Environmental Impact on Water Resources at the Northwestern Part of the Nile Delta, Egypt

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Abstract: Surface water and groundwater in the northwestern part of the Nile Delta is of vital importance for domestic, agricultural, and industrial water supply. The increases in population together with the agricultural and industrial development have resulted in increasing pollution of water resources. The main objective of the present study is to assess the environmental impact on the quality of water resources in the study area. To achieve that, surface water and groundwater samples have been analyzed for major ions, nitrates, and trace elements, in addition to detection of total and fecal coli-form bacteria. The distribution maps for different pollutants in groundwater are carefully studied. Results indicate that both surface water and groundwater in the study area are suffering from quality problems. The majority of the studied area are characterized by fresh water (TDS <1000 ppm) with low contents of Na, Cl, and SO_4 and the groundwater is suitable for drinking. High contents are recoded mostly at the northwestern portions as local polluted zones distributed within the area. This is referred to extensive withdrawing in the newly reclaimed areas in the northwestern portions and to the existence of local pollution sources resulted from the infiltration of domestic, agricultural and industrial wastes in the intensive populated area. The distribution of nitrate content in groundwater wells shows that the low concentration (<50 ppm) exist at the south western parts of the investigated area, whereas the maximum content (>50 ppm) exists at the east and the northern portions. The increase of nitrate is due to domestic conditions in highly urbanized areas and the use of fertilizers in the old land. The concentrations of trace elements (chromium, lead, nickel and zinc) in groundwater are within the acceptable limits for drinking and domestic uses. Iron, manganese, Cadmium and Copper contents are over the acceptable limits and this could be referred to fertilizer application, and sewage sludge disposal. The number (count/100 ml) of total coli-form and fecal coli-form bacteria are high in surface water and shallow groundwater. So, the surface water and shallow groundwater should be treated and sterilized before drinking.
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1. Introduction

Groundwater in study area is of vital importance for domestic, agricultural, and industrial water supply. The increase in population together with the agricultural and industrial development has resulted in increasing pollution of water resources. The study area lies in the northwestern part of the Nile Delta bordered by Rosetta Branch in the east, and the Cairo–Alex Desert Road in the west between longitudes 29º 58' and 30º 44' 20'' E and latitudes 30º 30' and 31º N (Fig. 1).

The study area is characterized by a low relief and slope gently from south to north and from west to east. The ground elevation varies between less than sea level at the north near Hush Isa and more than 50 m above mean sea level at the southwestern periphery nearby Cairo-Alex. desert road.

Topographic features cause variations in depth to groundwater and presence of water logged areas and environmental problems. The air temperature (T) exceeds 40 ºC during summer days or it may reach below zero during winter nights. The annual mean of the air temperature is around 20 ºC. The annual mean of the evaporation intensity (Ev.) decreases from south to north and from summer to winter influencing both groundwater and surface water quality, particularly where groundwater is close to the ground surface. The rainfall intensity (R.F.) effect on the surface and groundwater is negligible especially during summer. The 100-200 mm amount of rainfall may take place intermittently and in a short time.

The traditionally cultivated lands are predominated in the northeastern part of the study area. Reclaimed lands are present on the western fringes using surface water from El-Nubariya, El-Nasr, and El-Bustan canals. Groundwater, or conjunctive use of surface water with groundwater, is used for irrigation. Drainage water from open drains is partly reused for irrigation to cover the shortages of the irrigation water. Many of concentrated towns and villages with extensive population and small scale industries are present in the area. Generally, surface water system directed into large population densities and activated industrial areas. Untreated liquid wastes and effluents directly discharged into canals, drains and on land surface. Because of the small thickness of the clay cap, contaminated waste water infiltrates contaminating the groundwater in the aquifer.

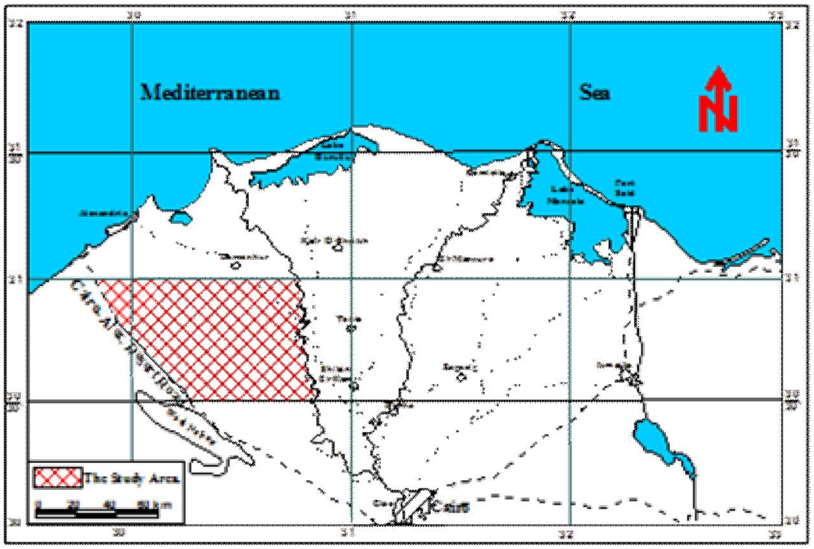

Fig. (1): Location Map of the Study Area.

2. Objectives and Methods

The main objective of the present study is to assess the environmental impact on the quality of water resources in the study area. To achieve this purpose, field and laboratory measurements carried out for the collected surface water and groundwater samples (Fig. 2). Both surface water and groundwater samples analyzed for major ions, nitrates, and trace elements, in addition to detection of total and fecal coli-form bacteria. The hydrogeological and hydrochemical data were processed by different software programs as Surfer, Aquachem…etc., besides construction of water level map of the Pleistocene aquifer, thickness map of the Holocene aquitard, hydrogeological cross sections and distribution maps for different pollutants in groundwater.

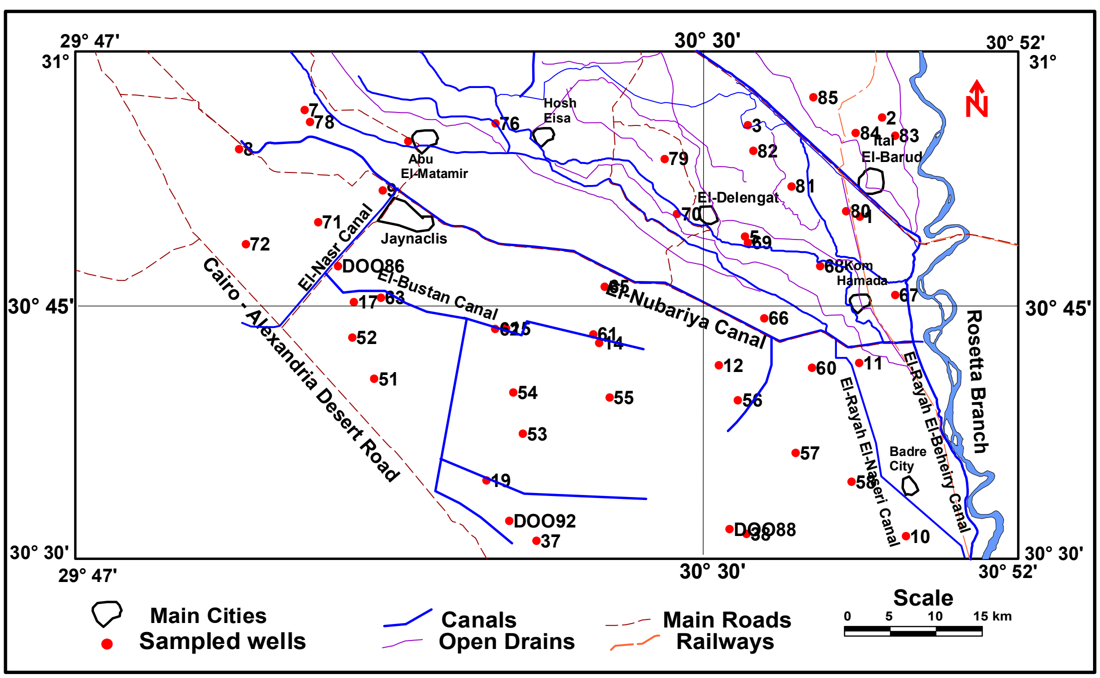

Fig. (2): Location Map of Surface Water and Groundwater Samples

3. Results and Discussions

3.1. Geology

The geology of the considered area and its vicinities have been discussed by several workers, among them are Sandford and Arkell (1939), Shata (1953, 1955, 1959 and 1961), El Fayoumy (1964), Attia (1975), El Ghazawi (1982), and Shedid (1989).). Generally, the Quaternary sediments belonging to the Pleistocene and Holocene mainly cover the study area, while Miocene and Pliocene sediments outcrop at the southwestern portions (Fig. 3). The lithostratigraphy of the area could be summarized from base to top as follows:

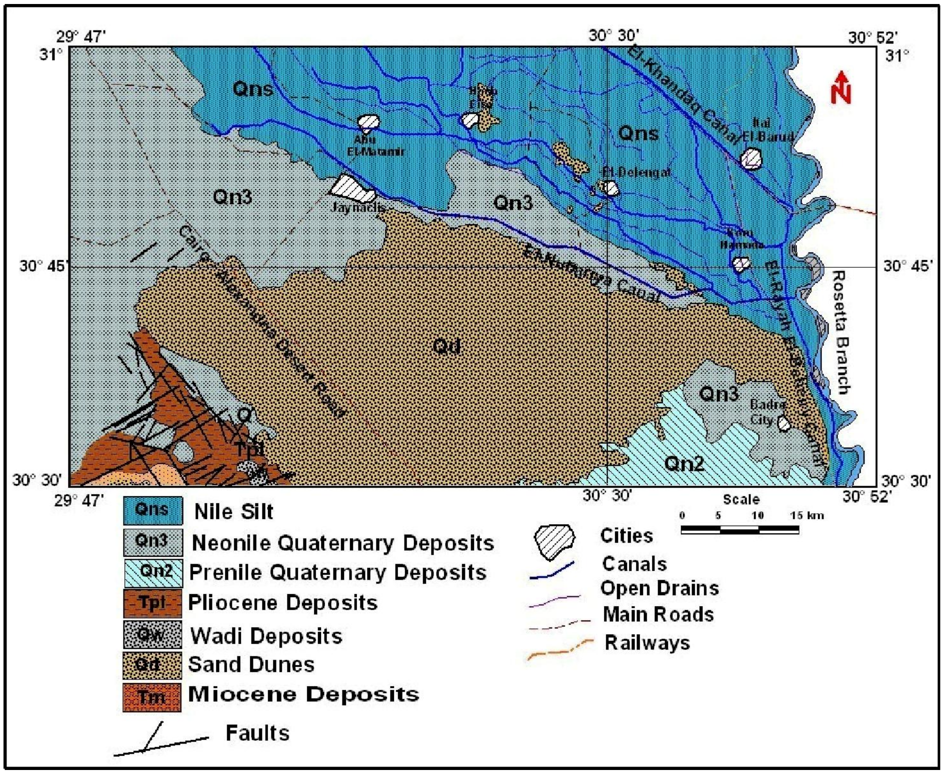

Fig. (3): Geologic Map of the Study Area and its vicinities (After EGSMA, 1981 and EGPCO/CONOCO, 1988).

1-The Miocene sediments are composed of thick clastic sequence carrying mixed fluviomarine fauna. It overlies the basalt of the Abu Roash and extends northward into the north western desert.

2-The Pliocene sediments are formed of clay, sand, gravelly sand with limestone interbeds. The Pliocene clay is overlain by the Quaternary deposits in the Nile Delta flood plain.

3-The Pleistocene sediments are exposed at the western parts of the studied area, while in the northeastern portions they are overlain by the Holocene Nile silt and clay and rest on the Pliocene clay. They are composed of sand and gravel intercalated with clay lenses. The Pleistocene sediments have a variable thickness, ranges between 300 min the eastern portions near Kom Hamada and 80 m near Cairo-Alexandria desert road.

4-The Holocene Nile silt and clay deposits are occupying the northeastern parts. Their thickness changes from place to place ranging from 0 to 25 m. Sand dunes belonging to Holocene age are found covering the middle and southern portions of the study area.

3.2. Hydrogeology

The hydrogeological conditions of the study area could be discussed under the following topics including surface water system and groundwater system.

3.2.1. Surface water system

The surface water system comprises Rosetta branch and a set of canals and a set of open drains (Fig.2). Generally, the surface water levels of canals increase in summer and decrease in winter in response to the water quantities entered these canals. The canals and drains are passing mainly through Nile silt and clay deposits of Holocene age. Locally, where the Nile silt and clay deposits disappeared, the canals and drains are passing through the Pleistocene sediment. Direct connection between surface water and groundwater exists.

The water levels in Rosetta branch varies from

5.56 m amsl to 3 m amsl, whereas the groundwater level in adjacent area varies from 7 m amsl to 5 m amsl. This means that Rosetta branch acts as drain for the groundwater in this area (Abd El Mogheith, 1975). It receives drainage water of El Rahawy and El Tahrir drains from the Western parts. Rosetta branch receives also sanitary water and industrial drainage water increasing pollution potential of the branch with time.

El Rayah El Beheiry and El Rayah El Nasseri are the main irrigation channels in the Western Nile Delts. They are starting from the Delta barrages extending northward to feed El Nubarya, El Mahmoudya and El Tawfikya channels. The water levels in El Rayah El Beheiry and El Rayah El Nasseri vary from 11.8 m amsl to 9.12 m amsl, whereas the groundwater levels in adjacent area vary from 11 m amsl to 5.5 m amsl. This indicates that the two canals operate as recharge sources for groundwater. In El Nubariya canal, the water level is about 8 m amsl at beginning in the southeastern area, but in the northwestern portion, the canal water level is about 4 m amsl. The groundwater level, adjacent to the canal, varies from 5 m amsl in the southeastern area to 10 m amsl in the northwestern area. Therefore, El Nubariya canal acts as recharge source in the southeastern area, whereas in the northwestern part acts as a discharge drain for groundwater. El Nasr canal was constructed in 1966 as entirely lined branch of El Nubariya canal at km 57.5 in the left bank. Water is lifted to E1 Nasr canal from 4 m amsl at El Nubariya canal to 32 m amsl by three electrical lifting stations. El Bustan canal was constructed in 1980 as a branch from El Nasr canal at km 12.700 on the left bank for irrigation water in El Bustan area.

3.2.2. Groundwater system

The Pleistocene (Quaternary) aquifer is the main water bearing formation in the study area. It is highly productive aquifer made up of successive layers of sand and gravels with occurrences of clay lenses. The bottom of the aquifer rests on a thick section of Pliocene clay (Fig. 4). The total thickness of the aquifer ranges between 400 m at the northeastern portions and 100 m near Cairo-Alexandria Desert Road to the southwest (Fig. 5). The groundwater exists mainly under free water table conditions (unconfined) to semi-confined where the clay cap covers the aquifer especially in the north and northeast of the study area with a maximum thickness of about 25 m (Fig. 6). The saturated thickness is about 100 m at the southern part and reaches the maximum thickness towards the north making waterlogged areas in low lands. Depth to water ranges from 3 m to 8 m in northeastern part and increases in the southwest direction to more than 20 m from ground surface near Cairo-Alex desert road (Fig. 7). Groundwater levels range from about 20 m amsl in the southwest to about 4 m amsl in the northeast part of the study area (Fig. 8). So, the groundwater flows mainly from the southwest towards the northeast direction. The main source of recharge is the seepage water from adjacent canals and infiltration from excess irrigation water. The main discharge of the Pleistocene aquifer takes place artificially through pumping of large number of production wells and naturally along the Rosetta Branch and discharge areas in low lands.

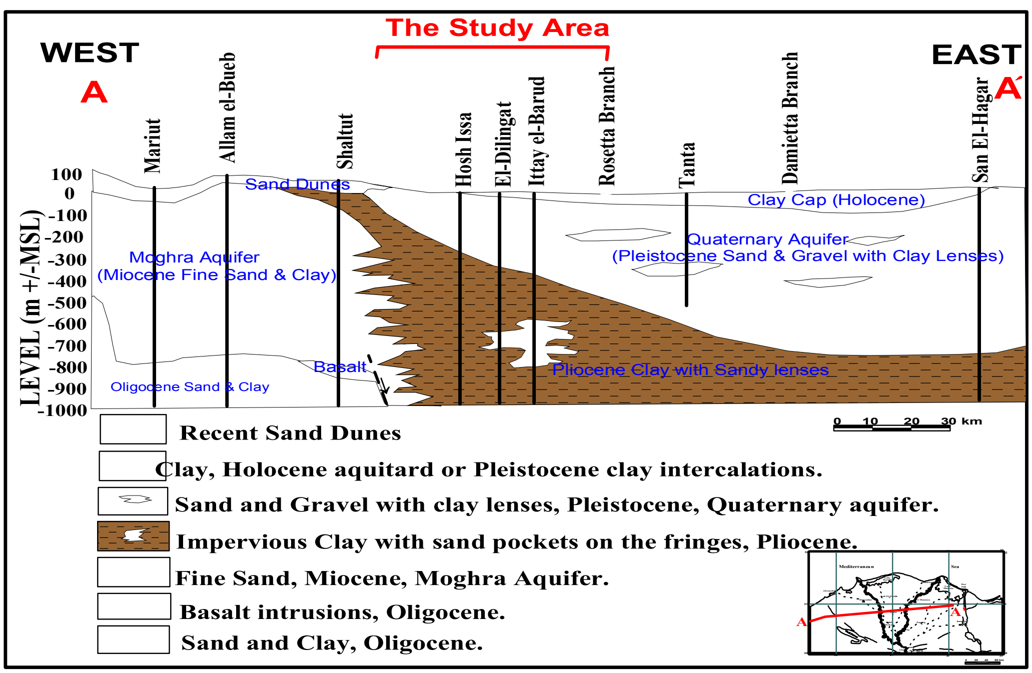

Fig. (4): Hydrogeological Cross Section (after RIGW/IWACO, 1998)

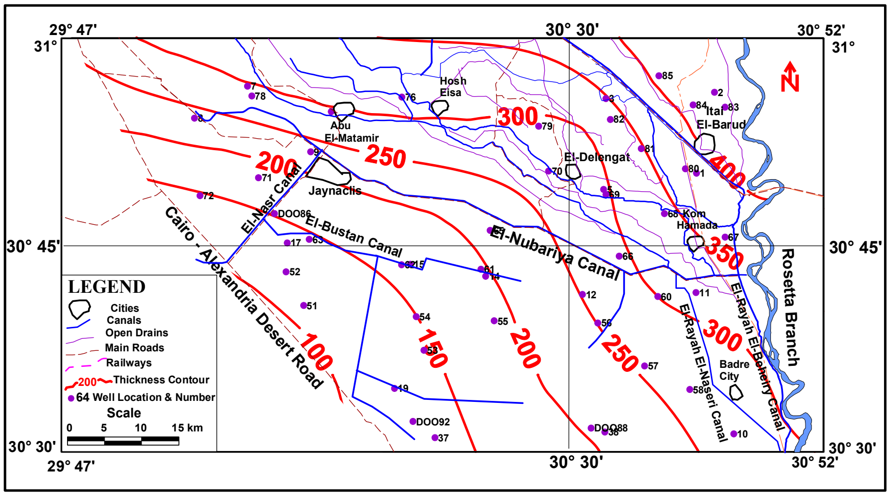

Fig. (5): Quaternary Aquifer Thickness (After Said, 1990 and RIGW/IWACO, 1998)

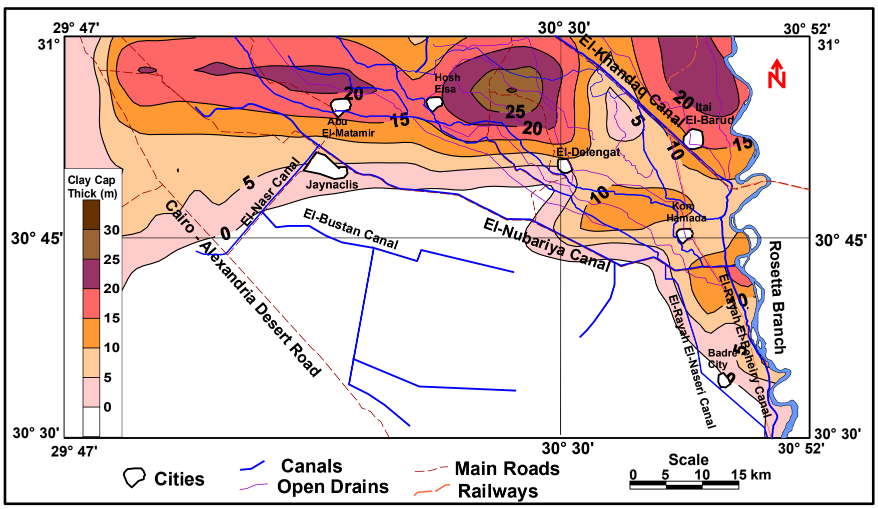

Fig. (6): Thickness Map of the Holocene Aquitard (After Said, 1990)

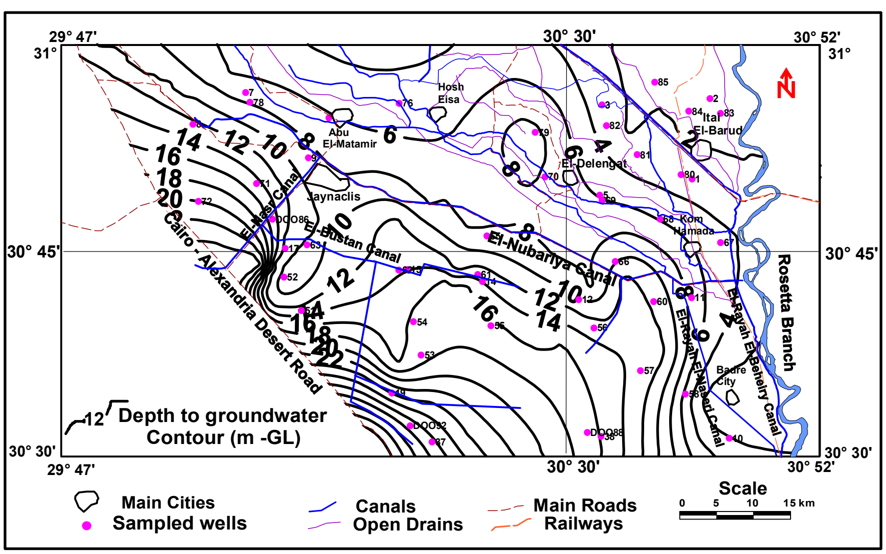

Fig.(7): Depth to Water Map of the Pleistocene Aquifer

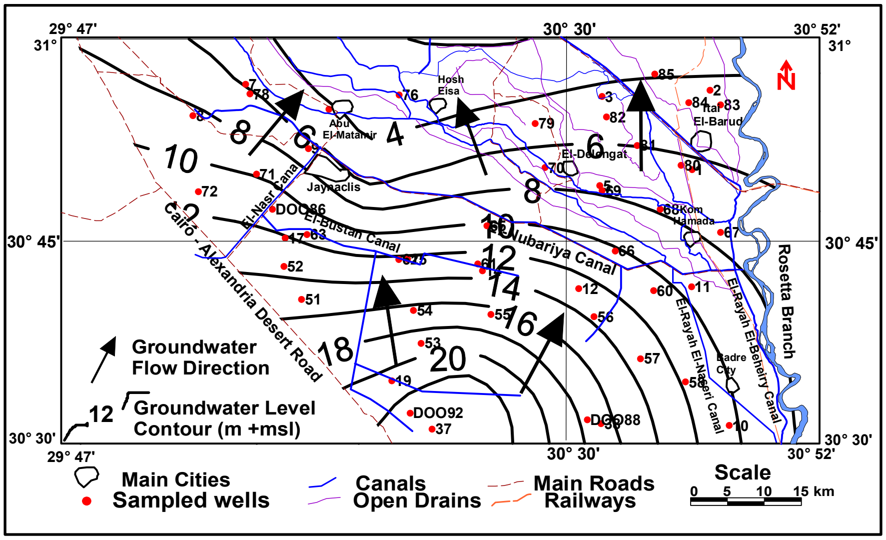

Fig.(8): Groundwater Levels Map of the Pleistocene Aquifer

3.3. Water Quality and Pollution

In order to assess the quality and pollution of groundwater and its suitability for different uses in the study area, chemical and microbiological analyses were performed for water samples from groundwater wells as well as from surface water canals and drains. The groundwater pollutants include inorganic pollutants, trace metals, nutrients and microbiological pollutants. The distributions of each pollutant are discussed for surface water and groundwater in addition to evaluation of water for drinking and irrigation based on the limits presented by the WHO (2004) and the Egyptian Ministry of Health (EMH, 2007) and the guidelines of FAO, 1985.

3.3.1 Surface water quality

Hydrochemical compositions of surface water indicate that the salinity ranges between 437 and 716 ppm in canals, and reaches 3406 ppm in drains (Table 1). The concentrations of trace elements (copper, chromium, lead, and nickel), and nitrate are within the permissible limits of drinking water. Some elements such as cadmium, iron and manganese show high concentrations in some canals and drains.

Table (1) Salinity and Ions Contents (ppm) in Surface Water Canals and Drains

Ions	Canals	Drains	Ions	Canals	Drains
TDS	437 - 716	3406	Sodium	65 - 178	620
Cl	58 - 96	802	Potassium	5 - 9	13
SO_4	42 - 65	751	Magnesium	10 - 15	99
HCO_3	152 - 345	793	calcium	21 - 42	328
NO_3	0 - 2	0.2	Nickel	0 - 0.002	0.001
Iron	0.12-0.482	0.344	Chromium	0.02 - 0.04	0.013
Manganese	0 - 0.65	0.192	Lead	0.012 - 0.016	0.038
Copper	0.36 - 1.19	0.049	Cadmium	0.035 - 0.075	0.001

Results of bacteriological analyses indicate that the number of total Coliform group reaches 140 MPN/100 ml and fecal Coliform reaches 20 MPN/100 ml in water samples collected from Hosh Isa Canal. The total Coliform group reaches 560 MPN/100 ml and fecal Coliform reaches 60 MPN/100 ml in water samples collected from drains.

3.3.2 Groundwater quality

3.3.2.1- Total dissolved salts

The groundwater samples classified as fresh to brackish water, where the total dissolved salts ranges between 333 and 2219 ppm with average of 843 ppm (Table 2). The areal distribution of salinity content in groundwater wells (Fig. 9) shows that the majority of the studied area is characterized by fresh water (TDS <1000 ppm) and the groundwater is suitable for drinking. High contents (>1000 ppm) are recorded at the northwestern portions due to extensive withdrawing in the newly reclaimed areas. This confirms the existence of local pollution sources resulted from the infiltration of domestic, agricultural and industrial wastes resulting in polluted zones (TDS >1000 ppm) and the water becomes unsuitable for drinking.

3.3.2.2. Major elements

1-The sodium content in groundwater wells varies from 35 to 658.72 ppm with an average 175 ppm (Table 2). The areal distribution of sodium content in groundwater wells (Fig. 10) shows that the majority of the area, specially in the eastern portion, is characterized by low sodium concentrations (<200 ppm) and the groundwater is suitable for drinking. High concentrations of sodium (>200 ppm) are recorded specially at the northwestern portions where the groundwater becomes unsuitable for drinking.

Table (2): Descriptive Statistics for Different Constituents in Groundwater in the Study Area and the Standard Values for Drinking and Irrigation Water (ppm)

Parameters	**Number of Samples**	**Minimum**	**Maximum**	**Mean**	**Standard deviation**	**Drinking water critical values (EMH, 2007)**	**Irrigation water standard (FAO, 1985)**
EC	52	0.5	**3.5**	1.2	0.6	--	--
TDS (ppm)	52	333	**2219**	843	389	1000	2000
pH	52	6.88	8.65	7.86	0.40	6.5-8.5	6.5-8.5
K^+	52	0.18	14.00	5.62	2.70	--	--
Na^+	52	35.00	**658.72**	175.00	137.13	200	--
Mg^{++}	52	6.24	95.00	30.39	17.42	150	--
Ca^{++}	52	12.00	151.80	51.39	29.24	200	--
Cl^-	52	50.00	**990.00**	230.80	213.00	250	355
SO_4^{--}	52	13.80	**260.00**	108.02	66.60	250	--
HCO_3^-	52	96.00	488.00	237.70	76.88	--	520
CO_3^{--}	52	0.00	45.00	2.48	8.95	--	--
NO_3^-	52	2.60	**83.00**	42.50	18.90	50 (as NO3)	135
NO_2	14	0.00	0.48	0.06	0.14	1	--
SAR	52	0.91	**29.50**	5.21	4.93	--	3-9
HARDNESS	52	63.62	**560.81**	253.41	98.90	500	--
RSC	52	0.00	**22.38**	**3.50**	5.47	--	2.5
Fe^{++}	52	0.011	**4.200**	**0.643**	0.779	0.3	10
Mn^{++}	52	0.000	**0.821**	**0.162**	0.195	0.1	10
Zn^{++}	52	0.001	1.500	0.704	0.477	5	10
Pb^{++}	52	0.001	0.020	0.006	0.006	0.05	10
Cd^{++}	52	0.000	**0.710**	**0.052**	0.153	0.003	0.05
Cr^{++}	52	0.008	0.045	0.041	0.008	0.05	1
Cu^{++}	52	0.021	**1.895**	0.420	0.612	1	5
Ni^{++}	52	0.000	0.580	0.085	0.099	-	2
Total Coliform (MPN/100 ml)	46	0	**300**	**74**	89	2	--
Fecal Coliform (MPN/100 ml)	44	0	**72**	**4**	11	0	--

2-The chloride content in the study area ranges between 50 to 990 ppm with an average 230.8 ppm (Table 2). The areal distribution of chloride content in groundwater wells (Fig. 11) shows that the majority of the area, specially the eastern portion, is characterized by low chloride concentrations (<250 ppm) and the groundwater is suitable for drinking. High concentrations of chloride (>250 ppm) are recorded at the northwestern portions and in two local zones classified as polluted zones and the water is unsuitable for drinking.

3- The sulfate content in groundwater wells varies from 13.8 to 260 ppm with an average 108 ppm (Table 2). The areal distribution of sulfate content in groundwater wells (Fig. 12) shows that most of the area is characterized by low sulfate concentrations (<250 ppm) and the groundwater is suitable for drinking.

The presence of large concentrations of these ions in water may affect human health. The discharge of human, animal, industrial wastes and irrigation return flows may add substantial quantity of sodium, chloride and sulfate to groundwater. Consumption of water with high concentrations of sodium may affect persons with cardiac difficulties and hypertension. High concentrations of sulfate and chloride ions may produce objectionable taste and act as laxative on certain users (Hem, 1985 and Probe *et al.,* 1999).

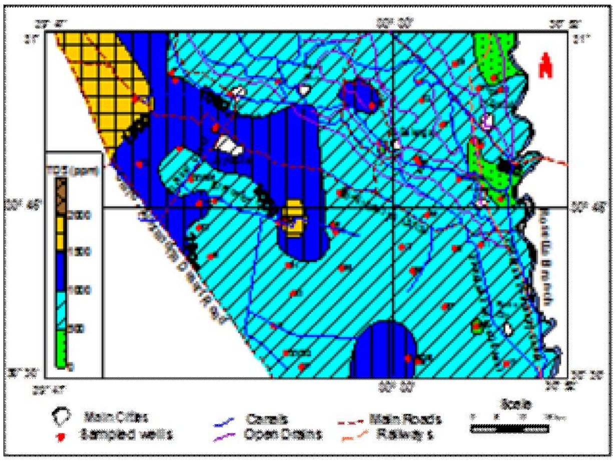

Fig.(9) Distribution of salinity in groundwater

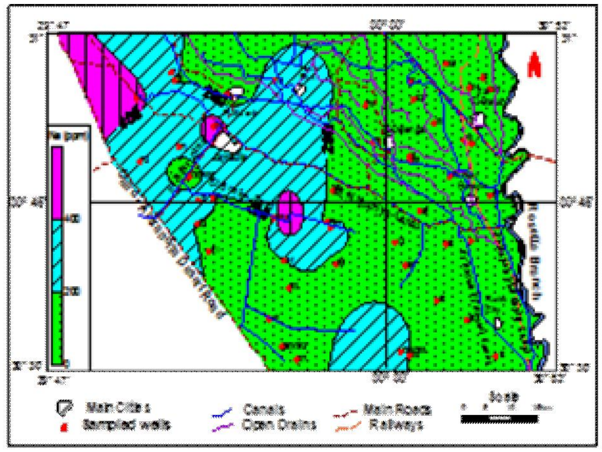

Fig.(10) Distribution of Sodium in groundwater

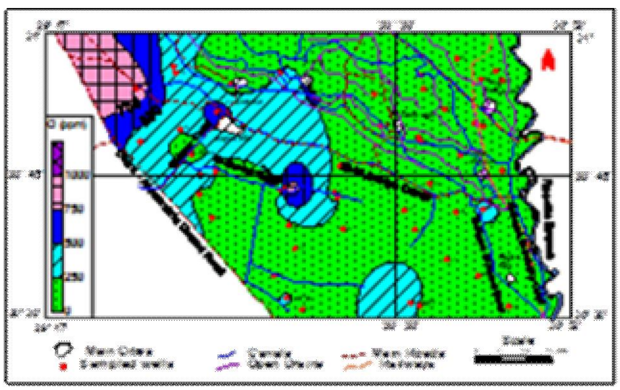

Fig. (11) Distribution of chloride in groundwater

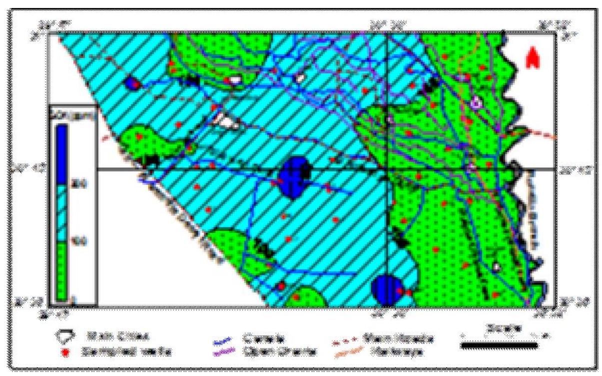

Fig. (12) Distribution of Sulfate in groundwater

3.3.2.3. Nutrients

The health effects related to contamination by nitrogen compounds include the "methanoglobinemia" that is a type of blood disorder in which oxygen transport in young babies or unborn fetuses is impaired or the possibility of forming cancer-causing compounds as nitrosamines after drinking contaminated water (Craun, 1984).

Nitrate increases in groundwater due to agricultural activities and disposal of sewage on or beneath the land surface. Through the process of nitrification, NH_4^+ is converted into NO_3^- by oxidation.

Nitrate content in the study area ranges between 2.6 to 83 ppm (as NO_3) with an average 42.5 ppm (Table 2). The distribution of nitrate content in groundwater wells (Fig. 13) shows that the low concentration (<50 ppm) exist at the southwestern parts, whereas the maximum contents (>50 ppm) exist at the east and the northern portions of the study area. The increase of nitrate in the north and east direction is due to domestic conditions in highly urbanized areas and the use of fertilizers in the old land. The decrease of the nitrate in the southwestward direction may be due to the denitrification at greater depth by bacteria where the oxygen in nitrate ions is consumed by denitrifying bacteria.

3.3.2.4. Trace elements

Besides the major elements, minor and trace elements are of special and considerable importance for studying groundwater pollution because minute amounts of dissolved heavy metals are effective and of special interest. Many of heavy metals in groundwater are attributed to dissolution from minerals in the sediments through which groundwater passes especially under reducing conditions. At many industrial sites, soil and groundwater is polluted with heavy metals or other chemicals due to leakage and spilling.

Based on the limits presented by WHO (2004) and the Egyptian Ministry of Health (EMH, 2007), the concentrations of trace elements (chromium, lead, nickel and zinc) in groundwater are within the acceptable limits for drinking and domestic uses. Iron, manganese, Cadmium and Copper contents are over the acceptable limits. Excess absorbed iron is being stored primarily in the liver, bone marrow and spleen resulting in many dangerous diseases (WHO, 1984). So, the drinking water must be treated for eliminating these elements before use. High manganese contents cause stain laundry and objectionable in food processing, dyeing, and certain other industrial processes (Heath, 1987).

The concentration of iron in the study area ranges between 0.011 and 4.2 ppm with an average 0.643 ppm which is relatively high for drinking water but suitable for irrigation. The distribution map of iron contents in groundwater wells (Fig. 14) shows that the majority of the area characterized by high iron concentrations (>0.3 ppm). Low contents (<0.3 ppm) are recorded as local zones scattered in the area. Iron is probably produced from iron oxide coating quartz sand grains of the Pleistocene aquifer sediments.

The manganese contents in the study area range between 0.0 to 0.821 ppm with an average 0.162 ppm. The distribution map of manganese contents in groundwater wells (Fig. 15) shows that the majority of the area characterized by high manganese concentrations (>0.1 ppm). Low contents (<0.1 ppm) are recorded as local zones scattered in the area.

Cadmium contents in the study area range between zero and 0.71 ppm with an average 0.052 ppm. The distribution map of cadmium contents in groundwater wells (Fig. 16) shows that the majority of the area characterized by low cadmium concentrations (<0.003 ppm). High cadmium contents (> 0.003 ppm) are recorded as local zones scattered in the area. The increase of cadmium could be referred to fossil fuel use, fertilizer application, and sewage sludge disposal.

Copper contents in the study area range from 0.021 to 1.895 ppm with an average 0.42 ppm. The distribution map of copper contents in groundwater wells (Fig. 17) shows that the majority of the area characterized by low copper concentrations (<1 ppm). High copper contents (>1 ppm) are recorded as local zones scattered in the area. The presence of high copper concentrations could be usually attributed to industrial wastes or agricultural sources for the control of algae and other aquatic growths.

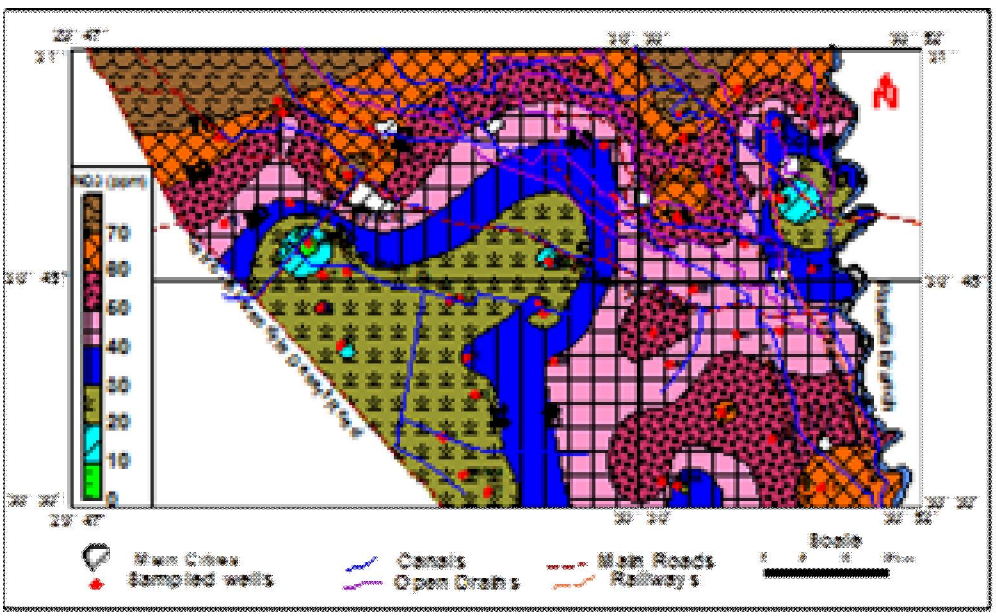

Fig. (13) Distribution of Nitrate in Groundwater in the Study Area

3.3.2.5. Bacteriological analyses

The results of bacteriological analyses for groundwater samples (Table, 2) indicate that the total Coliform bacteria vary from 0 to 300 MPN/100 ml, while the fecal Coliform bacteria vary from 0 to 72 MPN/100 ml. Generally, it is possible to conclude that the number of bacteria decreases with depth, the surface water is highly polluted, and the deeper groundwater shows less pollution with bacteria than the shallow groundwater. The absence of a covering clay layer above the aquifer and a high groundwater table result in intensive movement of microorganisms through soil especially in extensively populated areas.

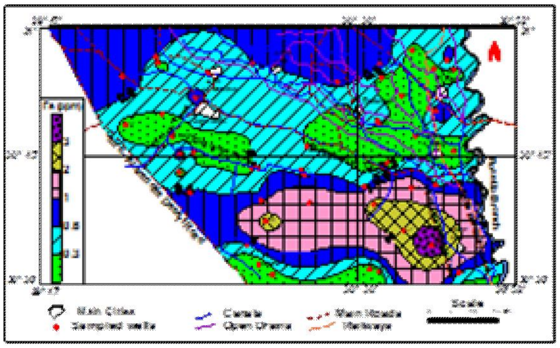

Fig. (14) Distribution of Iron in groundwater

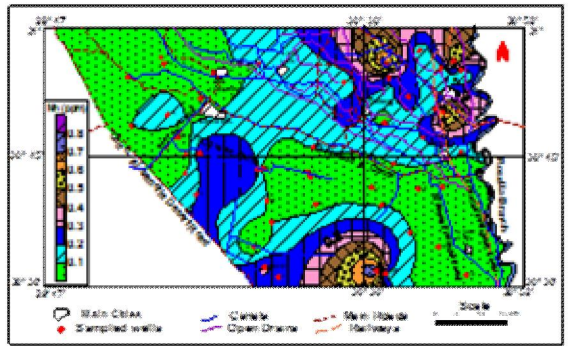

Fig. (15) Distribution of Manganese in groundwater

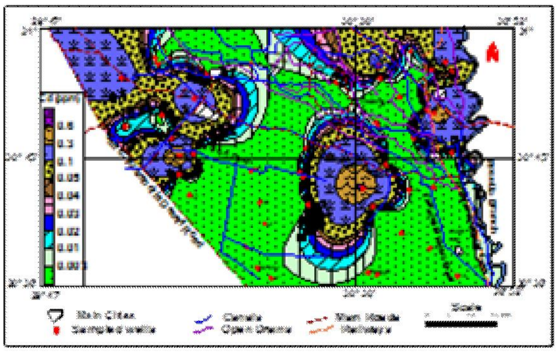

Fig. (16) Distribution of Cadmium in groundwater

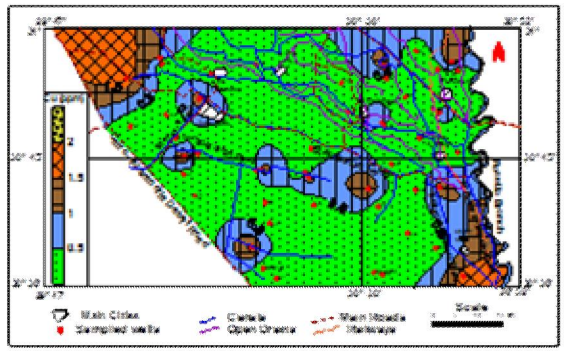

Fig. (17): Distribution of Copper in groundwater

4. Conclusions and Recommendations

Surface and ground water in the study area are vital for domestic, agricultural, and industrial water supply. The increase in population with the agricultural and industrial development has resulted in increasing pollution of water resources. The Pleistocene (Quaternary) aquifer is the main water bearing formation in the study area with a total thickness ranging between 300 m near Kom Hamada and 100 m near Cairo-Alexandria Desert Road to the southwest. The groundwater flows mainly from the southwest towards the northeast direction. The main source of recharge is the seepage water from adjacent canals and infiltration from excess irrigation water. The main discharge of the Pleistocene aquifer takes place artificially through pumping of large number of production wells and naturally along the Rosetta Branch and discharge areas in low lands.

Chemical and bacteriological analyses of water samples indicate the following results:

1- The surface water salinity ranges between 437 and 716 ppm in canals, and reaches 3406 ppm in drains. The concentrations of trace elements (copper, chromium, lead, and nickel), and nitrate in surface water are within the permissible limits of drinking water. Some trace elements such as cadmium, iron and manganese show high concentrations in some canals and drains.

2- The majority of the studied area characterized by fresh groundwater (TDS <1000 ppm) with low contents of Na, Cl, and SO4 and the groundwater is suitable for drinking. High contents are recoded at the northwestern portions as local polluted zones distributed within the area. This is referred to extensive withdrawal in the newly reclaimed areas in the northwestern portions and to the existence of local pollution sources resulted from the infiltration of domestic, agricultural and industrial wastes in the intensive populated areas.

3-The low nitrate contents in groundwater wells (<50 ppm) exist at the south western parts of the study area, whereas the maximum contents (>50 ppm) exist at the east and the northern portions. The increase of nitrate in the north and east direction is due to domestic conditions in highly urbanized areas and the use of fertilizers in the old lands.

4-The concentrations of trace elements (chromium, lead, nickel and zinc) in groundwater are within the acceptable limits for drinking and domestic uses. Iron, manganese, cadmium and copper contents are over the acceptable limits. This could be referred to fertilizer application, and sewage sludge disposal.

5-The results of bacteriological analyses for groundwater samples indicate that the total Coliform bacteria vary from 0.0 to 300 MPN/100 ml, while the fecal Coliform bacteria vary from 0.0 to 72 MPN/100 ml.

The following recommendations must be taken in mind to avoid dangerous impacts of water pollution on different hygienic, agricultural, and/or industrial development plans:

- The treatment of the drinking water is a very important process and must be applied properly and completed by specialists after knowledge with the constituents of water and the hydrochemical action. Electro-dialysis method could be used for removing trace elements, and water sterilization with ozone or chlorination can be used to remove microbiological pollution.
- Sewerage systems must be implemented at all population areas including all towns and villages. This will encourage to advice the people to avoid the use of septic tanks.
- Open drains must be used only for irrigation water drainage, not for industrial wastes and sewage disposal.
- Wastewater of factories must be treated to be in standard limits of effluents before its drainage. Projects must be planned to use solid wastes and sewage in different industries such as fertilizers.
- More studies are recommended to assure the hydrogeologic connection between different groundwater aquifers in the Western Nile Delta regions. More data about wells encountering different aquifers are required to study more about groundwater in these regions.

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