 6), respectively. This mean that the groundwater of the Oligocene and M. Eocene aquifers display values below the recommended limits (1.25) and are good for use in agricultural.

Permeability index (PI)

Long-term exposure of land to irrigation water containing high concentrations of sodium, calcium, magnesium, and bicarbonate ions affects the permeability of soil **(Ravikumar *et al.*, 2011 and Srinivasamoorthy *et al.*, 2014)**. The permeability index (PI), created by **Doneen, (1964),** to assess the suitability of irrigation water, is computed using the method below:

$$PI=(Na+ + \sqrt{}HCO_3^{-}) \times 100/ (Ca^{2+} + Mg^{2+} + Na^{+} + K)$$

All ion contents are expressed in meq/l.

Three categories of PI exist: class I (> 75% appropriate), class II (25–75% good), and class III (< 25% unsuitable) **(Doneen, 1964, Sundaray *et al.*, 2009 ; Das and Nag 2015)**. In the Oligocene and M. Eocene aquifers, respectively, the PI values varied from 46.3 to 76.3 and from 53.4 to 74.7 (Table 5), indicating a good category.

Magnesium hazard (MH))

High quantities of magnesium ions in water reduce the quality of the soil and result in low crop output **(Sundaray *et al.*, 2009).** Greater exchangeable Na ion levels in irrigated soils are typically caused by higher Mg ion concentrations in water. The following formula is used to compute the magnesium ratio (MH):

$$\mathrm{MH} = \frac{mg}{ca+mg}*100$$

The relationship between the quantities of calcium and magnesium ions in meq/l was first described by **Paliwal, (1972)** and is now known as the magnesium ratio. A magnesium hazard rating greater than 50% would have a negative influence on agricultural yield as soils become more alkaline. The MR values in the Oligocene and M. Eocene aquifers, respectively, ranged from 33.9 to 48.8 and from 34.7 to 48.5. (Table 5). Therefore, the groundwater samples in both aquifers are considered suitable for irrigation (i.e., MH < 50%).

CONCLUSIONS

In the current study, the WQI method and other irrigation quality criteria were employed to assess the groundwater quality of the Oligocene and M. Eocene aquifers for drinking and irrigation purposes in the West Mallawi District. Findings revealed that the spatial variations of TDS values and major ions in the groundwater of both aquifers are suitable for drinking, except for the eastern and the northeastern portions of the Oligocene aquifer, where the contents of TDS, Na+, $SO4^{-2}$, and Cl^- exceeds the permissible limits and the groundwater is unacceptable for drinking. The concentration of trace elements (Fe, Mn, Li, V, Zn, and Al) in groundwater of the Oligocene and M. Eocene aquifers were within acceptable limits for drinking. The results of the calculated WQI showed that the groundwater of both aquifers was classified as excellent to good samples for drinking with exception of two water samples in the Oligocene aquifer recorded in the eastern portions which fall under the poor water category. The Spatial variations of EC, TDS, SO_4^{-2}, and Cl-, revealed that the groundwater of the M. Eocene aquifer and Oligocene aquifers are suitable for irrigation uses, except for two samples of the Oligocene aquifer were recorded at the eastern portions and classified as unsuitable for the same purpose. According to the USSL diagram, the groundwater of both aquifers falls in (C3–S1) class, which is usually of a medium category for irrigation with exception of two samples of the Oligocene aquifer fall in the category of C4–S2 and C4–S3 reflecting a bad and very bad for irrigation. According to the Wilcox diagram, the groundwater of both aquifers falls in the good to a permissible category of irrigation except for two samples of the Oligocene aquifer, which were classified as unsuitable for irrigation. The Oligocene and M. Eocene aquifers' groundwater can be used for irrigation, except for 25 and 27.3% of the groundwater, which are not suited for the same use, according to Kelly's ratio (KR). In terms of magnesium hazard, permeability index, and residual sodium carbonate, the groundwater from both aquifers are appropriate for agriculture.

REFERENCES

Abdel Moneim, A.A. ; J.P. Álvarez ; E.M. Abu El Ella and A.M. Masoud (2016): Groundwater management at West El-El Minia desert area, Egypt using numerical modeling. J. Geosci. and Environ. Prot., 4: 66-76.

Abdulhady, Y. ; E. Zaghlool and Y. Gedamy (2018): Assessment of the groundwater quality of the quaternary aquifer in reclaimed areas at the northwestern El-El Minia governorate—Egypt, using the water quality index. Int. J. Recent Sci. Res., 9: 23033-23047

Aguilera, M. and R. Martínez (1996): Relaciones agua suelo planta atmósfera. 4a ed. Departamento de Irrigación. México: Universidad Autónoma Chapingo.

Akter, T. ; F.T. Jhohura ; F. Akter; T.R. Chowdhury; S.K. Mistry ; D. Dey; M.K. Barua; M.A. Islam and M. Rahman (2016): Water quality index for measuring drinking water quality in rural Bangladesh: A crosssectional study. J. Health, Population and Nutrition, 35:4. DOI 10.1186/s41043-016-0041-5

Alavi, N.V. ; V. Nozari ; S.M. Mazloumzadeh and H Nezamabadi-pour (2010): Irrigation water quality evaluation using adaptive network-based fuzzy inference system. Paddy Water Environ. 8:259–266.

Al-Mohammed, F.M. and A.A. Mustasher (2013): Application of water quality index for evaluation of groundwater quality for drinking purpose in dibdiba aquifer, Kerbala City, Iraq. J. Babylon Univ. Engine. Sci., 21: 1647-1660.

ASAM (Agriculture Salinity Assessment and Management) (1990): "Mass Crop Soil Tolerance ", manual. K. K. tanji (ed.). ASCE, New York. P. 262.

APHA (American Public Health Association) (2005): Standard Method for Examination of Water and Wastewater, 21st Ed. APHA, AWWA, WPCF, Washington D. C.

Ayers, R.S. (1975): Quality of water for irrigation. Proc. Irrig. Drain. Div. Specially Conf., Am Sc. Civ. Eng., Longen, Utah. pp. 24-56.

Ayers, R.S. (1977): Quality of water for irrigation. J. Irrigation and Drainage Division, 103: 135-154.

Ayers, R.S. and D.W. Westcot (1985): Water Quality for Agriculture vol 29. Food and Agriculture Organization of the United Nations Rome.

Balan, I.N. ; M. Shivakumar and P.D.M. Kumar (2012): "An assessment of groundwater quality using water quality index in Chennai, Tamil Nadu, India", Chronicles Young Sci., 3(2): 146-150.

Boateng, G.K. ; F. Opoku ; S.O. Acquaah and O. Akoto (2016): Groundwater quality assessment using statistical approach and water quality index in Ejisu-Juaben Municipality Environ. Earth Sci., 75:489.

Brown, R.M. ; N.J. McCleiland ; R.A. Deininger and M.F. O'Connor (1972): A Water Quality Index - Crossing the Psychological Barrier (Jenkis, S.H., ed.) Proc. Int. Conf. on Water Poll. Res., Jerusalem, 6: 787-797.

Chatterji, C. and M. Raziuddin (2002): Determination of water quality index of a degraded river in Asanol industrial area, Raniganj, Burdwan, West Bengal, Nature, Environ. and Poll. Technol., 1 (2): 181-189.

Conoco Coral (1987): Geological Map of Egypt, Scale (1:500,000), NH 36 SW-B.S. sheet.

Das, S. and S.K. Nag (2015): Deciphering groundwater quality for irrigation and domestic purposes – A case study in Suri I and II blocks, birbhum district, west bengal, India. J. Earth System Sci., 124 (5): 965–992.

Doneen, L.D. (1964): Water Quality for Agriculture. Department of Irrigation, University of California, Davis, p 48 .

Deshpande, S.M. and K.R. Aher (2012): Evaluation of groundwater quality and its suitability for drinking and agriculture use in parts of Vaijapur, district Aurangabad, MS, India. Res. J. Chem. Sci., 2(1): 25-31.

Eaton, E.M. (1950): Significance of carbonate in irrigation water. Soil Sci., 69: 123-133.

EGSMA; NARSS; UNDP; UNESCO (2005): "Geological Map of Al Minya Quadrangle, Egypt" Scale 1:250 000, Sheet NH - 36 A

Eslami, F. ; R. Shokoohi ; S. Mazloomi ; M.D. Motevalli and M.Salari (2017): Evaluation of water quality index (WQI) of groundwater supplies in Kerman province in 2015. J. Occupational and Environ. Health., 3(1):48-58.

FAO (2008) Guide for Laboratory Establishment for Plant Nutrient Analysis. FAO, Rome

Gedamy, Y. ; Y. Abdulhady and E. Zaghlool (2019): Hydrochemistry of the Eocene aquifer at the desert fringes of west El-El Minia Governorate, Egypt. Curr. Sci. Int., 8(4): 734-763.

Gaber, M.E. ; H. Soussa and E. Fattouh (2021): Groundwater quality evaluation for drinking and irrigation use in Dayrout city Upper Egypt. Ain-Shams Eng. J., 12(1):327–340.

Hamill, L. and F.G. Bell (1986): "Groundwater Resource Development" British Library, ISBN 0-408-01409-1, pp. 1-32.

Haritash, A.K. ; S. Gaur and S. Garg (2016): Assessment of water quality and suitability analysis of River Ganga in Rishikesh, India. Appl. Water Sci., 6:383–392.

Hem, J.D. (1989): Study and Interpretation of Chemical Characteristics of Natural Waters. 3rd Edition, US Geological Survey Water-Supply Paper 2254

Horton, R.K. (1965): An index number system for rating water quality. J. Water Poll. Control Federation, 37(3): 300–306.

Ismail, E. ; E. El-Sayed ; S. Sakr and E. Youssef (2017): Characteristic of groundwater potentialities in West Nile Valley South, El Minia Governorate, Egypt. Arabian J. Geosciences, 10: 521

Ismail, E. ; A. Abdelhalim and M. Abou Heleika (2021): Hydrochemical characteristics and quality assessment of groundwater aquifers northwest of Assiut district, Egypt. J. Afr. Earth. Sci., 181:104260.

Karanth, K.R. (1987): Groundwater Assessment Development and Management. Tata McGraw Hill Publishing Company Ltd., New Delhi, p 725

Kelly, W.P. (1940): Permissible Composition and Concentration of Irrigated Waters. In: Proceedings of the A.S.C.F, 607

Klitzsch, E. ; F. List and G. PÖhlmann (1987): Geological Map of Egypt, scale 1:500,000, Sheets NG 36 NE Quseir; NH 36 NW Cairo; NH 36 NE North Sinai; NH 36 SW Beni Suef; and NH 36 SE South Sinai, Conoco Coral and Egyptian General Petroleum Corporation (EGPC), Cairo

Korany, E. ; S. Sakr ; M. Darwish and S. Morsy (2008): Hydrogeologic modeling for the assessment of the continuous rise of groundwater levels in the quaternary aquifer, Nile valley, Egypt: case study. International Conf. Geol. Arab world (Gaw8), Cairo University, pp 703–711.

Magesh, N.S. ; S. Krishnakumar ; N. Chandrasekar and J.P. Soundranayagam (2013): Groundwater quality assessment using WQI and GIS techniques, Dindigul district, Tamil Nadu, India Arab J. Geosci., 6:4179–4189.

Ochuko, U. ; O. Thaddeus ; O.A. Oghenero and E.E.John (2014): A comparative assessment of water quality index (WQI) and suitability of river Ase for domestic water supply in urban and rural communities in Southern Nigeria. Int. J. Human Soc. Sci., 4(1):234–45.

Palacios, O. and E. Aceves (1970): Instructivo para el registro, muestreo einterpretación de datos de calidad del agua para riego. Colegio de Posgraduados. Serie de Apuntes No. 15. Chapingo, México.

Paliwal, K.V. (1972): Irrigation with Saline Water. Water Technology Centre, Indian Agriculture Research Institute, New Delhi, p 198.

Rabeiy, R.E. (2018): Assessment and modeling of groundwater quality using WQI and GIS in Upper Egypt area. Environ. Sci. and Poll. Res., 25:30808–30817.

Ramesh, K. and L. Elango (2012): Groundwater quality and its suitability for domestic and agricultural use in Tondiar River Basin, Tamil Nadu, India. Environ. Monit Assess., 184(6):3887–3899

Ravikumar, P. ; R.K. Somashekar and M. Angam (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.

Richard, L.A. (1954): Diagnosis and Improvement of Saline Alkali Soils, Agriculture, 160, Handbook 60. US Department of Agriculture, Washington DC.

Rifat, M. ; A.H. Milton and J. Hall (2014): Development of Multidrug-Resistant Tuberculosis in Bangladesh: A Case-Control Study on Risk Factors. PloS ONE, 9, e105214.

USSL, Staff. (1954): Diagnosis and Improvement of Saline and Alkali Soils. USDA Agricultural Handbook No. 60. U.S. Government Printing Office, Washington, D.C.

Sahinci A (1991): Geochemistry of Natural Waters (in Turkish). Izmir: Reform printing office, p 54

Salim, A.A. (2015): Hydrogeological studies on the shallow aquifers in the area west Samalot, El Minia Governorate, Egypt. Egyptian J. Pure and Appl. Sci., 53(4):49-60

Srinivasamoorthy, K. ; M. Gopinath ; S. Chidambaram ; M. Vasanthavigar and V.S. Sarma (2014): Hydrochemical characterization and quality appraisal of groundwater from Pungar sub-basin, Tamilnadu, India. J. King Saud Univ. Sci., 26:37–52.

Subba-Rao, N. (1997): Studies on Water Quality Index in Hard Rock Terrain of Guntur District, Andhra Pradesh, India (pp. 129–134). National Seminar on Hydrology of Precambrian Terrains and hard rock areas.

Sundaray, S.K. ; B.B. Nayak and D. Bhatta (2009): Environmental studies on river water quality with reference to suitability for agricultural purposes: Mahanadi river estuarine system, India - A case study. Environ. Monitoring and Assessment, 155: 227–243

Tyagi, S. ; B. Sharma ; P. Singh and R. Dobhal (2013): Water Quality Assessment in Terms of Water Quality Index. Am. J. Water Resources, 1(3): 34-38

Wagh, V.M. ; D.B. Panaskar ; A.A. Muley and S.V. Mukate (2017): Groundwater suitability evaluation by CCME WQI model for Kadava river basin Nashik Maharashtra India. Modeling Earth Systems and Environ., 3(2):557-565.

Wilcox. L.V. (1955): Classification and Use of Irrigation Waters. US Department of Agriculture, Washington

WHO (2017): Guideline for Drinking Water Quality, 4th edition World Health Organization, Geneva.

Yesilnacar, M.L. and M.S. Gulluoglu (2008): Hydrochemical characteristics and the effects of irrigation on groundwater quality in Harran plain, GAP project, Turkey. Environ. Geol., 54(1): 183-196.

Yousif, M. ; H.S. Sabet ; S.Y. Ghoubachi and A. Aziz (2018): Utilizing the geological data and remote sensing applications for investigation of groundwater occurrences, West El El Minia, Western Desert of Egypt. NRIAG J. Astronomy and Geophysics, 7: 318–333.

تقييم جودة المياه الجوفية في منطقة غرب ملوي، جنوب محافظة المنيا، مصر، باستخدام مؤشر جودة المياه ومعلمات الري

محمد عبدالله الفخرانى[1] ، ابراهيم عيد موسى[2] ، نهاد محمود منصور[1]

1- كليه العلوم– قسم الجيولوجيا– جامعه بنها

2- شركة اسكندريه المتحدة لاستصلاح الاراضى

استخدمت الدراسة الحالية مؤشر جودة المياه (WQI) ومعايير جودة مياه الري لتقييم المياه الجوفية لخزاني الأوليجوسين والإيوسين الاوسط في منطقة غرب ملوي لاستخدامات الشرب والري. وللقيام بذلك، تم تحليل سبعة وعشرين عينة كيميائيًا تمثل كلا الخزانين لمعرفة تركيزات الكاتيونات والأنيونات الأساسية، ودرجة الحموضة، والمواد الصلبة الذائبة الكلية، ومعامل التوصيل الكهربائي، والعناصر الشحيحة. كما تم حساب مؤشر جودة المياه للشرب وستة من معاملات جودة مياه الري الهامة لتقييم ملاءمة المياه الجوفية للري. بالإضافة إلى إنشاء وتفسير خرائط التباين المكاني للايونات الريسية ومؤشر جودة المياه لخزانات المياه الجوفية.

أشارت نتائج التوزيعات المكانية للملوحة، والأيونات الرئيسية، وقيم مؤشر جودة المياه لعينات المياه الجوفية لكلا الخزانين إلى أن هذه المياه الجوفية مقبولة للشرب، باستثناء الأجزاء الشرقية من خزان الأوليجوسين، حيث كانت قيم الملوحة، والصوديوم، والكلوريدات والكبريتات تتجاوز الحدود المسموح به وتندرج عينات المياه الجوفية تحت تصنيف المياه الرديئة (WQI> 50). وقد اظهرت نتائج تركيزات العناصر الشحيحة (الحديد، المنجنيز، الليثيوم، الفانديوم، الزنك والالومنيوم) في المياه الجوفية لكلا الخزانين قيم ضمن الحدود المقبولة للشرب. وقد بينت التوزيعات المساحية لمعامل التوصيل الكهربائي والملوحة والكلوريدات والكبريتات، بالإضافة إلى مؤشركيلي، ورسم مخطط النسبة المئوية للصوديوم (Na %) و معامل ادمصاص الصوديوم (SAR) مقابل معامل التوصيل الكهربائي (EC) أن المياه الجوفية في خزان الإيوسين الاوسط و87.5٪ من عينات المياه في خزان الأوليجوسين يتم تصنيفها جيدة إلى مسموح بها للري، في حين أن 12.5٪ من عينات المياه في خزان الأوليجوسين تعتبر غير صالحة لنفس الغرض. وقد بينت نتائج حساب قيم معامل كربونات الصوديوم المتبقية (RSC) و معامل النفاذية (PI) و خطر الماغنيسيوم (MH) ان المياه الجوفية أقل من الحدود الموصى بها للري.