CHAPTER (VI)
SUMMARY AND CONCLUSIONS

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The area under consideration lies west of the Nile Delta. It is bounded by 29° 50' and 30° 13' latitudes N and 30° 45', 31° 14' longitudes E.

1. Geomorphology

The study area.is classified into four landforms namely, the alluvial plains, the structural plains, the southern tableland and the shifting sand.

1. The alluvial plains extend between the Rosetta Branch and the eastern fringes of the structural plains. These plains are classified into young and old alluvial plains.
2. Structural plain consists of a number of alternating ridges and depressions.
3. The southern tableland is represented by El Hadid plateau and Qaret El Haddadein plateau.
4. The shifting sand is represented by a series of elongate sand dunes known as El Heneishat sand dune chains located to the south of the area.

2. Geology

The exposed rocks in the studied area ranges in age from Late Cretaceous to Recent. The stratigraphic succession from base to top is described as follows:

The Upper Cretaceous rocks ranges in age from Cenomanian to Senonian. The Cenomanian rocks are exposed at Abu Roash area.

The Tertiary rocks include Mokattam Formation (Middle Eocene) and El Maadi Formation (Upper Eocene). Oligocene sediments consist of red, violet and yellow ferruginous sandstone and sands, sometimes with gravel and occasionally indurate into quartzite (Qatrani Formation). Abu Roash Oligocene sandstones are overlain by some dissected basaltic sheets, which are belonging to Gebel Qatrani volcanics (Upper Oligocene to Lower Miocene age). The Miocene rocks have been represented by two facies: Gebel El Khashab red beds in Abu Roash area along Cairo direction and El Moghra Formation which is mainly exposed in Wadi El-Farigh along Alexandria direction. Three members were recognized within the Moghra Formation, these are El Raml Member, Bait Owian Member and Monqar El Dowi Member. The Pliocene sediments divided into two main facies, marine (Kom El Shellul, El Hagif Formation) and non-marine.

The Quaternary unconsolidated deposits cover the major part of the study area. These deposits are mostly composed of fluvial sediments prevailed during the Pleistocene and early Holocene. The fluvial deposits are restricted to the Nile Delta area, while the aeolian sediments characterized most of the landscapes of the recent times.

Folds, faults, unconformities, and basaltic intrusions mainly affect the study area. These types of structural elements are the most important factors influencing the groundwater conditions in the area.

3. Hydrogeology of the study area

In discussing the hydrogeological conditions of the study area, the following topics will be emphasized: -

3.1 Surface water system

3.2 Groundwater system

3.1 Surface water system:

The surface water system in the study area comprises the Nile River, the Rosetta Branch and the irrigation canals and drains. The Nile River increased by 30 cm after utilization of the High Dam. The Rosetta Branch is considered as discharging area for the groundwater, at El Qatta area. From the study of surface water and groundwater relationship, it is concluded that the main source of recharge to the aquifer is from the Nile River.

3.2 Groundwater system:

The Quaternary (Pleistocene) aquifer (Nile Delta aquifer), the Lower Miocene aquifer (Moghra aquifer) and the Oligo – Miocene aquifer are the main aquifers in the investigated area.

3.2.1 The Quaternary (Pleistocene) aquifer:

The Quaternary (Pleistocene) aquifer occurs to the east of Cairo – Alex. Desert road. It is bounded to the west with the Miocene outcrops and to the south with the Mesozoic and Cenozoic exposures lying to the north of Abu Roash locality. It is mainly composed of fluviatile graded sand and gravel intercalated with clay lenses, capped by silty clay (5 to 15 m thickness). Its thickness decreases to the south and southwest reaching less than 80 m near Cairo-Alexandria Desert Road. The groundwater level ranges between +11 m and +15 m. The direction of groundwater flow is towards southwest. (Fekry, 1993). According to Gomaa (1994), the general trend of water flow is due west and locally towards northwest. The main discharge of the Quaternary (Pleistocene) aquifer takes place artificially through pumping of high quantity of water used for irrigation and domestic uses. The transmissivity values ranges between 51.9 m^2/hr at the southern part and 121.75 m^2/hr in the northern part, therefore the aquifer is classified as very highly potential aquifer. The hydraulic conductivity of this aquifer ranges between 1.730 and 5.04 m/hr. The storage coefficient ranges from 0.0005 to 0.005.

3.2.2 Lower Miocene Aquifer (Moghra aquifer):

The Lower Miocene aquifer (Moghra aquifer) extends westward to the Moghra Depression. This aquifer is mainly composed of fluviatile and fluvio-marine coarse sand and sandy clay, clay interbeds with vertebrate remains and silicified wood. The thickness reaches about 75 m in the eastern area, 150 m in Wadi El Farigh area, 250 m at Wadi El Natrun area. The groundwater level in the Lower Miocene aquifer varies between +10 m at the border with the Quaternary (Pleistocene) aquifer to about – 60 m at El Qattara depression in the west with hydraulic gradient of about 20 cm/km. The regional groundwater flows are towards the west and southwest. This means that it is recharged directly from the Quaternary (Pleistocene) aquifer. The discharge takes place through the extraction from the wells in Wadi El Farigh and along Cairo-Alexandria Desert Road.

3.2.2.1 Hydrogeological problems at Tabark area

Tabark area (Located west of Cairo-Alexandria Desert Road at Km 56) represents a part of Wadi El Farigh, where the Lower Miocene aquifer is well represented and the groundwater plays an essential role for satisfying water demands. During the last few years, a sudden increase in the demand for irrigation water has been arisen due to intensification of cultivation. The people have now over-pumping the aquifer to meet water requirements.

From the hydrogeological cross sections, it is concluded that the Lower Miocene aquifer is hydraulically connected with the underlying

Oligocene aquifer in this portion, where both aquifers come in contact with each other as result of faulting. The depth to water ranges between 87- and105 m. The water level ranges between –12.75 and 3.25m. The transmissivity ranges between 46.9 and 855.3 m^2/hr, which indicates a very high potentiality. The calculated values of hydraulic conductivity, varies from 0.24 to 4.65 m/hr.

Excessive withdrawals of groundwater from wells cause a decline in water levels, due to increasing of well loss and aquifer loss, consequently decreasing of specific capacities and efficiencies of such wells.

The results of selected step drawdown tests, which were executed by the Arab Constructing Company, are re-evaluated by the author using GWW Software. It can be concluded that, The well loss increases (ranged between 0.01 and 4.36), specific capacity (ranged between 14.48 and 110.76) and well efficiency (ranged between 52.3% and 100%) decreases with increasing pumping rate (ranged between 24 m^3/hr and 151.72 m^3/hr). This problem is more pronounced in well nos.9M, 12M and 14M. Proper well design and suitable production rate can minimize well-loss, increases specific capacity and well efficiency.

3.2.3 The Oligo-Miocene aquifer:

The Oligo-Miocene aquifer extends from the south of the study area, at Wadi El Lulu and Wadi El Samya, to the northwest of Gebel El Mansouria and Qaret El Haddadein. This aquifer is mainly composed of sands and gravels with clay interbeds as well as a thin limestone band at the base. These deposits are covered at the top by the basaltic sheets of an average 30m thick. The groundwater exists under confined conditions, where its piezometric level exists at nearly 3m above sea level, and the saturated thickness is more than 60m. The groundwater of Wadi El Lulu may originate from the rainwater of the recent and paleo periods. The discharge takes place through well Field in Green Belt around Six of October City.

3.2.3.1 Hydrogeological problems at Green Belt around Six of October City

This Belt is constructed to protect the city from dusty winds and reuse treated sewage water in the irrigation woody trees and desalinated water in cultivation vegetables and fruits, construction and drinking purposes. The thickness of Oligo-Miocene aquifer ranged between 80.5 and 182 m and water level ranged between – 2 and 12.5 m. The depth to water ranges between 128 and 199.5 m. The transmissivity, T, value ranges between 0.76 and 60.39. The Oligo-Miocene aquifer is varied from low potentiality to very highly potentiality. The hydraulic conductivity ranged between 0.005 and 0.4 m/hr. The results of selected step drawdown tests, which were executed by the Arab Constructing Company, are re-evaluated by the author using GWW Software. It can be concluded that, The well loss increases (ranged between 0 and 75.12), specific capacity (ranged between 0.22 and 50.82) and well efficiency (ranged between 35.5% and 100%) decreases with increasing pumping rate (ranged between 6.5 m^3/hr and 144 m^3/hr. This problem is more pronounced in well nos. 8S, 11S and 12S. Proper well design and suitable production rate can minimize well-loss, increases specific capacity and well efficiency.

However, brine water as waste product from desalination, will be mixed by groundwater to:

a. Dilute water concentration.

b. To be used in closed lake system for shrim farms.

c. To join water streems in create water fun in the area.

d. Some of it will be used in extracting economic salts.

4. Hydrogeochemical aspects of surface water and groundwater in the study area

In discussing the Hydrogeochemical conditions of the study area, the following topics will be emphasized:

4.1 Hydrogeochemistry of surface water in the study area

4.2 Hydrogeochemistry of groundwater in the study area

4.1 Hydrogeochemistry of surface water in the study area:

The salinity content of the main canals (Nile River, Rosetta Branch, El Rayah El Beheri, El Rayah El Naseri, Nahya Canal and Mansouria Canal) ranges between 235 and 553 ppm. The electrical conductivity ranges between 360 and 831 µs/cm. The water samples are alkaline in reaction, where the pH value varies from 4 to 7.8. The ionic concentration of bicarbonate is the dominant and followed by chloride and sulphate. Among the cationic concentrations, the calcium or sodium ion prevails. Hydrochemical parameter (Na%, RSC and SAR) reveals that the surface waters of the main canals are good for irrigation.

The salinity content of the main drains (El Moheet drain and Abd El-Aal drain) ranges between 632 and 2521 ppm. The electrical conductivity ranges between 963 and 3878 µs/cm. The water is alkaline in reaction, where the pH value ranges between 8.5 and 8.6. The ionic concentration of bicarbonate is the dominant and followed by chloride and sulphate. Among the cationic concentrations, sodium ion prevails and followed by calcium. The hydrochemical parameters (Na%, RSC and

SAR) reveal that the surface waters of the main drains are good for irrigation.

The salinity content of the sewage station ranges between 433 and 1138 ppm. The electrical conductivity ranges between 666 and 1750µs/cm. (pH value is 8). The ionic concentration of bicarbonate is the dominant and followed by chloride and sulphate. Among the cationic concentrations, sodium is the dominant and followed by magnesium and calcium. The Hydrochemical parameters, (Na%, RSC and SAR) reveals that the water is good water for irrigation.

4.2 Hydrogeochemistry of the Quaternary (Pleistocene) aquifer:

The salinity in groundwater of the Quaternary (Pleistocene) aquifer in both shallow and deep wells ranges between 616 and 1936 ppm and from 344 to 1246ppm, respectively. The salinity distribution in both shallow and deep wells indicates that the salinity increases from east to west. However, local anomalies in water salinity are detected (e.g. El Oweina village,. El Motamedeya, Safet El Laban, Nekla, Burtus, and Ausim shallow wells). These local variations are coincident in both shallow and deep wells and confirm the good hydrochemical connection between shallow and deep groundwater and advocate the existence of local pollution sources resulted from the infiltration of domestic, agricultural and industrial wastes.

The potassium concentration in shallow wells ranges from 7.5 to 83ppm and from 2.9 to 87.4ppm deep wells, respectively. The distribution of potassium in groundwater shows a good similarity in its content in both shallow and deep wells.

The sodium content in shallow wells, ranges between 55.6 and 332 ppm, whereas it varies from 26.3 to 224.2 ppm in deep groundwater wells. The distribution of sodium ion in shallow wells show local polluted zones at Ausim, El Motamedeya and El Oweina (>200 ppm). The sodium content profiles show the conformable relationship between sodium content in both shallow and deep groundwater wells and the presence of local pollution sources.

The magnesium concentration in shallow wells ranges between 25.2 and 109.5 ppm, whereas, in deep wells it ranges between 12.6 and 59 ppm. The magnesium distribution in shallow and deep wells show the presence of local zones of high concentrations but, the magnesium content still below the excessive limits for drinking.

Calcium content in groundwater of the Quaternary (Pleistocene) aquifer ranges between 54.4 and 170 ppm in shallow wells, whereas, in deep wells it ranges between 33.3 and 140.2 ppm. The calcium distribution in groundwater in shallow and deep wells show the presence of local zones of high concentrations but, the calcium content still below the excessive limits for drinking. The calcium profiles show a good correlation in calcium contents between shallow and deep wells.

The chloride content in groundwater of the Quaternary (Pleistocene) aquifer ranges between 30 and 700 ppm and from 28 to 360 ppm in both shallow and deep wells, respectively. The distribution of chloride in shallow groundwater wells shows the existence of wide local polluted zone (>250 ppm) include El Oweina village, Ausim, Burtus and El Motamedeya. The distribution of chloride content in deep groundwater wells show polluted zone at El Oweina village and at the south of the study area.

The sulphate content in groundwater of the Quaternary (Pleistocene) aquifer ranges between 43 and 567 ppm in shallow wells. In deep wells, the sulphate content varies from 23 to 338 ppm. The sulphate distribution in shallow wells show the presence of local zones of high concentrations (> 250 ppm) at El Oweina village, Ausim and El Motamedeya. These local zones have great effect on its content in deep wells at the same sites. This also confirms the existence of local pollution sources. The sulphate content in deep wells shows high sulphate content (> 250 ppm) are noticed at El Oweina village. The sulphate profiles also illustrate the local influences on groundwater and again confirm the existence of local pollution sources in the study area.

The bicarbonate content in the groundwater of the Quaternary (Pleistocene) aquifer ranges between 146 and 659 ppm in shallow wells and varies from 146 to 339 ppm in deep wells. The distribution of bicarbonate content in shallow wells shows the high bicarbonate content and the presence of local variations advocates the existence of local pollution sources. Also the bicarbonate content in deep wells show the existence of local polluted zones (HCO_3 ranges from 300 to 400 ppm) around El Oweina village and El Motamedeya and extend toward the south conformable with that of shallow wells.

The Hydrochemical Coefficients of the Quaternary (Pleistocene) aquifer includes rNa/rCl, r(K+Na)-rCl]/rSO_4, [rCl-r(K+Na)]/rMg and rCl/r(CO_3+HCO_3). The ratio rNa/rCl is more than unity and generally varies between 1.06 and 2.45, which indicates the continental origin of the groundwater. In some samples, it varies between 0.4 (11P Nahya) and 0.95 (28P El Mansouria), which indicates groundwater pollution due to mixing with infiltrated sewage water. In shallow wells of the Quaternary (Pleistocene) aquifer, 53.33% of water samples have Na_2SO_4 water type and 20% have $NaHCO_3$ water type. In deep wells, 53.33% of water samples have Na_2SO_4 water type, whereas 20% have $NaHCO_3$ water type, which reflects the meteoric origin of groundwater. In shallow wells of the Quaternary (Pleistocene) aquifer, 13.33% of water samples have $CaCl_2$ water type, while 13.33% have $MgCl_2$ type. In deep wells 26.66% of water samples have $MgCl_2$ water type. The presence of $MgCl_2$ and $CaCl_2$ water types indicate groundwater pollution due to mixing with infiltrated sewage water. In shallow wells of the Quaternary (Pleistocene) aquifer, 40% of water samples have Revelle Coefficient more than one and ranges between 1.22 and 2.02, whereas 60% of samples have values less than one. This reflects good fresh water. In deep wells 33.33% of water samples have Revelle Coefficient more than one and ranges between 1.13 and 1.91, whereas 66.67% of samples have values less than one with good quality fresh water. Values more than one and less than ten indicates groundwater pollution due to mixing with infiltrated sewage water.

The Hypothetical salt assemblages in the Quaternary (Pleistocene) aquifer reveal the following assemblages: -

1. KCl, NaCl, Na_2SO_4, $MgSO_4$, $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$.

This assemblage reflects deep meteoric origin.

2. KCl, NaCl, Na_2SO_4, $NaHCO_3$, $MgSO_4$, $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$.

These types of salts are very close to the Nile water salts.

3. KCl, NaCl, Na_2SO_4, $MgSO_4$, $CaSO_4$ and $Ca(HCO_3)_2$

The presence of $CaSO_4$ instead of $Mg(HCO_3)_2$ is due to the leaching of gypsum cement.

4. KCl, NaCl, $MgCl_2$, $MgSO_4$, $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$.

This type characterizes marine water genesis and indicates the mixing processes of meteoric water with sewage water.

5. KCl, NaCl, $MgCl_2$, $CaCl_2$, $CaSO_4$ and $Ca(HCO_3)_2$.

This type characterized old marine geneses and indicates the mixing processes of meteoric water with sewage water.

4.3 Hydrochemistry of the Lower Miocene aquifer at Tabark area:

The total salinity values ot groundwater tapped in the Lower Miocene aquifer at Tabark area are ranging from 543 to 871 ppm, with an average content of about 660 ppm. Such salinities reflect that most of the water samples have good fresh water quality. With exception of water sample (12M) has salinity content reaches to 1982 and classified as fairly fresh water. The salinity distribution show that, the highest salinity content zone (>1000 ppm) is recorded at the northwest of the study area. The suddenly increasing in salinity content of the Lower Miocene aquifer at northwest of the study area is due to excessive withdrawals (over-pumping) of groundwater from wells.

The concentration of potassium in the Lower Miocene aquifer ranges from 6.3ppm (well number 14M) to 7.8 ppm (well number 12M) with average content of about 6.6 ppm. The distribution of potassium content in this aquifer shows that the majority of the area is characterized by concentrations less than 15 ppm.

The concentration of sodium in the Lower Miocene aquifer ranges from 98 to 215 ppm, with an average content of about 135ppm. With exception of water sample (12M) has sodium content reaches to 500 ppm. The distribution of sodium content in this aquifer shows polluted zone at northwest of the study area (> 200 ppm).

The concentrations of magnesium in the Lower Miocene aquifer ranges from 19.7 to 27.2 ppm, with an average content of about 22.8 ppm. With exception of water sample (12M) has magnesium content reaches to 79.7 ppm. The distribution of magnesium in this aquifer show the presence of local zone of high concentrations in the northwest of the studied area but the magnesium contents still below the excessive limits for drinking.

The concentrations of calcium in the Lower Miocene aquifer ranges from 30.4 to 42.4 ppm, with an average content of about 36.7 ppm. With exception of water sample (12M) has calcium content reaches to 96 ppm. The calcium distribution in this aquifer shows high concentration zone at northwest of the study area.

The concentrations of chloride in the Lower Miocene aquifer ranges from 85 to 160 ppm, with an average content of about 177.8 ppm. With exception of water sample (12M) has chloride content reaches to 800 ppm. The distribution of chloride in groundwater shows the existence of local polluted zone of high chloride concentration (> 600 ppm) at northwest of the study area. High sodium content reflects mixing of meteoric water with marine water ascending along fault planes. This reflects over-pumping of wells.

The concentrations of sulphate in the Lower Miocene aquifer ranges from 35.5 to 215.8 ppm, with an average content of about 125.2 ppm. With exception of water sample (12M) has sulphate content reaches to 320.7 ppm. The sulphate content distribution in groundwater shows local zone of high sulphate content (>250 ppm) at the northwest of the study area.

Bicarbonate ion concentration in the Lower Miocene ranges from 176.9 to 225.7 ppm with an average concentration about 213.1 ppm.

These relatively high values are mainly attributed to the dissolution of cement material of calcium carbonate.

At Tabark area, rNa/rCl ratio varies between 1.03 and 2.6 in well number 9 and 22M, respectively. This indicates the continental origin of the groundwater. With exception of well number 12M that has rNa/rCl ratio less than unity (0.93). This indicates that the groundwater of Lower Miocene aquifer is suffering from salt-water intrusion due to excessive withdrawals (over-pumping) of groundwater from this well.
53.84% of water samples have $r(K+Na)-rCl]/rSO_4<1$, and 38.46% of water samples have $r(K+Na)-rCl]/rSO_4>1$. This reflects Na HCO_3 and Na So_4 water types of meteoric origin. 7.7% of water samples (well no. 12M) has $[rCl-r(K+Na)]/rMg<1$ and reflect $MgCl_2$ water type of marine origin. The presence of $MgCl_2$ water type indicates the leaching action of the original marine water between rock pores by the meteoric water percolation, or due to mixing with old marine water discharges along fault planes. The Revelle coefficient of well numbers 9M, 20M, 21M and 12M vary from 1.121 to 7.78, indicating salt water intrusion at the northwestern part of the studied area.

The ion dominance reveals the occurrence of three salt assemblages in groundwater of the Lower Miocene aquifer as following:

2. KCl, NaCl, Na_2SO_4, $NaHCO_3$, $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$.
   NaCl, NaHCO3 and Ca(HCO3)2 are the major salts which reflects fresh water type and meteoric origin.
2. KCl, NaCl, Na_2SO_4, $MgSO_4$, $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$.
   The major hypothetical salts are NaCl, Mg(HCO3)2 and Ca(HCO3)2 which indicates fresh water type and deep meteoric genesis.
3. KCl, NaCl, $MgCl_2$, $MgSO_4$, $CaSO_4$ and $Ca(HCO_3)_2$

The presence of $MgCl_2$ water type which characterized marine origin in well no. 12M is mainly due to upward leakage of old groundwater from underlain Oligocene aquifer as result of over pumping.

4.4 Hydrochemistry of the Oligo-Miocene aquifer at Green Belt around Six of October City:

The total salinity of groundwater in Oligo-Miocene aquifer is varying from 8725 ppm in well number1S to 28405 ppm in well number 8S. The salinity content distribution map of groundwater in the Oligo-Miocene aquifer show that it decreases in northwest and southeast directions. High salinity of the groundwater indicates probable recharge from deep-seated aquifers, whereas the relatively low salinity of shallow groundwater suggests a recharge from surface rainwater during old rainy periods.

The concentration of potassium ion in Oligo-Miocene aquifer, varies from 9.5ppm in well number 18S to 200 ppm in well number 6S. Generally, the potassium content in Oligo-Miocene aquifer decreases in northwest and southeast directions.

The concentrations of sodium ion in Oligo-Miocene aquifer are ranging from 2142 ppm (well 12S) to 7700ppm (well 8S), with average content of about 3024 ppm. The sodium content distribution map of groundwater in the Oligo-Miocene aquifer shows that it decreases to northwest and southeast directions.

The concentration of Magnesium ion in Oligo-Miocene aquifer is varying from 244.8 ppm (wells 1S&11S) to 960 ppm (well 6S), with average content of about 459.05ppm. The magnesium content distribution map of groundwater in the Oligo-Miocene aquifer show that it decreases in northwest and southeast directions.

In investigated aquifer, calcium concentration ranges between 408 ppm (well 1S) to 1958 ppm (well 8S). The average content is about 1113.9 ppm. The calcium content distribution map of groundwater in the Oligo-Miocene aquifer shows that it decreases to northwest and southeast directions.

In Oligo-Miocene aquifer, the concentration of Chloride ion ranges between 3570ppm (well 12S) to 14500 ppm (well 8S), with average content of about 7377 ppm . The chloride content distribution map of groundwater in the Oligo-Miocene aquifer show that it decreases in northwest and southeast directions.

In the concerned aquifer, sulphate concentrations are varying between 1000 ppm (well 9S) and 5120 ppm (well 6S) the average content is about 2029.9 ppm. The sulphate content distribution map of groundwater in the Oligo-Miocene aquifer show that it decreases in northwest and southeast directions.

In the studied aquifer, Bicarbonate ion concentration is ranging from 216.4ppm (well 16S) to 584.5 ppm (well13S) with an average content of about 313.3 ppm. The bicarbonate content distribution map (Fig. 79) of groundwater in the Oligo-Miocene aquifer show that it increases in northwest and southeast directions.

The ratio rNa/rCl ranges between 0.5 and 0.93. This indicates the marine origin of the groundwater. The [rCl-r(K+Na)]/rMg coefficient ranges between 0.28 and 3.23. 52.63% of water samples have values more than one and represent $CaCl_2$ water type. 47.37% of water samples have values less than one and reflect $MgCl_2$ water type. The presence of $MgCl_2$ and $CaCl_2$ water types indicate mixing of marine water with meteoric water origin. The calculated values of Revelle coefficient [rCl/r(CO3+HCO3)] ranges between 15.74 and 85.38. This indicate that all groundwater samples of Oligo-Miocene aquifer have high values (>10) indicating marine water origin.

The calculated salt combinations in groundwater of the Oligo-Miocene aquifer reveal the existence of two assemblages as following:

KCl, $NaCl$, $MgCl_2$, $MgSO_4$, $CaSO_4$ and $Ca(HCO_3)_2$.

KCl, $NaCl$, $MgCl_2$, $CaCl_2$, $CaSO_4$ and $Ca(HCO_3)_2$.

The presence of $MgCl_2$ and $CaCl_2$ salts indicates old marine genesis of groundwater.

5. Pollution of groundwater of the Quaternary (Pleistocene) aquifer

The distribution of different pollutants in the groundwater of the Quaternary (Pleistocene) aquifer can be summarized under the following items:

5.1 Trace metal pollutants

5.2 Nutrients pollutants

5.3 Microbiological pollutants

5.1 Trace metals pollutants

Trace metals can be toxic and even health hazard to human beings even at relatively low concentrations because of their tendency to accumulate in the body.

Iron content in groundwater of the Pleistocene aquifer ranges between 0.1 ppm and 0.9 ppm in shallow wells, whereas it varies from 0.1 ppm to 0.7 ppm in deep groundwater wells. The distribution of iron content in shallow groundwater wells in the study area shows that most of the area have high iron content (>0.3), with the exception of El Mansouria, El Baragel, and Safet El Laban. The distribution of iron content in deep groundwater wells in the study area shows high iron

(> 1ppm) at El Oweina and southward. The distribution of phosphate content of groundwater in deep wells show some local zones at El Oweina village and Safet El Laban which have phosphate content > 1 ppm.

5.3 Microbiological pollutants

The results of bacteriological analyses of surface water samples indicate that all water of canals, drains, sewage and treated sewage water are highly polluted by coliform group and E.Coli. The number of the total coliform varies from 400 /100 ml (in sewage lake – Abu Roash station) and 15000 /100 ml in El Moheet drain. The results of bacteriological analyses for shallow groundwater samples indicate that, the total coliform count/100 ml varies from 40 to 4000/ml. Some wells are free of total coliform bacteria (nos. 3P, and 16P). The E. Coli count/100 ml varies from 9 to 230/ml. Some wells are free of E. Coli bacteria (nos. 1P, 2P, 3P, 6P, 7P 9P, 11P, 15P, 16P, 23P and 26P).

6. Evaluation of Groundwater for different purposes

The WHO (1984) gives the permissible limits of water used for domestic purposes.

The permissible limit of the salinity content (TDS) for drinking water is 500 ppm while the excessive limit is 1000 ppm (WHO, 1984). Both shallow and deep wells of Quaternary (Pleistocene) aquifer are acceptable for drinking, except some samples have TDS more than 1000ppm (at El Oweina , El Motamedeya and Ausim). The groundwater samples of the Lower Miocene aquifer are acceptable for drinking, except the well no. 12M (TDS >1000 ppm). All groundwater samples of the Oligo-Miocene aquifer is unsuitable for that purpose. The groundwater of

Quaternary (Pleistocene) and Miocene aquifers are suitable for irrigation purpose, except some local zones at El Oweina, El Motamedeya, Safet El Laban, Nekla, Burtus, Ausim, and Kirdasa, where salinity ranges between 1024 and 1936 ppm. The groundwater of the Oligo-Miocene aquifer at Green Belt project around Six of October City is characterized by very high salinity water and cannot be used under any conditions.

The permissible limit of the concentration of chloride for drinking water is <200 ppm while the excessive limit is 250 ppm (WHO, 1984). The groundwater of shallow and deep wells are suitable for drinking purpose, except the wells Nos. 1P, 2P, 3P, 5P, 6P, 7P, 9P, 11P, and 25P) at El Oweina village, El Motamedeya, Safet El Laban, Nahya, and Ausim (chloride content > 250 ppm). The groundwater of the Lower Miocene aquifer at Tabark area is suitable for drinking purpose, except the well no. 12M, where the chloride content is more than the permissible limits (>250 ppm). All groundwater samples collected from the Oligo-Miocene aquifer are unsuitable for drinking purposes.

Based (WHO, 1984), the permissible limit of bicarbonate for drinking water is 300 ppm. The concentrations of bicarbonate in the groundwater of the Quaternary (Pleistocene) aquifer indicates that, the groundwater in shallow and deep wells are suitable for drinking purpose, except the wells at El Oweina village, El Motamedeya, Safet El Laban, Nekla, El Baragrl, Burtus, Ausim, Mansouria and Kirdasa (bicarbonate content > 300 ppm). The groundwater of the Lower Miocene aquifer at Tabark area is suitable for drinking purpose (bicarbonate content < 300 ppm). All groundwater samples collected from the Oligo-Miocene aquifer are not suitable for drinking purposes. RSC in the groundwater of the Quaternary (Pleistocene) aquifer varies from – 4.61 to 0.7. Accordingly, this water mainly suitable and safe for water irrigation purposes. The groundwater of the Lower Miocene aquifer is characterized by RSC varies from – 8.29 to 0.43. Consequently, this water is suitable and safe for irrigation. The groundwater of the Oligo-Miocene aquifer is free from RSC, where it ranges between –143.3 and – 35.5.

The permissible limit for the concentration of sulphate for drinking water is 200 ppm while the excessive limit is 400 ppm (WHO, 1984). For reasons of taste, sulphate content must be below 250 ppm (U.S.EPA 1976a). The concentration of sulphate ion in groundwater of the Quaternary (Pleistocene) aquifer indicates that, the groundwater is suitable for drinking purpose, except the shallow wells in the local polluted zones at El Oweina village, El Motamedeya and Ausim, where sulphate ion is more than 250 ppm. The sulphate content in the groundwater of the Miocene aquifer is suitable for drinking, except the sample no. 12M ($SO_4 > 250$ ppm). The groundwater of Oligo-Miocene aquifer is unsuitable for drinking purpose.

The excessive limit of the concentrations of sodium for drinking water is 200 ppm (WHO, 1984). The groundwater of Quaternary (Pleistocene) aquifer indicate that, the groundwater of both shallow and deep wells are suitable for drinking, except the shallow wells in the local polluted zones at El Oweina village, El Motamedeya, and Ausim. The groundwater of the Lower Miocene aquifer is suitable for drinking, except the well nos. 20M and 12M ($Na > 200$ ppm).The groundwater of the Oligo-Miocene aquifer is unsuitable for drinking purpose ($Na > 200$ ppm). Sodium Adsorption Ration (SAR) in the groundwater of the Quaternary (Pleistocene) aquifer varies from 0.74 to 6.20. The groundwater is characterized by low sodium water ($SAR < 10$) and can be used for irrigation. In the Lower Miocene aquifer, water is suitable and safe for irrigation. The groundwater of the Oligo-Miocene aquifer is unsuitable for irrigation as it is plotted outside the diagram, where SAR ranges between 19.10 and 38.93.

The permissible limit of the concentration of magnesium for drinking water is 50 ppm, while the excessive limit is 150 ppm (WHO, 1984). The concentration of magnesium in the groundwater of the Quaternary (Pleistocene) aquifer indicates that the groundwater in the study area is suitable for drinking with respect to magnesium content, and consequently, it is suitable for irrigation purposes. The groundwater of the Lower Miocene aquifer is suitable for drinking and irrigation with respect to magnesium content. The groundwater of the Oligo-Miocene aquifer is not suitable for drinking and irrigation with respect to magnesium content.

The permissible limit of the concentration of calcium for drinking water is 75 ppm, while the excessive limit is 200 ppm (WHO 1984). The concentration of calcium in the groundwater of the Quaternary (Pleistocene) aquifer indicates that the groundwater in the study area is suitable for drinking and irrigation with respect to calcium content. The groundwater of the Miocene aquifer is suitable for drinking and irrigation with respect to calcium content. The groundwater of the Oligo-Miocene aquifer is not suitable for drinking and irrigation with respect to calcium content. The groundwater of the Quaternary (Pleistocene) aquifer ranges from hard to very hard. The groundwater of the Miocene aquifer ranges from hard to very hard. The groundwater of the Oligo-Miocene aquifer is very hard.

The recommended guideline of iron for the drinking water is 0.3 ppm (WHO, 1984). The groundwater of the Quaternary (Pleistocene) aquifer in the study area is suitable for drinking except the wells nos. 1P, 6P, 7P, 8P, 11P, 12P, 13P, 14P, 15P, 17p, 18P, 23P, 25P, 29P and 30P at El Oweina, El Motamedeya, Nahya, Bani Magdoul, Kombera, Burtus, Ausim and Kirdasa (Iron content > 0.3).

The guideline value of manganese for drinking water is 0.1 ppm, the maximum allowable limit is 0.5 ppm. The maximum recommended concentration of manganese in irrigation water is 0.2 ppm (FAO 1985). The concentration of manganese in the groundwater of the Quaternary (Pleistocene) aquifer indicate that the groundwater in the study area is unfit for drinking except wells at Safet El Laban, Bani Magdoul, Kombera, El Mansouria and Kirdasa.

The guideline value of copper for the drinking water was recommended to be 1 ppm (WHO 1984,a). According to FAO (1985), the guideline value for copper in irrigation water is 0.2 ppm. The groundwater of the Quaternary (Pleistocene) is suitable for drinking and irrigation with respect to copper concentration.

According to WHO (1984,a), the guideline value of zinc for drinking water is 5 ppm. The groundwater of the Quaternary (Pleistocene) aquifer is suitable for drinking, with the respect to zinc concentration. According to FAO (1985), the maximum concentration of zinc recommended for irrigation water is 2 ppm, the groundwater of the Quaternary aquifer is classified as good for irrigation purpose.

The guideline value of lead for drinking water is recommended to be 0.05 ppm (WHO, 1984). The concentration of lead in the groundwater of the Quaternary (Pleistocene) aquifer indicate that the groundwater of both, shallow and deep wells is suitable for drinking except the local polluted zones at El Motamedeya, Nekla, Mansouria and Kirdasa. According to the FAO (1985), the maximum recommended concentration of lead in irrigation water is 5 ppm. Based on these limits, the groundwater of the Quaternary aquifer is classified as good for irrigation purpose.

The recommended guideline value of nitrate for drinking water is 45 ppm as NO_3^- (10 ppm as N) (WHO, 1984). The recommended limit of nitrate-N in drinking water is 10 ppm (U.S.EPA. 1976a). The concentrations of nitrate-N in groundwater of the Quaternary (Pleistocene) aquifer indicates that the groundwater in the study area of both shallow and deep wells is acceptable for drinking, with exception of the local polluted zone at El Oweina, which characterized by nitrate-N more than 10 ppm. Based on the FAO (1985) limits, the groundwater samples of the most of Quaternary aquifer are classified as very good for irrigation purpose, except the sample number 1P, which can be used for irrigation but with slight to moderate restrictions.

The excessive limit of ammonium concentration for drinking water is 0.05 ppm (WHO, 1984). The concentration of ammonium in the groundwater of the Quaternary (Pleistocene) aquifer indicate that the groundwater in the study area is unfit for drinking except the well nos. 26P at Ausim and 30P at Kirdasa.

The excessive limit of phosphate concentration for drinking water is 1 ppm (WHO, 1984). The groundwater of the Quaternary (Pleistocene) aquifer is suitable for drinking. With the exception of the local polluted zones at El Oweina, El Motamedeya, Safet El Laban.