

# Assessment of the environmental impacts on the groundwater resources in Southern part of Nile Delta, Egypt

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## Abstract

This study aimed to give an insight on the environmental impacts on the groundwater aquifer in southern part of Nile Delta. Major and minor ions were determined as well as trace elements are used to determine the chemical types of groundwater and their relations to the prevailing hydrogeological and environmental conditions, and evaluate the suitability of groundwater for different uses. Regarding the chemical properties of groundwater, it was also discussed through the chemical analysis of 80 groundwater samples.

The analytical data were interpreted using numerical and graphical methods. Appreciable increase in salinity contents and change in groundwater quality were recorded especially at the central and northeastern parts of the study area. Geochemical model named NETPATH was also used to simulate net geochemical mass-balance transfer of probable minerals and gases and evolution of groundwater in this region.

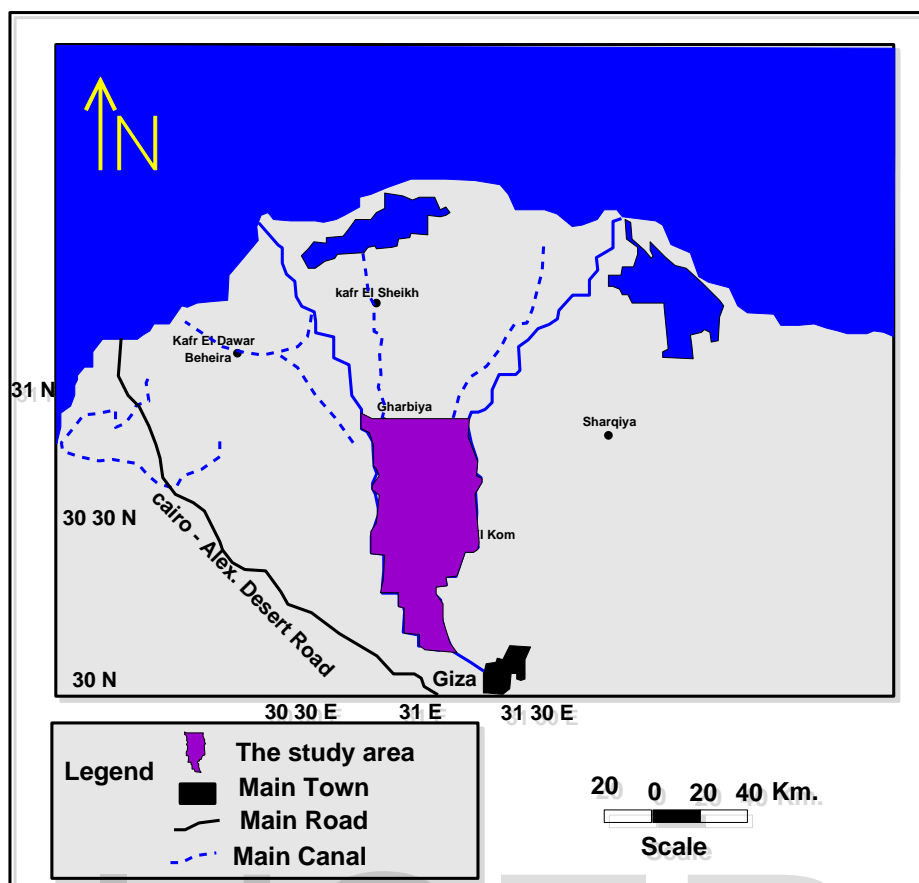
**Keywords:** *Groundwater, Environmental impacts, Aquifer, Net-Path program.*

## INTRODUCTION

The increase in population in the *Nile Valley* and Delta together with the agricultural and industrial development has resulted in the increasing pollution of surface and ground water. Domestic, industrial and agricultural waste water is often discharged untreated into the drainage network and injected into groundwater. The use of fertilizers and pesticides in agriculture is becoming a common practice. The effects of water pollution are not only devastating to people but also to animals, fish, and birds. Polluted water is unsuitable for drinking, recreation, agriculture, and industry. The modern society is completely depending on sufficient supplies of fresh water to meet the demands for drinking and other purposes such as agriculture and industry. The chemistry of groundwater is an essential parameter for assessing the environmental characteristics of an area (Gallardo and Tase 2007). The main factors affecting water quality changes are lithofacies geographical conditions, groundwater recharge and runoff conditions, and the degree of openness of groundwater systems (Xu et al. 2009) hydrochemical evolution, is commonly used to reconstruct geochemical evolution of groundwater from one point in an aquifer to another point located in the inverse direction along the groundwater flow path (Wang et al. 2010). Nile Delta area, is one of the most important areas for the land living. Accordingly, extensive need to the water as a supplement for irrigation and domestic use attracted more attention, and great efforts were established to evaluate water resources in the investigated area. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities (Belkhiri et al. 2010).

### 1. The study area:

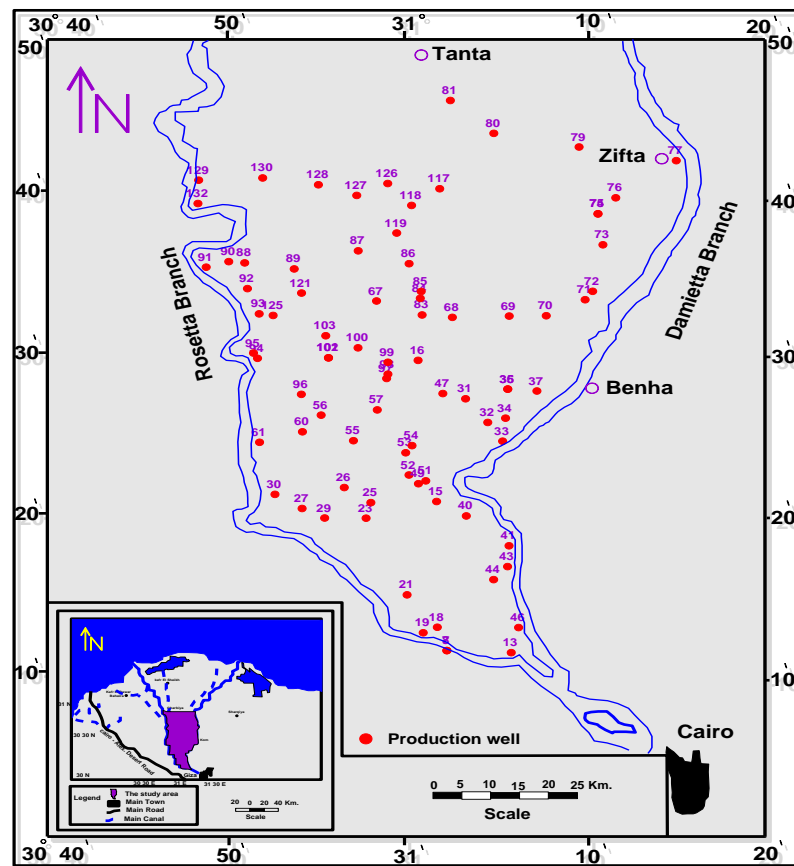
The study area occupies the southern part of the Nile Delta. This area is bounded by longitudes  $30^{\circ} 50'$  and  $31^{\circ} 20'$  E and latitudes  $30^{\circ} 10'$  and  $31^{\circ} 50'$  N. (Fig1).



(Fig. 1): Key map of the study area

## 2. Materials and methods:

Detailed Chemical analyses were carried out for the collected samples (Fig. 2). Different methods were used for these analyses, ASTM, American Society for testing and material (2002), ( $\text{Ca}^{++}$ ,  $\text{Mg}^{++}$ ,  $\text{CO}_3$ ,  $\text{HCO}_3$ ,  $\text{Cl}$ ) were measured volumetrically by titrimetric method. Sodium ( $\text{Na}^+$ ) and potassium ( $\text{K}^+$ ) were determined calorimetrically by means of Flame photometer. Sulphate ( $\text{SO}_4$ ) and Nitrate ( $\text{NO}_3$ ) is determined calorimetrically by means of Ultraviolet spectrophotometer screening method at wave length (690, 220nm). Phosphorus ( $\text{P}^{+++}$ ) is determined calorimetrically by using spectrophotometer at wave length (700 nm). Chemical tests of trace elements ( $\text{Fe}^{++}$  and  $\text{Mn}^{++}$ ) were determined by means of Atomic Absorption. Also, saturation indices were calculated with the help of NETPATH computer program Plummer NP, Prestemon EC, Parkhurst DL. (1994). A global positioning system (GPS) Garment 12 was used for location and elevation readings.



(Fig. 2): Location map samples of groundwater in study area (2012)

### **3. Results & Discussion:**

#### **3.1. Geological and hydrogeological setting:**

The geology of the study area has been discussed by different workers and it's concluded that; geologically, the stratigraphical succession under the surface of the study area belongs to the Quaternary sediments which constitute the main aquifer in the Nile Delta. The Quaternary sediments in the Nile Delta has been classified into two rock units Mit Ghamr Formation and the Bilquas Formation. Mit Ghamr Formation (pre Nile sediments) belongs to Early and Middle Pleistocene and composed of thick layers of quartzose sand and pebbles that occur above El- Wastani Formation. The pebbles are mainly quartz, but occasionally silicified limestone and chert pebbles are also found. Bilquas Formation belongs to Holocene. It consists of fine detrital materials ranging between the two classic end members; clay and silt including some sand tracks and sand dunes in the northern coastal area. Also some calcareous spots were detected at different depths.

The hydrogeology of the study area has been discussed by different workers and it's concluded that Rosetta branch starts from south Delta barrages and extends for a distance of about 239 Km towards the north, its water discharge directly in the Mediterranean Sea through Edfina barrages. The width of the branch varies along its course; it ranges from 1000 m at Tamalay, 450 m at Kafer El-Ziat to 650 m at Disuq town. Moreover it exhibits variable depths along its course ranging between 12 m and 20 m. The branch in its southern part is nearly directed to Northwest, while in its middle part directed almost to the north.

Groundwater aquifer belongs to early and middle Pleistocene time is composed mainly of thick layers of quartzes sand and pebbles that occur above El-Wastani formation. This aquifer is capped with Holocene aquitard. The top Holocene aquitard is mainly composed of silt and clay which change into clayey sand and fine sand towards the western parts. The thickness of top Holocene aquitard show wide range from 5 to 20 m in the study area (Fig. 3)

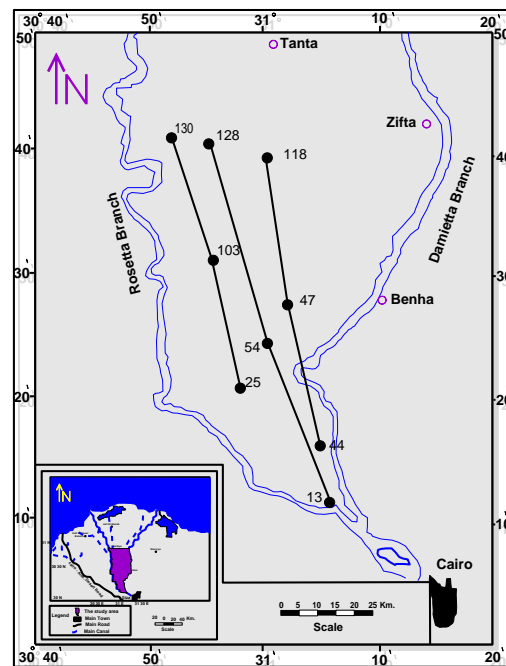
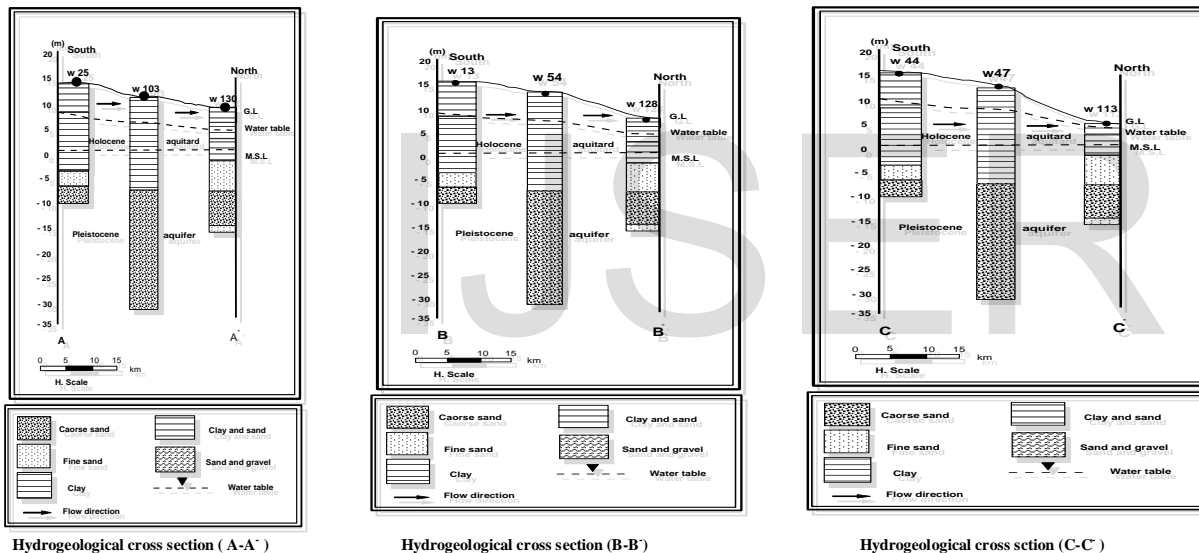
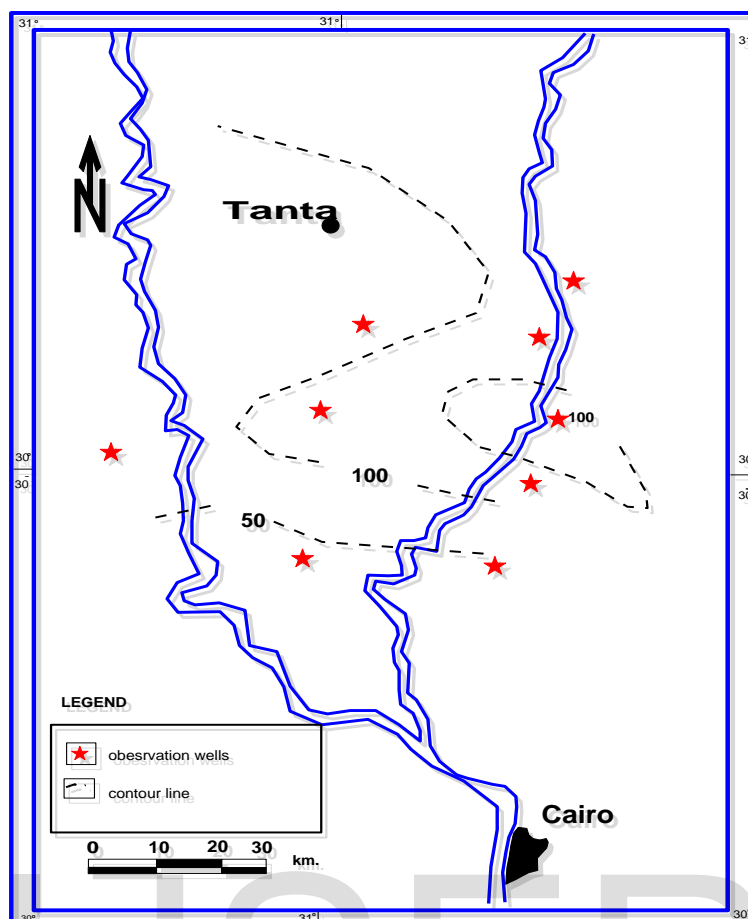


Fig. (3) Hydrogeological cross sections of groundwater observation wells



Hydraulic parameters of the Pleistocene aquifer were estimated. It has been found that transmissivity show different values, it reaches its minimum values at the middle and southwestern parts, where it ranges between 2000 and 3000m<sup>2</sup>/day. On the other side it reaches its maximum values in the middle and southeastern part, it ranges between 15000 and 9000 m<sup>2</sup>/day. It is found that hydraulic conductivity values ranges between 60 and 70 m/day in the southwestern part of the study area. In the southeastern parts, it reaches its maximum values; it ranges between 100 m/day and 180 m/day (Fig. 4). It is found that the value of effective porosity over the whole area ranges between 12% and 19% with average value 15.5%. This indicates that the aquifer is mainly composed of coarse sand and gravel. It has been found that storage coefficient shows different values, it ranges between 0.28 and 0.00049 in the southern and southwestern parts. This indicates that the aquifer is confined to unconfined type. In the southeastern part, it ranges between .048 and .00557; this indicates that the aquifer is semi-confined to semi unconfined type in these parts. These data collected from data bank of research institute of groundwater (El-Kanater El-Khayriya, Qallubiyia).



**Fig. (4): The hydraulic conductivity value of Pleistocene aquifer  
(After RIGW, 1980)**

Depth to water and piezometric heads of the observation wells drilled in the study area were measured during year 2013. Depth to water and flow net map were constructed, from these maps depth to water increases towards Rosetta branch and decrease close main irrigation canals and El Rayahat. It ranges between 2.5 and 5 m. Potentiometric heads decrease from the southeastern part to the Northwestern parts; they range from 10.2 m (a.m.s.l) at the eastern part to 7.2 m (a.m.s.l) close to North western part around Rosetta branch. The direction of groundwater flow was deduced from the flow net map it is found that the general direction of groundwater movement is from south east to the North West towards Rosetta branch. Local directions of groundwater movement were also deduced particularly in the localities near to El –Rayah El-beheiry which acts as recharge resources for groundwater aquifer. This noticed from the concave shape of contour lines. Another local direction of groundwater movement was observed also along Rosetta branch which acts as effluent stream for groundwater along most of its course (Fig. 5). This noticed from the convex shape of the contour lines along it.

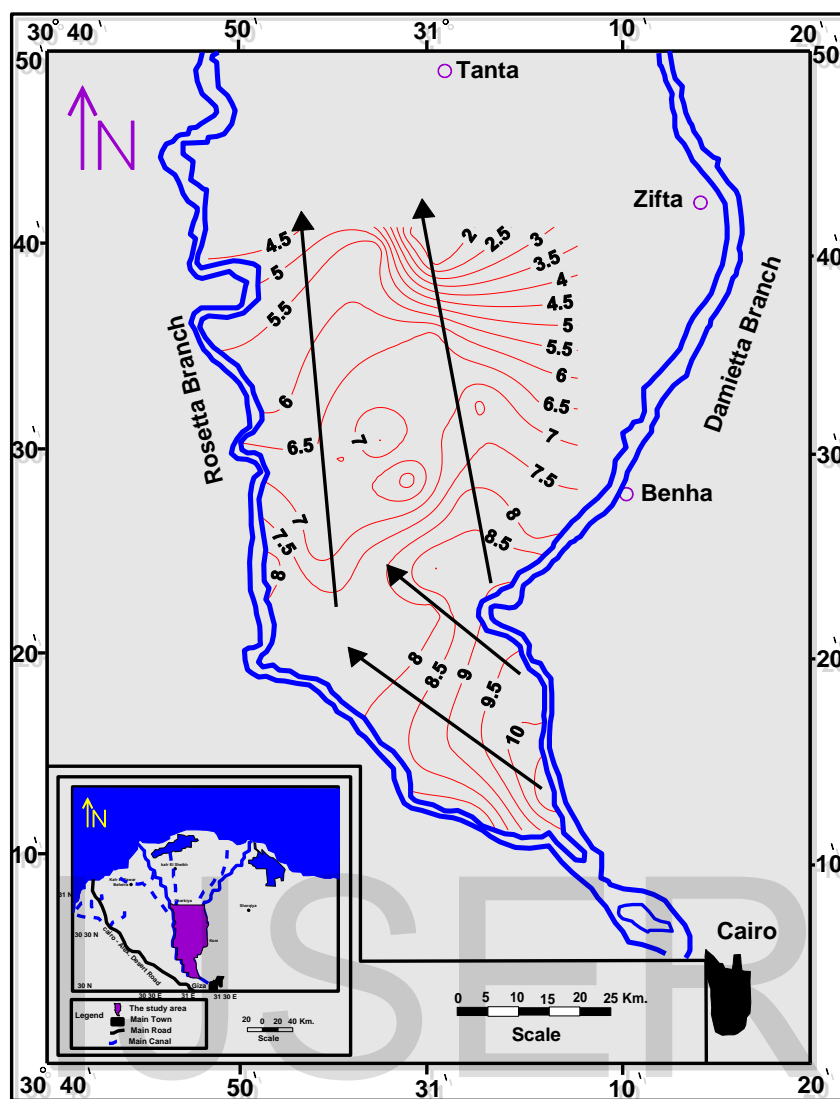
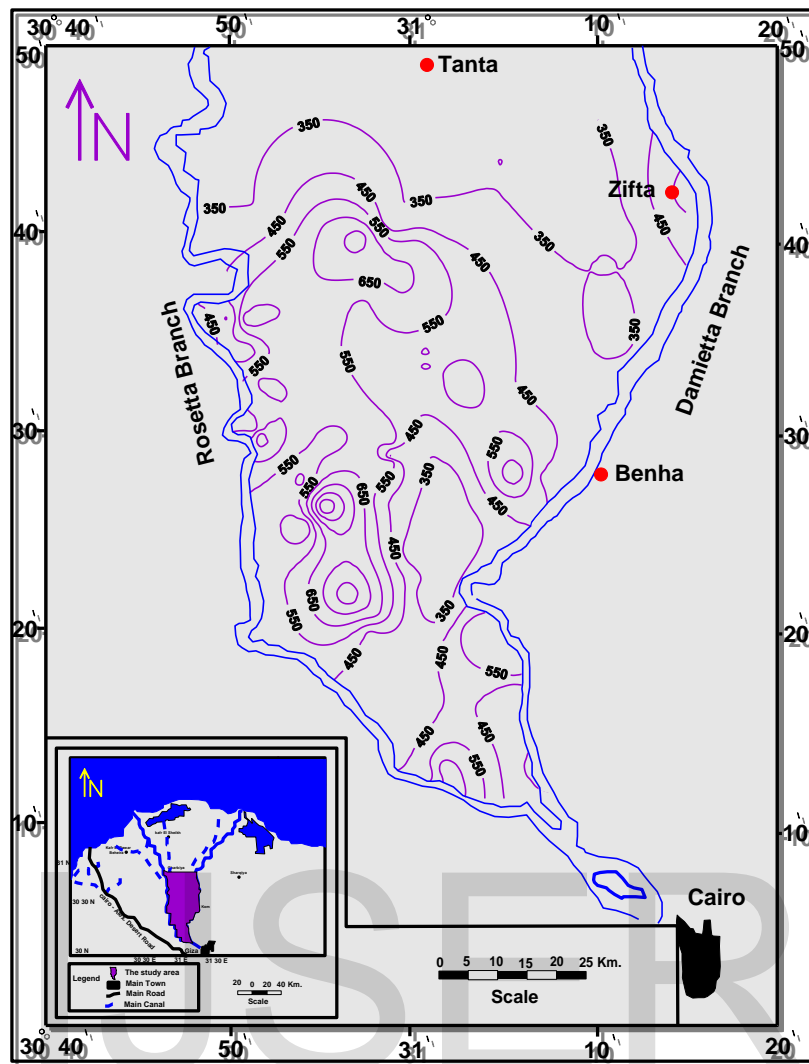


Fig. (5) Flow net map of Pleistocene aquifer in the study area.  
(December, 2012).

### 3.2. Hydrochemical aspects.

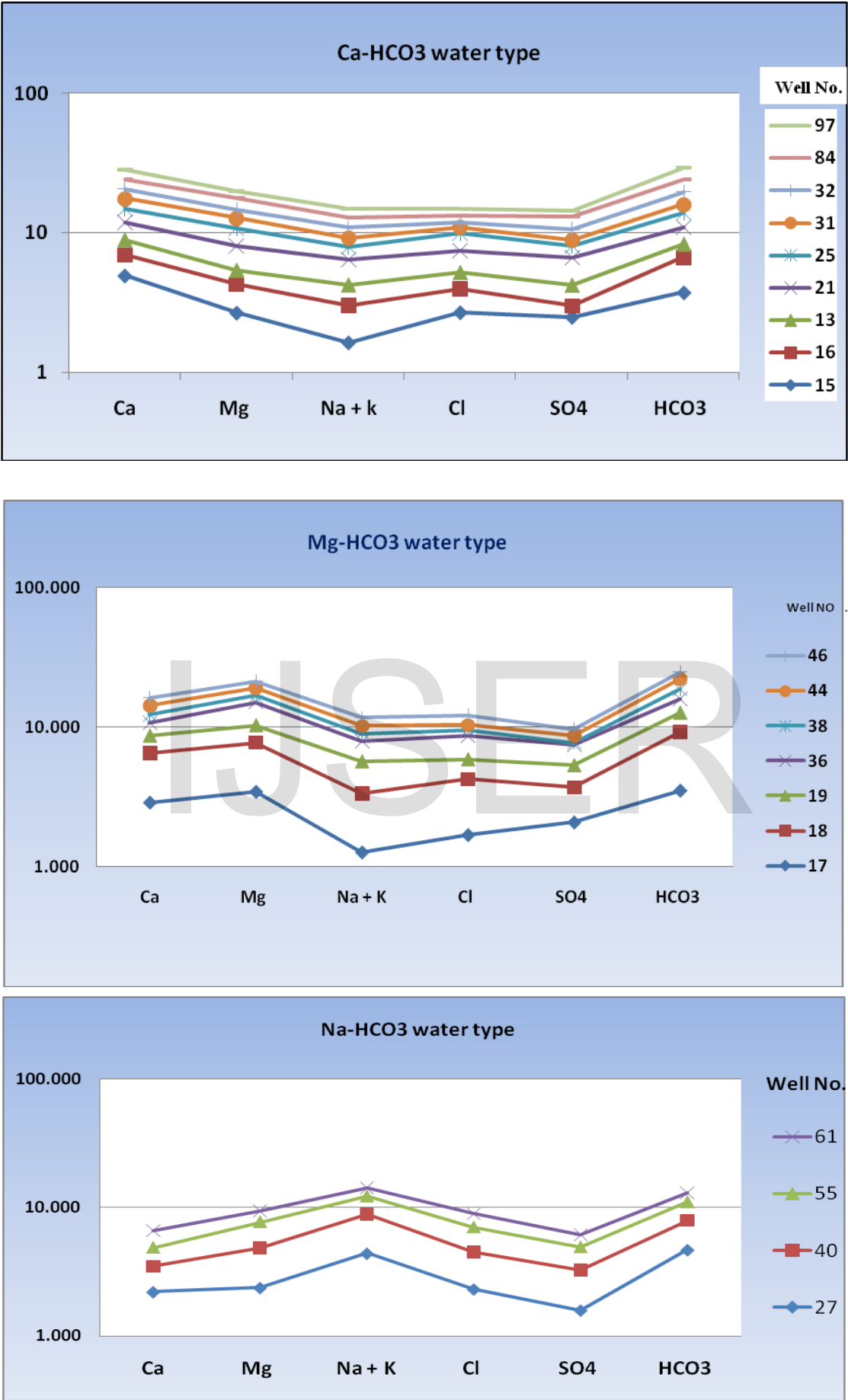
This part discuss the hydrochemistry of groundwater in the study area which including salinity contents, major ion contents and trace elements concentration. Groundwater quality has a wide range from fresh to fairly fresh water type. Salinity content of groundwater of the study area has values range from 269 mg/l to 810 mg/l in the majority of wells (Fig.6). Salinity and hydrochemical parameters of groundwater show large variation with movement from south to north. The increase of salinity is due to effect of vertical downward seepage of sanitary and agricultural waste water as well as the dissolution of salts from the sediments of the aquifer itself Diab (1982). **Dahab, K. A. (2003).**



(Fig. 6): Distribution map of salinity contents in the study area

### 3.3. Ions dominance and water type:

*Schoeller* Semi logarithmic graph (1962) is used to identify main orders of ions and consequent chemical types (Fig.7). Calcium is the most dominant cation followed by magnesium and Sodium cations ( $\text{Ca}^{++} > \text{Mg}^{++} > \text{Na}^+$ ). Some groundwater samples show increasing of Magnesium over Calcium and Sodium ( $\text{Mg}^{++} > \text{Ca}^{++} > \text{Na}^+$ ). Bicarbonate is the most dominant anions ( $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{--}$ ) of the majority of samples. This means that groundwater is still in early stage of mineralization **Hem, J. D., (1989)** and there is a continuous recharge of river Nile and main canals in the area.

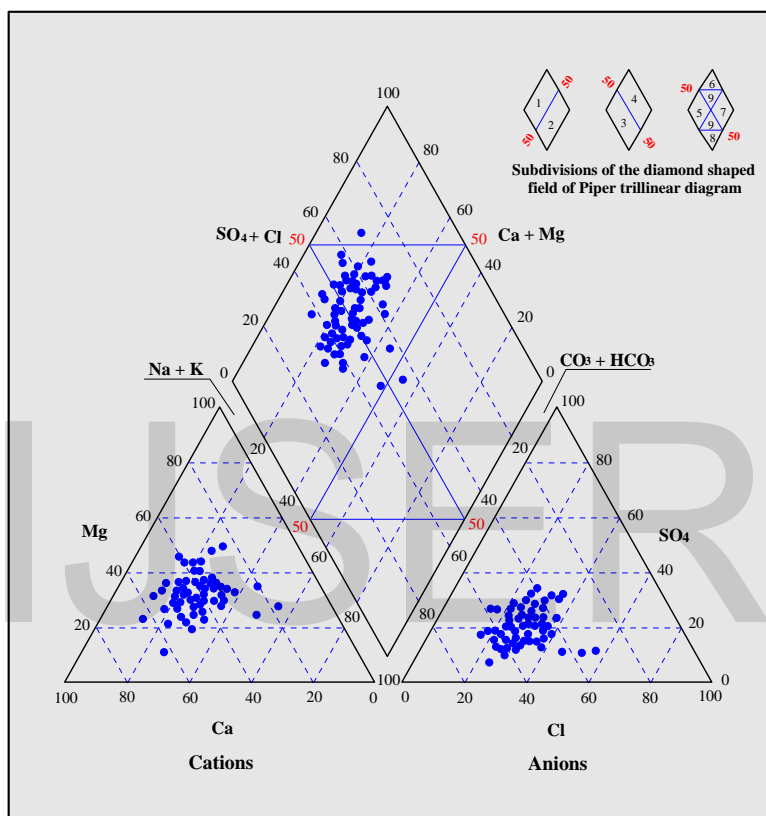


(Fig.7): Schoeller Semi logarithmic graph show water Type in study area



### 3.4- Geochemical classification of groundwater

The geochemical classification of groundwater is based on ion relationships, the most common are the trilinear diagram of Piper (1953). This diagram illustrates the trend of geochemical evolution of groundwater through mixing with other sources and through water-rock interaction. The diagram consists of two triangles, one for cations and the other for anions and a diamond shape field for representing the overall chemical character of the plotted data. The classification is based on the percentage of milli-equivalent per liter of the major anion ( $\text{HCO}_3^-$ ,  $\text{CO}_3^{2-}$ ,  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$ ) and major cations ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$ ). Piper's trilinear diagram for groundwater wells consequently show that chemical composition of groundwater diamond field revealed that most of water chemical compositions are plotted in sub area (9 and 5), (Fig. 8). Piper's trilinear diagram for groundwater wells show that, the projection of chemical composition of groundwater revealed that most of water chemical compositions are plotted in subarea 5 and in subarea 9, where subarea 9 reflects fresh water and that reflect  $\text{Ca-HCO}_3$  and  $\text{Mg-HCO}_3$  water type.



(Fig.8): Piper trilinear diagram for groundwater samples in the study area

### 5: Environmental impacts on geochemical mass-balance reactions:

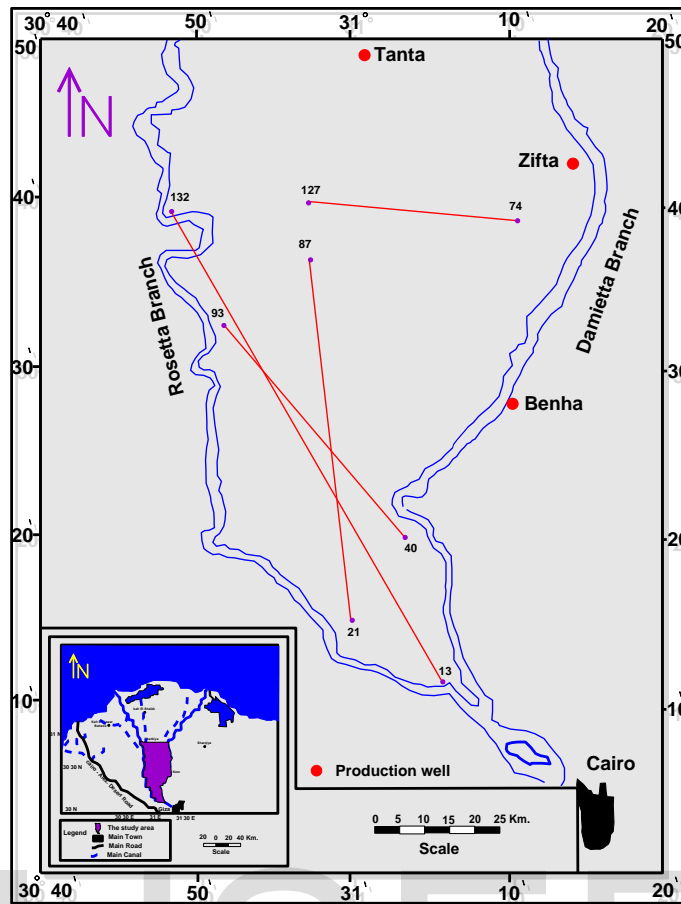
*NETPATH* (Plummer and others 1994) was used to environmental simulate net geochemical mass-balance reactions between initial and final waters along a hydrologic flow path. The program uses chemical data for waters samples. The processes of dissolution, precipitation, ion exchange, oxidation/reduction, degradation of organic compounds, incongruent reaction, gas exchange, mixing, evaporation, dilution can be considered. This program simulates selected evolutionary waters for every possible combination of the plausible phases that account for the composition of a selected set of chemical constraints in the system (Table 1). The *NETPATH* software includes a data-base program (DB) for storing and editing chemical data for use in *NETPATH*. A mass-balance is defined as the masses (per kilogram  $\text{H}_2\text{O}$ ) of a set of plausible minerals and gases that must enter or leave the initial solution in order to define exactly a set of selected elemental, electron transfer, and isotopic constraints observed in a final (evolutionary) water. In hydrochemical systems the number of reacting phases is often larger than the number of constraints necessary to define their composition. *NETPATH* solves a set of linear equations that account for conservation of mass, and (optionally) conservation of electrons and selected isotopes to find every subset of the selected phases (every model) that satisfies the chosen constraints. Each mass-balance model can be treated as an isotope evolution problem solving isotope mass balance and Raleigh distillation problems to predict the isotopic composition at the final point on the flow path.

**Table 1: Constraints and Phases used by NETPATH in the study area.**

NO.	CONSTRAINTS	PHASES	Parameter
1	Sodium	Na-Mont.	<b>Mixing: NO</b>  <b>Evaporation : NO</b>  <b>Rayleigh CalCs : NO</b>
2	Potassium	K-Mont.	
3	Calcium	Ca-Mont.	
4	Magnesium	Dolomite	
5	Chloride	Sodium Chloride	
6	sulfur	Gypsum	
7	Carbon	Aragonite	
8	Iron	Geothite	
9	Manganese	Rhodochr	
10	Nitrogen	NH <sub>3</sub> gas	
11	Phosphorus	Vivianit	

### **5.1. Input data:**

Water analyses are entered through the interactive data base (DB) program. DB allows editing and processing of the data through the WATEQF equilibrium model **Truesdell, A.H and Jones, B. F. (1973), (Plummer, L.N. Parhurst, D.L. Fleming, G.W. and Dunkel, S.A. 1988)**, to produce an input file (filename. PAT) to NETPATH. DB (and NETPATH) accept laboratory and field analytical data for waters containing the elements Na, K, Ca, Mg, Cl, S, C, Fe, Mn, N and P. Temperature and pH are required for every water analysis, the rest are optional. All files and data used by DB are interactively updated and maintained. DB produces full speciation output for all waters in the format of WATEQF results (Fig. 8), maintains the [filename]. LON data file of water analyses and produces the [filename]. PAT input file to NETPATH. Files for checking charge imbalances in original data and data reports of water analyses are optionally produced from DB. NETPATH automatically updates the minerals data file, NETPATH.DAT, upon normal termination, saves model input files and model result files. Samples were analyzed and the major anions and cations were processed into the program WATEQF as an input file for each sample. The program converts the concentrations into mol/l and calculates the activities of elements and species of each sample. The program calculates the saturation indices of Calcite, Aragonite, Dolomite, Rhodochr, Gypsum, Anhydrite, Hematite, Vivianit, H<sub>2</sub> Gas and Partial carbon dioxide P-CO<sub>2</sub>. The positive signs of the saturation index (SI) mean that the solution is supper saturated and the negative signs reflect that the solution is sub-saturated and zero value means that the solution is in equilibrium state (**Glynn PD and Plummer LN (2005)**). The saturation state is calculated as follows (Fig.9), (Table. 2):



(Fig. 9): Net path cross sections along to flow direction in the study area

**Table 2: Minerals results of mass balance transfer (NETPATH MODEL) along to flow directions:**

Well No.	Na-Mon	K-Mon	Ca-Mon	Mg Mon	Dolomite	Hematite	Sodium Chloride	NH3 Gas	Rhodochr	Vivianit
40 & 93	-1.33506	-4.84573	-4.688	-3.328	1.70436	-0.00050	-0.45116	0.28614	0.00456	0.00081
74 & 127	-4.00255	0.65945	-6.3746	-8.297	2.5633	-0.00298	2.82334	0.000	0.00365	0.00097
13 & 132	-0.885	0.3102	0.97644	0.9632	0.03673	-0.00184	0.64914	2.14269	0.00364	0.00242
21 & 87	-1.25473	-0.1551	-2.0309	-4.247	0.37904	-0.02184	-0.28228	0.21428	-0.00091	0.01211

Positive sign (+): dissolution of mineral (m.mole/Kg)

Negative sign (-): Precipitation of mineral (m.mole /Kg)

## 5.2. Model results:

The results obtained from NETPATH have been established (Table 3). The net geochemical mass-balance reactions between initial and final waters of four Profiles selected along the groundwater flow path of the Pleistocene aquifer , Fig.( 9) was preceded, Sodium, Potassium, Calcium, magnesium, Chloride, Sulfur, Carbon, iron, Manganese, Nitrogen

and Phosphorus were introduced into the model as constraints. Na-montmorillonite, K-montmorillonite, Ca-montmorillonite, Dolomite, Sodium Chloride, Gypsum, Aragonite, Goethite, Rhodochr, NH<sub>3</sub> gas and Vivianit were selected as interactive phases of the aquifer. The results of mass – balance transfer along groundwater flow path are presented in table 4.

**The following can be concluded:**

- 1- Profile (A):** This profile pass through well 40 in the south to well 93 in the north. The results of mass–balance transfer along this profile reflect precipitation of -4.688 mmole of Ca-mon, -1.33506 mmole Na-mon, -4.84573 mmole K- mon, -3.328 mmole Mg- mon, -0.45116 mmole Sodium Chloride, -0.0005 mmole Hematite. Dissolution of 1.70436 mmole Dolomite 0.00456 mmole Rhodosher, 0.28614 mmole NH<sub>3</sub> and 0.00081 mmole Vivianit (all expressed mmole per kg of groundwater). This leads to increase of calcium, magnesium, manganese, iron ,carbonate, phosphate and nitrate and this agreement with the sequence of cations ( $\text{Ca}^{++} > \text{Mg}^{++} > \text{Na}^{+}$ ) , ( $\text{Mg}^{++} > \text{Ca}^{++} > \text{Na}^{+}$ ) and anions ( $\text{HCO}_3^{-} > \text{Cl}^{-} > \text{SO}_4^{--}$ )
- 2- Profile (B):** This profile pass through well 13 in the south to well 132 in the north east .The results of mass–balance transfer along this profile reflect precipitation of 6.3476 mmole of Ca-mon, 4.00255 mmole Na-mon, 8.297 mmole Mg- mon, 0.00298 mmole Hematite. Dissolution 2.82334 mmole of Sodium Chloride, 1.70436 mmole Dolomite, 0.65945. mmole K- mon, 0.00365 mmole Rhodosher, , and 0.00097 mmole Vivianit (all expressed mmole per kg of groundwater). This leads to increase of halite salts (NaCl), salinity also calcium, magnesium, manganese, iron, carbonate, phosphate and nitrate. this agreement with the sequence of cations ( $\text{Ca}^{++} > \text{Mg}^{++} > \text{Na}^{+}$ ) , ( $\text{Mg}^{++} > \text{Ca}^{++} > \text{Na}^{+}$ ) and anions ( $\text{HCO}_3^{-} > \text{Cl}^{-} > \text{SO}_4^{--}$ ) , the dissolution of these salts and consequently increase the concentration of ions (Ca, Mg, Na, Mn, Fe , CO<sub>3</sub>, PO<sub>4</sub> and NH<sub>3</sub>) related to the effect of Rahway drain which distracted its polluted water directly in Rosetta branch without any treatments.
- 3- Profile (C):** This profile pass through well 74 in the south to well 127 in the north.The mass–balance transfer along this profile reflect the predominant reactions appear to be precipitation of -0.00184 mmole Hematite 4.002mmole Na- Mont, 6.37644 mmole Ca- Mont, and dissolution of 0.659 mmole K- Mont, 2.5633 mmole Dolomite, 7.933 mmole Gypsum, 2.8233 mmole Sodium Chloride, 0.00364 mmole Rhodochr, and 0.00079 mmole Vivianit. Even through primary silicate minerals (clay minerals) predominate in the mineralogy of the Quaternary aquifer in the study area, the mass balance modeling indicates that reactions with these minerals are secondary to those of the more reaction carbonate (2.5633 mmole Dolomite, 7.933 mmole Gypsum) and precipitation of -0.00184 mmole Hematite and 0.885mmole Na- Mont.
- 4- Profile (D):** This profile pass through well 21 in the south to well 87 in the north. The results of mass–balance transfer along this profile reflect precipitation of -4.6884 mmole of Ca-mon, -1.25473 mmole Na-mon, -4.84573 mmole K- mon, -3.3279 mmole Mg- mon,- 0.4512 mmole Sodium Chloride, 0.00091 mmole Rhodosher 0.02184 mmole Hematite. Dissolution of 1. 7904 mmole Dolomite, 0.26148 mmole NH<sub>3</sub> and 0.00081 mmole Vivianit and 0.00456 mmole Rhodochr (all expressed mmole per kg of groundwater).

The predominant reactions appear to be dissolution of 1. 7904 mmole Dolomite, and precipitation of -4.6884 mmole of Ca-mon, -4.84573 mmole K- mon , -3.3279 mmole Mg- mon and -1.25473 mmole Na-mon. Even through primary silicate minerals (clay minerals) predominate in the mineralogy of the Quaternary aquifer in the study area, the mass balance modeling indicates that reactions with these minerals are secondary to those of the more reaction carbonate (1. 7904 mmole Dolomite) and precipitation of Ca-mon, K- mon , Mg- mon and Na-mon. (**Appelo CAJ and Postma D.(2005)**, this reaction agreement with the sequence of cations ( $\text{Ca}^{++} > \text{Mg}^{++} > \text{Na}^{+}$ ) , ( $\text{Mg}^{++} > \text{Ca}^{++} > \text{Na}^{+}$ ) and anions ( $\text{HCO}_3^{-} > \text{Cl}^{-} > \text{SO}_4^{--}$ )

**Table.3: Mass balance transfers of four profiles along a flow path in shallow groundwater wells of the Pleistocene aquifer in the study area**

Initial water (Well No.40) Na-K-Ca-Mg-Cl-SO <sub>4</sub> -HCO <sub>3</sub> -NO <sub>3</sub> -PO <sub>4</sub>		
Rock formation Dissolution	Groundwater	Rock formation Precipitation
1.70436 mmole/kg Dolomite 0.2861 mmole/kg NH <sub>3</sub> 0.00456 mmole/kg Rhodochr 0.0008 mmole/kg Vivianit	-1.335 mmole/kg Na-Mon -3.328 mmole/kg MgMon -4.688 mmole/kg K-Mon -4.668 mmole/kg Ca-Mon -0.4512 mmole/kg NaCL -0.0005 mmole/kg Hematite	A
Final water (Well No.93) Na-K-Ca-Mg-Cl-SO <sub>4</sub> -HCO <sub>3</sub> -NO <sub>3</sub> -PO <sub>4</sub>		
Initial water (Well No.13) Na-K-Ca-Mg-Cl-SO <sub>4</sub> -HCO <sub>3</sub> -NO <sub>3</sub> -PO <sub>4</sub>		
Rock formation Dissolution	Groundwater	Rock formation Precipitation
0.31015 mmole/kg K-Mon 0.9764 mmole/kg Ca-Mon 0.9632 mmole/kg Mg-Mon 0.03673 mmole/kg Dolomite 0.64914mmole/kg Sodium Chloride 0.00364 mmole/kg Rhodochr 0.00242 mmole/kg Vivianit 2.1427 NH <sub>3</sub> Gas	-0.88545 mmole/kg Na-Mon -0.00184 mmole/kg Hematite	B
Final water (Well No.132) Na-K-Ca-Mg-Cl-SO <sub>4</sub> -HCO <sub>3</sub> -NO <sub>3</sub> -PO <sub>4</sub>		
Initial water (Well No.74) Na-K-Ca-Mg-Cl-SO <sub>4</sub> -HCO <sub>3</sub> -NO <sub>3</sub> -PO <sub>4</sub>		
Rock formation Dissolution	Groundwater	Rock formation Precipitation
0.6595 mmole/kg K-Mon 2.5633 mmole/kg Dolomite 7.933 mmole/kg Gypsum 2.82334mmole/kg Sodium Chloride 0.00365 mmole/kg Rhodochr 0.00097 mmole/kg Vivianit	-4.00255 mmole/kg Na-Mon -8.2973 mmole/kg Mg-Mon -0.00298mmole/kg Hematite -6.37461 mmole/kg Ca-Mon	C
Final water (Well No.127) Na-K-Ca-Mg-Cl-SO <sub>4</sub> -HCO <sub>3</sub> -NO <sub>3</sub> -PO <sub>4</sub>		
Initial water (Well No.21) Na-K-Ca-Mg-Cl-SO <sub>4</sub> -HCO <sub>3</sub> -NO <sub>3</sub> -PO <sub>4</sub>		
Rock formation Dissolution	Groundwater	Rock formation Precipitation
1.70436mmole/kg Dolomite 0.28614 mmole/kg NH <sub>3</sub> gas 0.00456 mmole/kg Rhodochr 0.00081 mmole/kg Vivianit	-1.33506 mmole/kg Na-Mon -4.84573 mmole/kg K-Mon -3.3279 mmole/kg Mg-Mon -4.6884 mmole/kg Ca-Mon -0.4512 mmole/kg NaCL -	D
Final water (Well No.87) Na-K-Ca-Mg-Cl-SO <sub>4</sub> -HCO <sub>3</sub> -NO <sub>3</sub> -PO <sub>4</sub>		

## 7. Groundwater evaluation for human drinking

The suitability of particular water for drinking, domestic, laundry and irrigation is controlled by many factors. In the following study, the evaluation of water quality for various intended used is based on the total dissolved salts (TDS) and the concentration of major, minor and trace elements. Ground water used in drinking, and domestic purposes should be free of undesirable physical properties such as color or turbidity and should have no unpleasant taste or odor, excessive amount of dissolved elements .Moreover, for using water. For laundry purposes, it should be soft or moderately hard .The European standard for drinking water (World Health Organization (WHO) (1984), (1984 a) and U.S. Environmental Protection

Agency, 1975), Egyptian standard for drinking and domestic uses (Table 4). All values of the pH of the Quaternary aquifer samples are within the safe limit. With respect to salinity criteria, 62.3 % of the samples have salinities less than 500 mg/l, and thus fall within the acceptable limits. And the rest 37.7% of the samples have salinities less than 1500 mg / l and more than 500 mg / l and thus fall within the permissible limits for drinking purposes. With respect to other major and minor ions all detected concentrations lie within the acceptable limits. The main objective for use this ground water for drinking is high pollution with iron, manganese and in some cases phosphate and nitrate as recorded above the limits.

**Table 4: International standards for drinking water (WHO, 1984)**

Substance or property	Acceptable (mg/l)	Permissible (mg/l)	Substance or property	Acceptable (mg/l)	Permissible (mg/l)
Color (Co.Pt unit)	5	50	Fe	0.3	1
Turbidity	5	25	Mn	0.1	0.5
pH	7-8.5	6.5-9.2	Pb	-	0.05
TDS	500	1500	Cu	1	1.5
Cl	200	600	Hardness (CaCO <sub>3</sub> )	250	500
SO <sub>4</sub>	200	400	Cd	-	0.01
Mg	50	150	Zn	5	15
Ca	75	200			

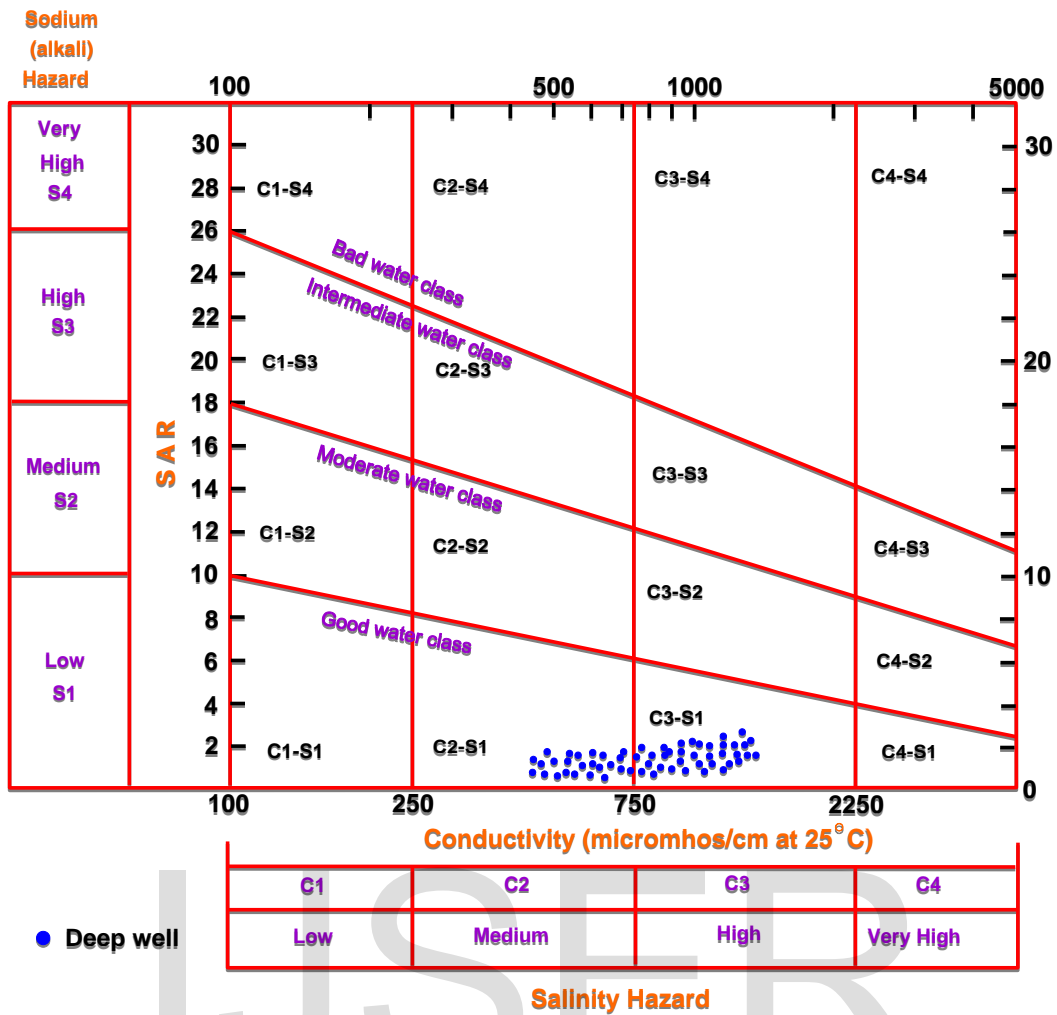
### **8. Suitability of groundwater for agricultural uses:**

Irrigation water quality has direct effects on plants, crop yield, and soils of any cultivated area. It depends on the content of elements that are harmful to plants and soils. The quality requirements of irrigation water vary between crops, types and drain ability of the soils and climate (Bouwer, 1987). The exchange of ions alters the physical characteristics of the soil. Clay that carries good excess of Ca<sup>++</sup> or Mg<sup>++</sup> has a good permeability. If the same clay takes up Na<sup>+</sup>, it becomes sticky and has very low permeability. It shrinks when dry and becomes difficult to break up by cultivation creating an alkali soil. The classification of the Quaternary groundwater according to U.S. Salinity Laboratory Staff (1954) based on the Sodium Adsorption Ratio (SAR), and the specific conductance. Generally, irrigation water with low SAR is much desirable (Fig.9).

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

Where, the concentration of these cations are expressed in meq/l according to the U.S. Salinity Laboratory diagram, the water is divided into classes C1, C2, C3, and C4, which denote the conductance and S1, S2, S3, and S4, which denote SAR.





(Fig. 10): water classification for irrigation purposes  
(According to U.S salinity Lab 1954)

As shown from figure 14 and according to the foregoing discussion, it clears that: all ground water samples in study area are good water for irrigation purposes. 60 % of samples lie on C2 S1 (good water) 40 % of the groundwater samples of the Quaternary aquifer fall in the good water class (C3-S1) which reflects that groundwater in the study area suitable for irrigation purposes under normal condition and Satisfactory for plants.

## Conclusion

From the chemical results, groundwater samples of the study area these conclusions are obtained:-

- 1- The groundwater belong to fresh water type and high TDS reflect leaching and dissolution of aquifer materials
- 2- Remarkable changes in physical, chemical characteristics of drinking water have been recorded through increase in salinity, chloride, and sulfate contents as well as appearance of Phosphate, Nitrates, iron, and manganese over permissible limits.
- 3- High scale of total hardness of groundwater resources is due to leaching and dissolution of calcium and magnesium bearing deposits present in aquifer materials.
- 4- Cation exchange and carbonate are the more reaction in the Quaternary aquifer and the groundwater type is still in early stage of mineralization.
- 5- There is continuous recharge from Nile River (both branches) and main canals in the study area.

6- Salinity Laboratory diagram reflects suitability of groundwater in the study area for irrigation purposes under normal condition.

## Recommendation

The following processes should be applied in drinking water stations to become suitable according to the European standard for drinking water (World Health Organization (WHO) (1984) and U.S. Environmental Protection Agency, 1975), Egyptian standard for drinking and domestic uses :-

- 1- Water softening processes are very necessary especially for groundwater pumping stations to reduce the concentration of calcium and magnesium, standard softening processes contribute to the removal of iron and manganese, organic material, bacteria, viruses, and other suspended solid.
- 2- Manganese can be removed by adsorption upon a bed of pyrolusite. This process is sometimes called the manganese zeolite process.
- 3- Ozonation processes should be applied in drinking water stations beside chlorination processes, since it is a strong oxidizing agent, and it is effective as a germicide, in destruction of organic matter which might produce tastes or odors, and in oxidation of iron and manganese.
- 4- Need to treatment for wastewater before discharge in the Rosetta branch

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### الملخص العربي

#### تقييم الأثر البيئية على مصادر المياه الجوفية بمنطقة جنوب الدلتا – مصر.

تمت هذه الدراسة على 85 عينة أخذت من منطقة الدراسة وذلك لدراسة مدى تعرض الخزان الجوفي بالمنطقة للملوثات المختلفة وكذلك مدى صلاحية هذه المياه للشرب والاستخدامات المنزلية والصناعية والري وقد تم تحليل هذه العينات كيميائياً وتبين من الدراسة ما يلي :-

- ارتفاع قيمة الأملاح الذائبة الكلية للمياه بمنطقة الدراسة بالاتجاه من الجنوب الى الشمال والغرب مع اتجاه سير المياه كما تلاحظ زيادة نسب الكالسيوم والماغنسيوم والصوديوم والكبريتات والكلوريد بالتبعية مع ارتفاع قيمة الأملاح الكلية مما يعد مؤشراً على وجود تلوث بالعناصر المذكورة
- ارتفاع نسب الحديد والمنجنيز بمنطقة الدراسة في معظم العينات المأخوذة للدراسة مما يشكل مصدراً للتلوث بالعناصر الثقيلة ويعيق الاستخدام للشرب
- وجد أن أغلب العينات يسود فيها كاتيونات الكالسيوم ثم الماغنسيوم مع انيونات البكربونات ثم الكلوريد وأن المياه الموجودة بالخزان ذات أصل مطري يغلب عليها الكالسيوم كربونات .
- التوصية باستخدام فلاتر لإزالة العسر والأملاح الزائدة والتخلص من الحديد والمنجنيز .

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