Impact of hydrogeological conditions and human activities on groundwater quality of the Quaternary aquifer at Belbies – Al-Abbasa area, east Nile Delta, Egypt

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Abstract

The Quaternary aquifer is the main groundwater resource in the study area; it mainly consists of graded sand and gravels intercalated with clay and silt lenses. Generally, the groundwater flow in the study area is from southwest to northeast. The groundwater of the Quaternary aquifer is now suffering from quality problems due to human activities.

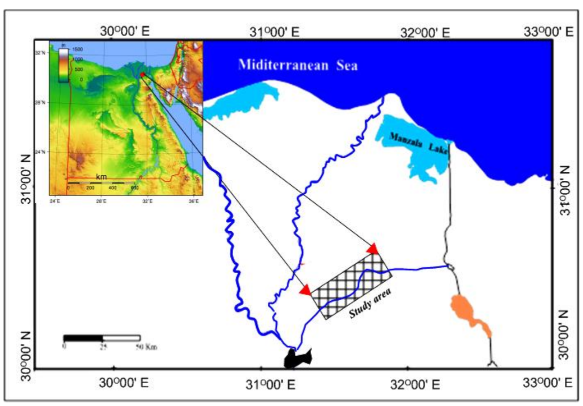
The present work aims to evaluate the impact of hydrogeological conditions and human activities on shallow groundwater quality at Belbies – Al-Abbasa area. To achieve that, 20 groundwater samples distributed over the study area are collected and chemically analyzed for both major and trace elements. The distributions of different pollutants in groundwater are carefully studied, in addition to construction of water level map of the Pleistocene aquifer.

Results indicate that the groundwater flow in the study area is from southwest to northeast. The formation of groundwater depression due to heavy pumping is recorded at the northeast (Kafer Al Azzazi, Manshiate Al-Abbasa) Al-Abbasa area. The concentrations of sulphate, chloride, iron, Nickel and lead at the northeast of the study area (at At Tall Al Kabir, Al Abbasa and Kafer El Azzazi) exceed the permissible limits for drinking. The probable sources of high contents of pollutants are mainly due to infiltration of domestic, agricultural and industrial wastes arise from the development of human activities. The lowest contents of such pollutants noticed beside the Ismailia canal, reflecting the positive hydrochemical impact of this canal on groundwater quality. For agricultural purposes, the ground water in the study area is suitable for irrigation purposes in accordance with SAR, RSC and Na %.

KEYWORDS: Groundwater, Water quality

Introduction

The area under investigation lies in the eastern Nile Delta. It is bounded by longitudes $31^{\circ} 25'$, 31° 50' E and latitudes 30° 20', 30° 40' N (Fig. 1). The groundwater of the Quaternary aquifer is the most important water resource in the study area. Quality of groundwater is affected by rainfall, climate, geology, irrigation practices, anthropogenic sources of contamination and several other reasons. The hydrochemical characteristics of groundwater play a significant role in assessing its quality for various purposes. It's also provides a better understanding of possible changes on groundwater quality. Generally, the area east of the Nile Delta is characterized by a long dry summer and short temperate winter with a rainfall period from October to March. The climate is hot in summer; the average temperature is in the range 19.7oC and 34.7oC, while during winter it range from 7.4 ^{o}C and 18.4 ^{o}C (EgyptianMeteorologicalAuthority2003).



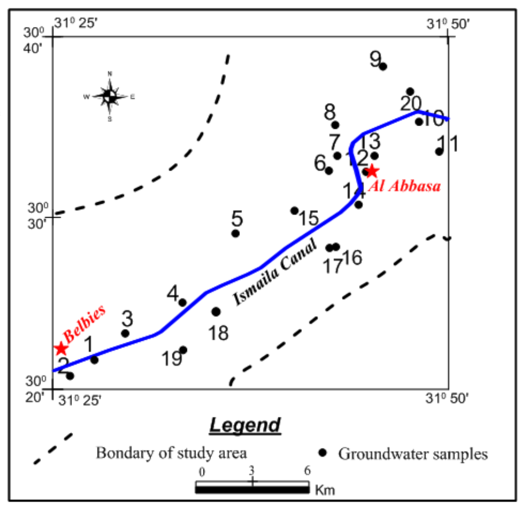


Fig. (1) Location map of the study area

Fig.(2) Groundwater samples map

Aims and method of study

The present work aims to evaluate the impact of hydrogeological conditions and human activities on shallow groundwater quality at Belbies – Al-Abbasa area. To achieve this purpose, field and laboratory measurements were carried out for the collected groundwater samples (Figs. 2). Determinations of electric conductivity and salinity were measured directly in the field. The groundwater samples were analyzed for major ions, and trace elements. Besides, constructions of water level map of the Pleistocene aquifer and distribution maps of different contaminants in groundwater.

Geology

According to Said and Beheri (1961), Shata (1965), El Fayoumy (1968); El Kotb 1988, RIGW/WACO (1988), Said (1991). The study area occupied by rock units belonging to the Tertiary and Quaternary. The Miocene sediments are dominated by clastic facies in the southern part of study area, changed into shallow marine sandy limestone and marls towards the north composed mainly of alternating sandy limestone and loose quartz sand and marl. The Eocene rocks are underling the Quaternary one, it is mainly consists of fissured and cracked carbonate rocks. The Pliocene sediments outcrop at the northeastern portions (Fig. 3). The Pliocene clay is overlain by the Quaternary deposits in the Nile Delta flood plain with a thickness of about 300m. The Quaternary deposits covers the majority of the area, it is classified into two rock units; the upper unit is the Holocene Nile silt and clay (flood plain deposits) with Sabkha and fine sand deposits, while the lower one is the Pleistocene sand and gravel. Some sand dunes and sand sheets distributed and belonged to Holocene.

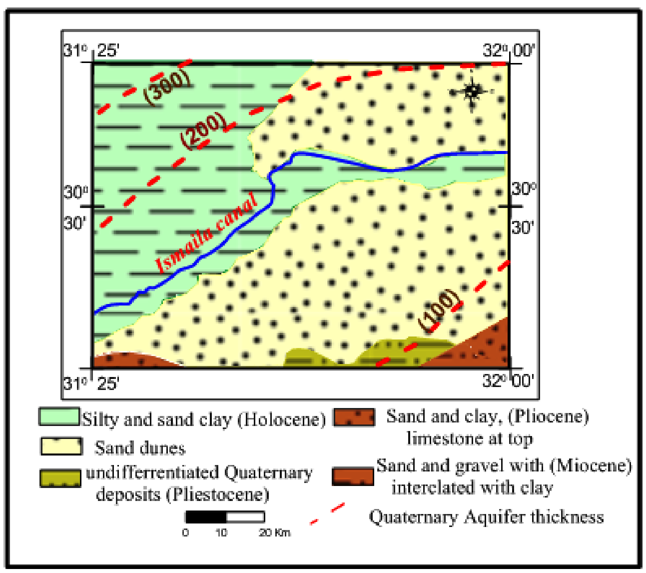


Fig. (3) Hydrogeological map of the study area (after RIGW1989)

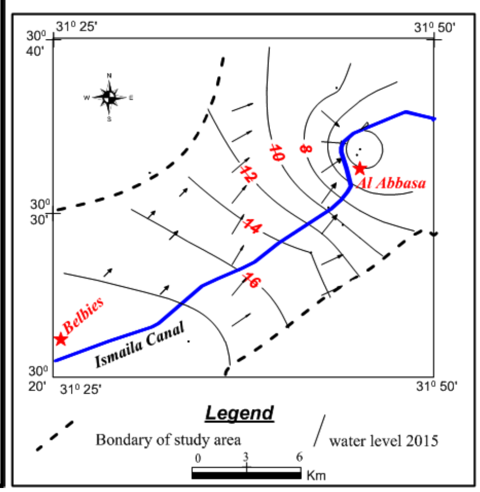


Fig. (4) Water level contour map of the Quaternary aquifer, (2015)

Hydrogeologic setting:

Many detailed works have discussed the hydrogeology of east Nile Delta area, among them are; Shata and El Fayoumy 1970; El Shazly et al. 1975a; El Diary 1980; Diab et al. (1984), RIGW 1989, Attia 1985, Korany et al. (1993), Taha et al (1997), Eweida et al. (1999), Yehia (2000) and Abd Alrahman etal 2014, Gomaa etal (2014).

The Quaternary aquifer represents as the main groundwater aquifer in the study area. It has a wide geographic distribution and high productivity. The total saturated thickness of Quaternary aquifer increases gradually from south to north and northwest, it ranges from 100 to 300m (Fig.3). It generally rests above the Pliocene clay which acts as an aquiclude. The transmissivity of the aquifer is considerably high with an average 10000 m^2/day (Attia, 1985). The average value of hydraulic conductivity in eastern portion of Delta is about 100m/day and the transmissivity about 15000m^2/day (Kotb, 1988). Generally, the groundwater flow in the study area is from southwest to northeast with some local deviations. The formation of groundwater depression due to heavy pumping is recorded at the northeast south of Ismailia canal (Manshiat Al-Abbasa and Al-Abbasa) at Al-Abbasa area (Fig. 4). The aquifer is mainly recharged by downward infiltration from surface water either directly or indirectly, the direct recharge took place by direct seepage from the main irrigation Ismailia canal. Very limits contribution from local rainfall is expected.

The inspection of the hydrogeological cross section along the right bank of Ismailia canal (Fig. 5) indicates that at Belbies area, Ismailia canal cut its course through sandy clay and clay layer, this lithology slightly minimizes the hydraulic connection between surface water in the canal and groundwater. At AL Abbasa, Ismailia canal cut its course through fine to medium sand, therefore the hydraulic connection between surface water in the canal and groundwater is good.

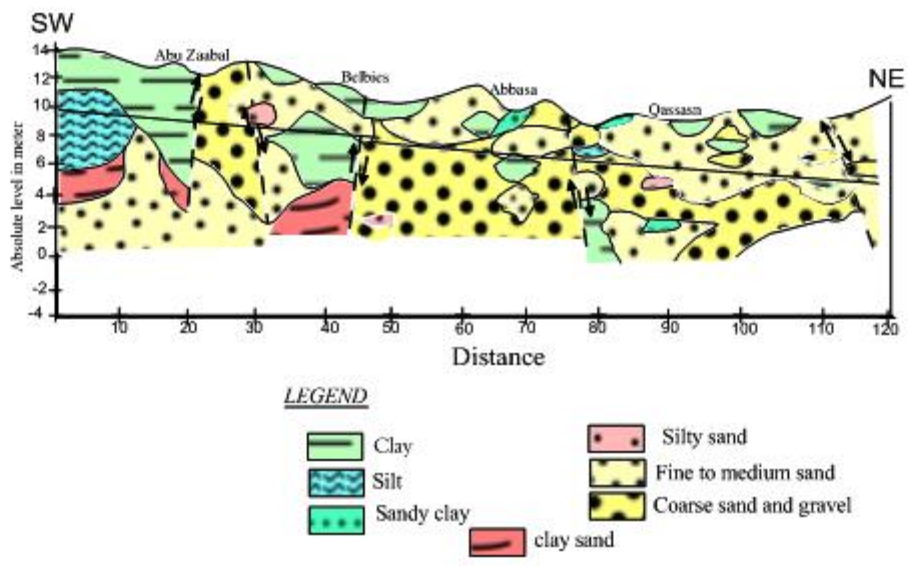


Fig. (5) Hydrogeological cross section along the right bank of Ismailia canal

Groundwater quality

Due to intensive agricultural practice, which involves the application of chemical fertilizers and pesticides, many soils and shallow aquifers are contaminated. Consequently, pollution of groundwater has become a major concern in recent years (Embaby and Dawoud, 2009). The groundwater in the study area is suffering from quality problems. Pollution can impair the use of water and can create hazards to public health through toxicity or the spread of disease. Problems of groundwater quality degradation related mainly to natural and human-related factors. The following discussion based relevant on chemical analyses of shallow groundwater samples collected from the study area and compared with WHO (2004) standards.

Total dissolved salts

Hem (1970) has classified the water according to its total dissolved solids content (Table 1). Based on this classification and on the results of chemical analyses (Table 2), Shallow groundwater samples classified as fresh to brackish water, where the total dissolved salts ranges between 240 and 1092 ppm. The areal distribution of salinity content in shallow groundwater wells (Fig. 6) shows that the majority of the study area is characterized by good potable water of low salinity (TDS < 500ppm). These zones surrounded by a major zone characterized by fresh water of salinity content ranges between 500 and 1000 ppm. The northeastern parts of the study aquifer classified as polluted zones where the salinity content varies from over 1000ppm and exceeds the permissible limits for drinking.

Table (1): Classification of water salinity according to Hem (1970)

T.D.S (ppm)	Type
<1000	Fresh
1000-3000	Brackish
3000-10000	Slightly salty
10000-35000	Saline water
>35000	Sabakh

Table (2) show the minimum, maximum and average concentration of the different pollutants

Pollutants		groundwater		Average	(WHO, limits 2004)
		Min	Max		Acceptable
E.C		400	1700	835	1500
SALINITY		240	1092	527	1000
MAJOR ELEMENTS	Na	27.6	150	78.7	200
	K	2.22	34.25	7.47	
	Ca	16	92	38	200
	Mg	7.65	55	25.7	150
	CL	40	285	110.58	250
	SO_4	42.8	339.7	157.3	250
	HCO_3	38	129	74.65	
TRACE ELEMENTS	Iron	0.02	0.8	0.4	0.3
	Manganese	0.001	0.25	0.13	0.4
	Copper	0.003	0.106	0.0612	2
	Lead	0.001	0.08	0.02	0.01
	Nickel	0.08	0.75	0.011	0.02
	Zinc	0.007	0.266	0.059	15

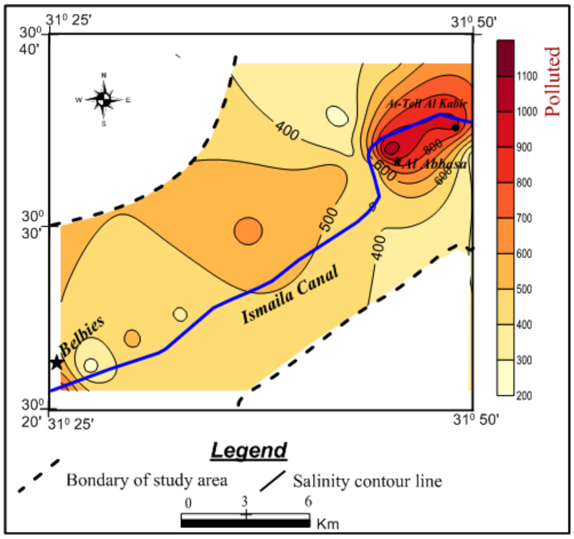
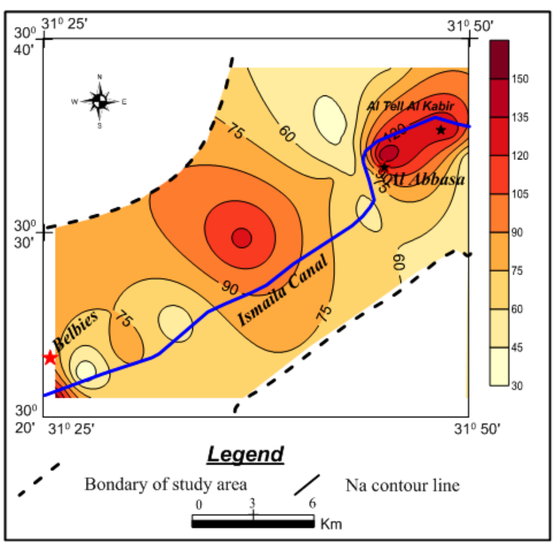


Fig. (6) Salinity content distribution map of the Quaternary aquifer

Major ion

The major constituents of dissolved solids in groundwater samples are the following cations calcium, magnesium, sodium, and potassium and the following anions chloride, sulfate and bicarbonates. The concentrations of major ions are listed (Table 2) and their distributions in groundwater are defined (Figs.7-10, inclusive). The inspection of these figures reveals the following:



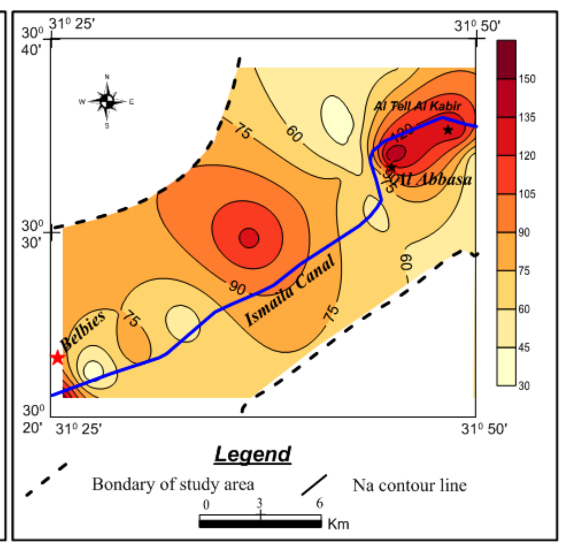


Fig. (7) Sodium content distribution map of the Quaternary aquifer

Fig. (8) Potassium content distribution map of the Quaternary aquifer

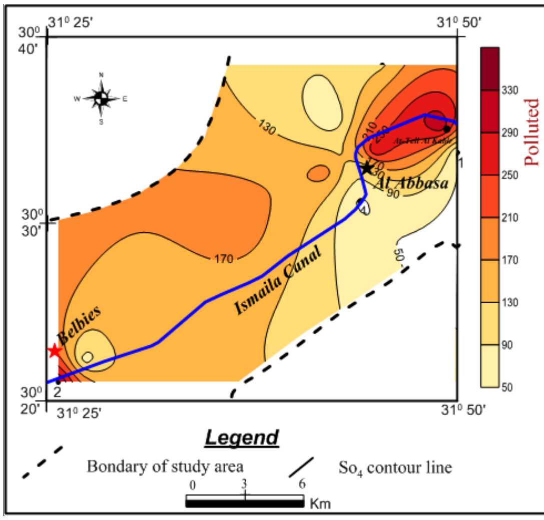


Fig. (9) Sulfate content distribution map of the Quaternary aquifer

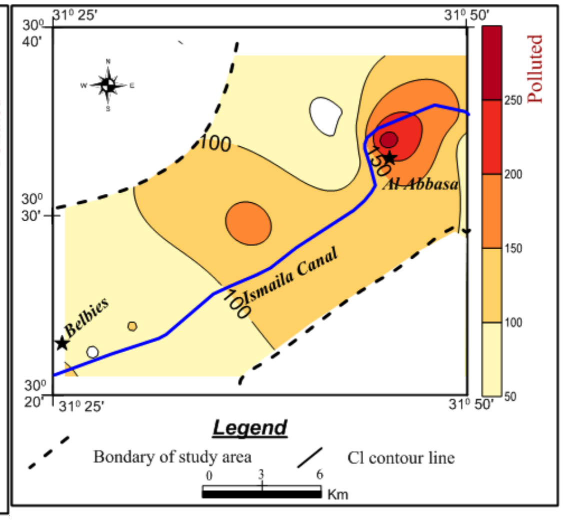


Fig. (10) Chloride content distribution map of the Quaternary aquifer

1- The lowest concentrations of these ions noticed beside the Ismailia canal, this reflect the positive hydrochemical impact of this canal on groundwater quality.

2- The concentrations of these ions increase in the northeastern portions of the study area at (at Al Abbasa, Mansiate Al Abbasa, Kafer Al Azzazi and At Tell Al Kabir). The probable sources of these high contents of pollutants are mainly due to decrease in water level in this area and the formation of water depression, infiltration of domestic, agricultural and industrial wastes arise from the development of human activities.

3-The sodium content in the shallow wells varies from 27.6to 149 ppm (Table, 2). High concentrations of sodium are recorded at At Tall Al Kabir and Kafer El Azzazi (Fig. 7).

4-The potassium content in the shallow wells varies from 2 to 35 ppm (Table, 2). High concentrations of potassium are recorded at At Tall Al Kabir and Kafer El Azzazi (Fig. 8). High potassium content (>10 ppm) is due to decaying of organic matter associated with sewage water.

5-The concentration of sulfate in groundwater ranges between 40 ppm and 339.7ppm in shallow wells. The areal distribution of sulfate content in shallow groundwater (Fig.9) indicate that the majority of study area characterized by low concentration of sulfate (<250ppm). The highest concentrations of sulfate noticed in the north eastern portion of the study area at At Tall Al Kabir, Al-Abbasa and Kafer El Azzazi.

6-The chloride contents in shallow groundwater vary from 40 to 285 ppm (Table 2). The majority of study area is characterized by low chloride concentration (<250 ppm). Local polluted zones of high chloride contents (> 250 ppm) recorded at the northeastern portions of the study area (Fig. 10).

The discharge of human, animal, industrial wastes and irrigation return flows may add substantial quantity of sodium, chloride and sulfate to groundwater. High concentrations of sulfate and chloride ions (>250 ppm) may produce objectionable taste and act as laxative on unacclimated users (Hem, 1985 and Probe et al., 1999).

Trace elements

The concentrations of the trace elements found in groundwater (Cu, Fe, Mn, Zn, ni, V) are much higher in shallow aquifer due to anthropic activities (Heredia and Cirelli, 2009). Trace elements such as copper, lead and zinc are used as structural or decorative components of buildings and as protective coating against corrosion and oxidation of framework or base metal. Large quantities of some trace metals have been released with effluent discharge from industrial activities (Probe et al., 1999). Based on the limits presented by WHO (2004), the concentrations of trace elements (copper, manganese and zinc) in groundwater are within the acceptable limits for drinking and domestic uses. Iron، Nickel and lead contents are over the acceptable limits. Excess of absorbed iron being stored primarily in the liver, bone marrow and spleen resulting in many dangerous diseases (WHO, 1984b). The recommended maximum concentration of iron in drinking is 0.3 ppm (U.S.EPA 2000) to avoid staining. The concentration of iron in groundwater of the Quaternary aquifer ranges between 0.1ppm and o.9 ppm (Table, 2). The distribution contour map of iron in shallow groundwater (Fig.11) shows that, the majority of the studied area characterized by concentration <0.3 ppm. Therefore, the northeastern of study area) Manshiat Al-Abbasa - Al-Abbasa and At Tall Al Kabir) is unsuitable for drinking (Fe >0.3ppm). The concentration of lead in groundwater of the Quaternary aquifer varies from o.o15 ppm and 0.08ppm (Table, 2). The distribution contour map of lead in groundwater (Fig. 12) shows that, the northwestern portions of the study area characterized by concentration <0.025ppm. Therefore, the northeastern portion of the study area characterized by concentrations >0.05 ppm and unsuitable for drinking.

The concentration of nickel in groundwater of the Quaternary aquifer varies from o.08ppm and 0. 8ppm (Table, 2). The distribution contour map of nickel in groundwater (Fig. 13) shows that, the majority of the studied area characterized by concentration >0.2 ppm, the northeastern of study area (Manshiat Al-Abbasa - Al-Abbasa and At Tall Al Kabir) and the southwestern of portion area Belbies is unsuitable for drinking

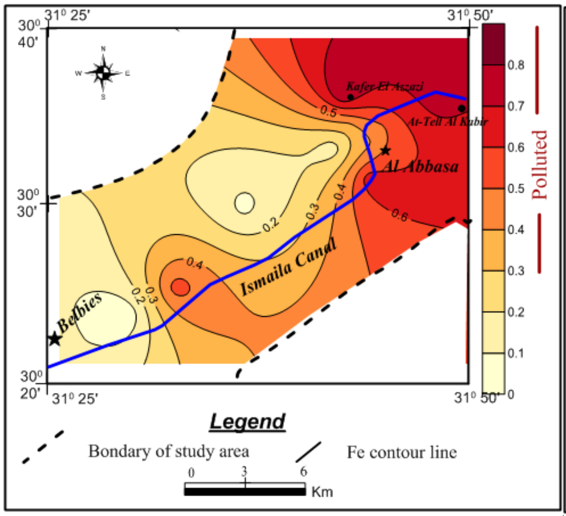


Fig. (11) Iron content distribution map of the Quaternary aquifer

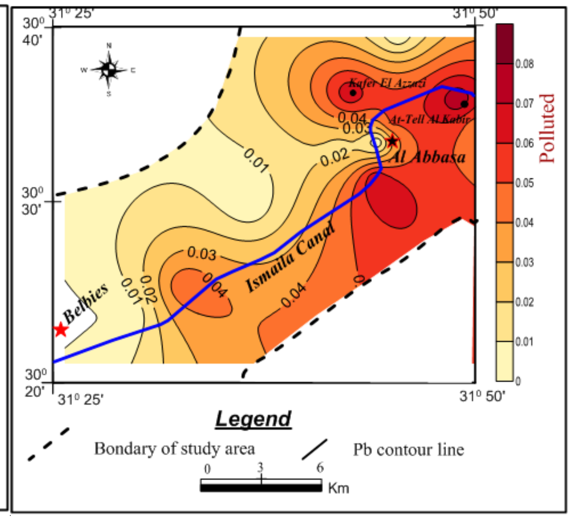


Fig. (12) Lead content distribution map of the Quaternary aquifer

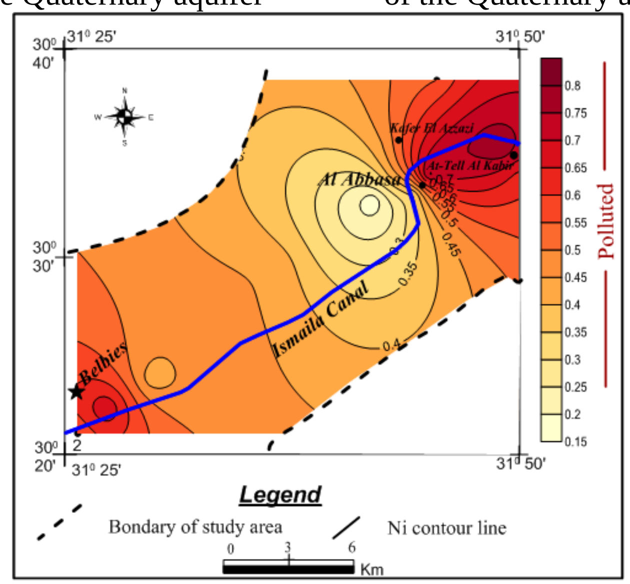


Fig. (13) Nickel content distribution map of the Quaternary aquifer

Irrigation water quality

Salinity and alkalinity hazard

Total amount of dissolved inorganic solid material of any natural water is termed as its salinity. Salinization of water related to the increase in TDS and overall chemical content of water. Presence of excessive dissolved chemical ions such as Sodium, HCO_3 and CO_3 in irrigation water will affect the soil fertility and thus crop productivity. Classification of water for irrigation water quality based on E.C (Raghunath,1987), is given in Table (3) which show 57% of samples are good, while 43% with permissible limits.

Table (3) Irrigation water quality based on E.C. according to Raghunath,1987

E.C (µS/cm	Water class	Percentage of samples
<250	Excellent	Nil
250-750	Good	57%
750-2000	Permissible	43%
2000-3000	Doubtful	Nil
>3000	unsuitable	Nil

Sodium adsorption ratio (SAR)

Excessive salinity will reduce the osmotic activity of plants which will interfere with the adsorption of water nutrients by the plants from the soil (Saleh et al, 1999). Sodium concentration plays a major role in evaluating the groundwater quality for irrigation because sodium causes an increase in the hardness of soil as well as a reduction in its permeability (Tijani 1994). High sodium can cause damage to the soil structure by making it compact and impervious by replacing the adsorbed calcium and magnesium. Sodium adsorption ratio (SAR) which determines the sodium or alkali hazard in water

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

used for irrigation is calculated by U.S.S.L. Staff (1954)

They proposed a diagram consists of a plot of specific conductivity (in micro-mhos/cm at 25Cº), which is a function of total dissolved solids concentration, against SAR. The water are divided into a classes C_1,C_2, C_3,…etc., which denote the conductance (C) and S_1, S_2, …etc., which denote the SAR (Table. 4). The comparison between the SAR of the samples and the U.S. Salinity Laboratory Staff classification indicate that; all the samples of shallow groundwater are plotted in S1 as good water class (Fig.13), which implies that there is no alkali hazard to crops on the study area. Most of groundwater samples fall in c2s1 and c3s1indcating the low sodium content and medium salinity nature of groundwater. This water can be used for irrigation on all crops.

Table (4) shows the average parameters of Irrigation water quality

Parameters	NA%	SAR	RSC
Min	37.18	1.2	-7.33
Max	56.59	3.74	-0.86
Average	46.55	2.35	-2.8

Sodium percentage (Na%)

Sodium percentage of groundwater samples was calculated by ((Raghunath,1987),

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

They proposed a diagram consists of a plot of specific conductivity (in micro- mhos/cm at 25Cº), which is a function of total dissolved solids concentration, against Na% (Wilcox 1955) diagram (Fig. 14). The plotting indicate that most of the groundwater samples were good to permissible for irrigation.

Residual sodium carbonate (RSC)

The residual sodium carbonate in a water sample is used to estimate the suitability of the sample for agricultural purposes. According to ***Eaton (1950)*** irrigation water will be suitable if RSC is negative and is unsuitable if it is positive. The term residual sodium carbonate RSC is defined as:-

$$RSC= (HCO_3+CO_3)-(Ca+Mg)$$

The comparison between Residual Sodium Carbonate (RSC) in groundwater with Eaton (1950) indicates that; Groundwater samples have a negative values table (4), this means that the groundwater is suitable for irrigation purposes.

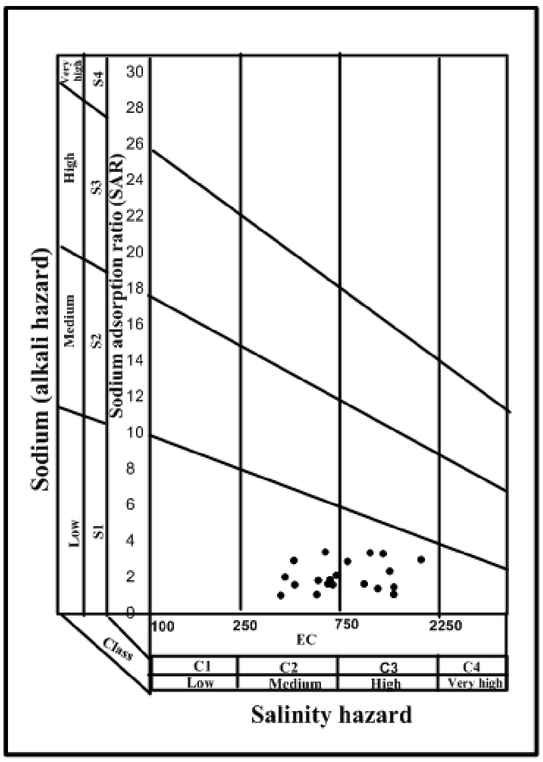


Fig.(13) Classification of groundwater samples for irrigation proposes according U.S. salinity staff method

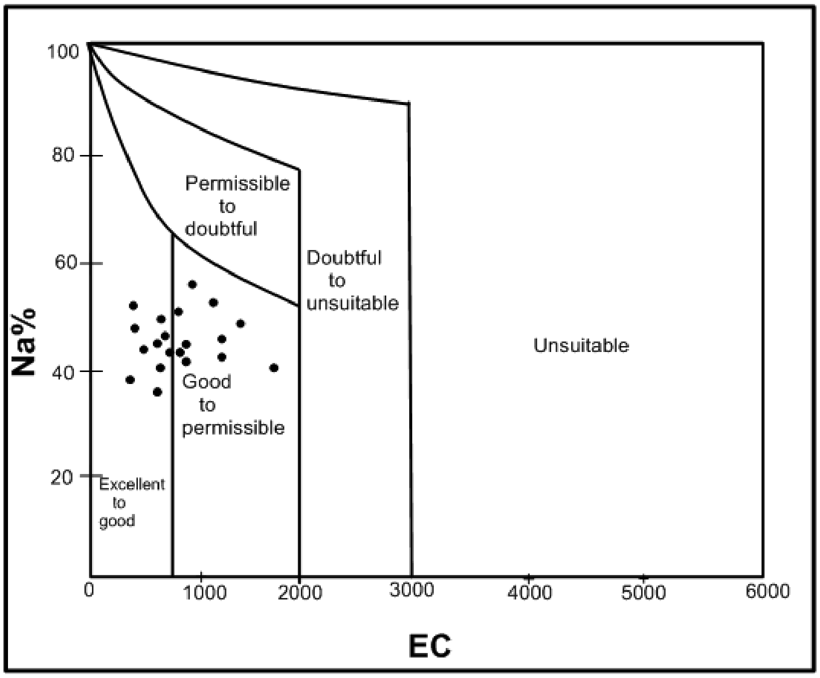


Fig. (14) Wilcox's classification of groundwater samples of Quaternary aquifer

CONCLUSION

The Quaternary aquifer is the main groundwater resource in the study area; it mainly consists of graded sand and gravels intercalated with clay and silt lenses. Generally, the groundwater flow in the study area is from southwest to northeast with some local deviations. The formation of groundwater depression due to heavy pumping is recorded at the northeast south of Ismailia canal (Manshiat Al-Abbasa and Al-Abbasa) at Al-Abbasa area. The aquifer is mainly recharged by downward infiltration from surface water either directly or indirectly, the direct recharge took place by direct seepage from the main irrigation Ismailia canal. Results indicate that groundwater in the study area are suffering from quality problems. The concentrations of sulphate, chloride, iron, Nickel and lead at the northeast of the study area (at At Tall Al Kabir, Al Abbasa and Kafer El Azzazi) exceed the permissible limits for drinking. The probable sources of high contents of pollutants are mainly due to infiltration of domestic, agricultural and industrial wastes arise from the development of human activities. The lowest contents of such pollutants noticed beside the Ismailia canal, reflecting the positive hydrochemical impact of this canal on groundwater quality. For agricultural purposes, the ground water in the study area is suitable for irrigation purposes in accordance with SAR, RSC and Na %.

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