EGYPTIAN JOURNAL OF AQUATIC RESEARCH ISSN: 1687-4285
VOL. 33 NO. 1, 2007: 22-42

IMPACT OF AGRICULTURAL ACTIVITIES ON GROUNDWATER QUALITY OF THE ITAY EL BAROUD AREA, WEST OF ROSETTA BRANCH, EGYPT

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Keywords: Agricultural Activities, Hydrogeochemistry, Contamination, Nutrients.

ABSTRACT

Groundwater is the main source of water supply in the Itay El Baroud area, Beheira Governorate, west of the Rosetta Branch. The water-bearing formation is belonging to made up of Pleistocene sand and gravel. The Pleistocene aquifer is directly affected by the agricultural canals and drains as well as the Rosetta branch of the Nile. Recently, groundwater exhibits significant quality problems due to high concentrations of potentially harmful constituents such as ammonia, manganese, lead, cadmium and chromium. The present study aims at understanding the spatial distribution and sources of groundwater constituents and studying the effect of contaminants from agricultural practices on groundwater quality of the Itay El Baroud aquifer. Thirteen wells ranging in depth from 48-67 m. and six surface water sites were sampled and chemically analyzed for major and some minor and trace constituents. The groundwater from the wells tapping this aquifer exhibits low TDS, relatively high NH_3, Mn, Pb, Cd and Cr contents. Hydrogeological cross-sections, water-level contour map and iso-salinity contour map were constructed. On the other hand, the water types, the hydrochemical coefficients, Schoeller diagram and Piper trilinear diagram show the effect of surface water recharge to the aquifer. The results reveal that some groundwater samples in Itay El Baroud area are not safe for drinking purposes. More treatment for groundwater to eliminate the harmful constituents is recommended.

1. INTRODUCTION

The area west of Rosetta Branch generally lies in an arid belt. It is characterized by long hot summer and short warm winter. The mean monthly minimum air temperature is 6.2°C recorded in February and the mean maximum air temperature is 35.7°C recorded in July and August. The mean monthly values of evaporation range between 2.64 mm/day in December and 13.6 mm/day in June. The mean monthly values of rainfall range between 30.48 mm in December and 5.75 mm in May (Embaby, 2003).

Itay El Baroud area lies to the west of Rosetta Branch of the Nile River between latitudes 30° 48' 00" – 30° 58' 00"N and longitudes 30° 35' 49" – 30° 47' 04"E (Fig. 1). The Itay El Baroud area depends on groundwater for drinking purposes. The groundwater is extracted through several wells scattered in the area of study and tapping the Pleistocene aquifer. The groundwater level ranges between 1 and 5.13 m. Thus, the contamination of groundwater becomes possible due to agricultural activities and anthropogenic factors. The agricultural activities involve the use of pesticides and fertilizers to increase land productivity. Consequences of pesticides and fertilizers application have negative impact on human health. Moreover, the anthropogenic factors are represented by sewage disposal in improperly designed septic tanks. All the above activities have led to pollution of shallow groundwater.

The present study deals with identifying the different species of contaminants through performing specialized chemical analyses for major, some minor and trace constituents in order to draw the attention to the principals of this serious problem which harm the inhabitants health in this area.

2. GEOLOGICAL SETTING

The area west of the Nile Delta is generally covered by extensive exposures of sedimentary successions belonging to Quaternary, Pliocene, Miocene and Oligocene (Fig. 2).

The area of study is characterized by a mild topography with low relief. The main geomorphologic feature that characterizes the area west of Nile Delta is the alluvial plains which extend from the Rosetta Branch of the Nile to the eastern fringes of the Maryiut tableland in the west. The alluvial plain can be distinguished into two types; the young alluvial plain which is occupied by the cultivated lands in the area of study, with flat low altitude surface; and an old alluvial plain, which lies directly south of the young alluvial plain with an elevation ranging between 25 and 108 m. These plains were dissected by drainage systems (Shided and El Sayed, 2003).

To the west of the old alluvial plains, Maryiut tableland starts and reaches an elevation of about 110 m.

Stratigraphically, the Quaternary sediments of the area west of Rosetta Branch include the soil cover and constitute the main aquifer of the study area. The subsurface sedimentary section in the western Nile Delta reaches a thickness of about 4000 m, where it rests unconformably on the basement (El Fayoumy, 1964).

The sedimentary sequence of the Nile Delta (Fig. 3) was classified into three cycles (Rizzini *et al*., 1978): a) Miocene cycle, includes Sidi Salem, Qawasim and Rosetta formations; b) Plio-Pleistocene cycle, includes Abu Madi, Kafr El Sheikh, Wastani and Mit-Ghamr formations; and c) Holocene cycle includes Bilqas Formation at the top.

Mit-Ghamr Formation belongs to Late Pliocene-Early Pleistocene age. It is composed of sand and gravel with few thin clay intercalations. The sand and gravel are more common in the southern part, while clay is dominant in the north with occasional discontinuities and intercalations of sand and gravel (Said, 1990). Mit-Ghamr Formation is capped by Bilqas Formation of the Holocene age. The Bilqas Formation is mainly composed of silt and sandy or clayey silt including some sand lenses in the lower part. It attains a maximum thickness of about 50 m in the north (El Fayoumy, 1987).

The Bilqas Formation consists mainly of clay and silt including some sand lenses, where it is generally divided into two layers. The top one consists of a varying thickness semi-pervious silty-clay layer (15-20 m) increasing northward. The underlying layer is about 10 m thick of high permeability clayey sand (Fig.4).

The soils of Bilqas Formation were divided into three types (El Nahal *et al*., 1977): a) soils of recent Nile alluvium, representing most of the delta area; b) soils of marine alluvium, are more complex; and c) sub-deltaic soils, scattered mainly in the east and south central parts of the delta.

The Nile Delta is considered as a graben-like feature, fractured in Late Oligocene or Early Miocene times. The Nile Delta occupied a large trough in the marginal part of the Mediterranean Sea. To the north, this trough is bounded by a deep rupture thrust fault. Southward, it is affected by a set of subparallel faults as well as a series of transverse faults (El Menayar, 1999).

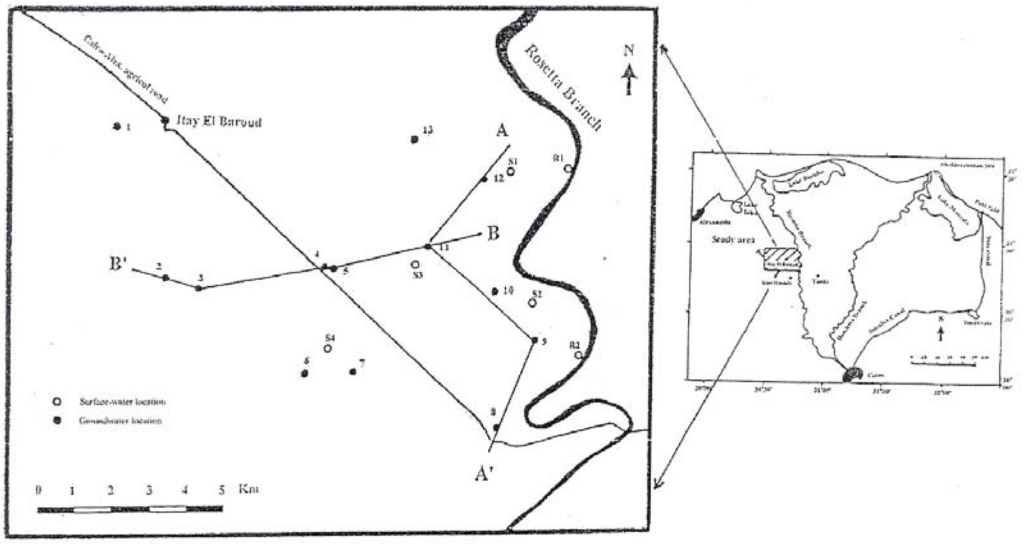

Fig. (1): Location map of the water samples and directions of the hydrogelogical cross-sections at the Itay El Baroud area, west of Rosetta Branch.

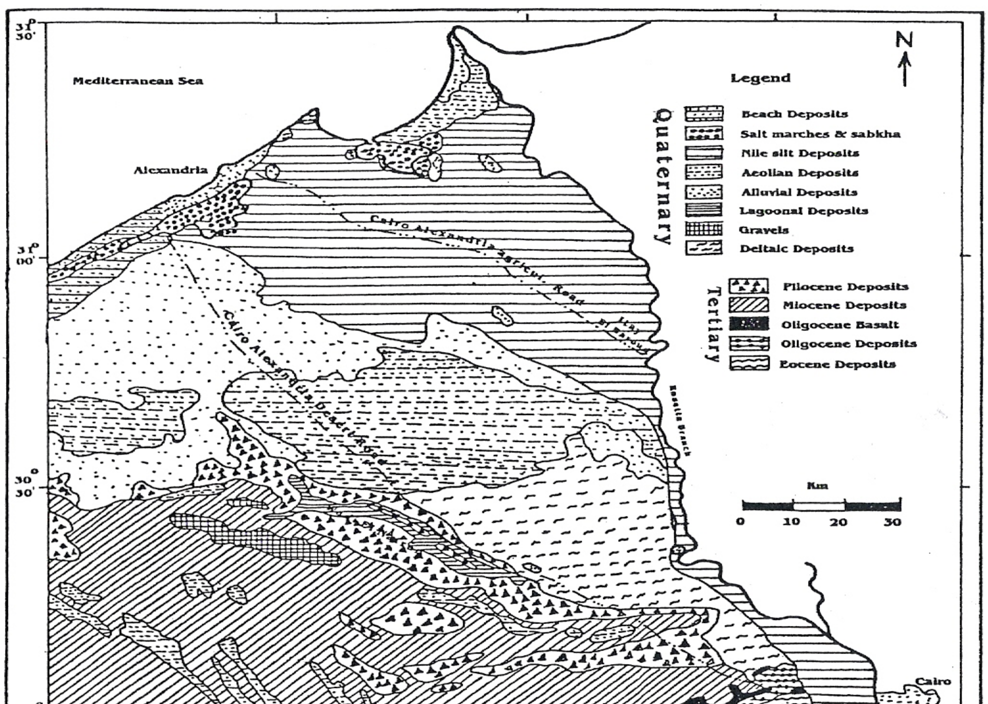

Fig. (2): Geological map of the area west of the Nile Delta (CONCO, 1987).

Period	Epoch	Formation	Thickness (m)	Facies	Lithology
Quaternary	Holocene	Bilqas	40	Deltaic	Silt and sandy or clayey silt
Quaternary	Pleistocene	Mit Ghamr /Baltim	700	Deltaic	Sand, medium-coarse, few clay intercalations
Neogene	Pliocene	Mit Ghamr /Baltim	700	Deltaic	Sand, medium-coarse, few clay intercalations
Neogene	Pliocene	El Wastani	300	Inner Neretic	Sands and sandy clays
Neogene	Pliocene	Kafr El Sheikh	1500	Lower Neritic to Bathyal	Hemipelagic fossiliferous clay, shale, siltstone, streaks of very fine sandstone (turbidites), thin limestone in NW
Neogene	Miocene	Abu Madi	300	Inner Neretic	Thick sands, some conglomerates, clay interbeds
Neogene	Miocene	Qawasim	>700	Littoral Deltaic	Poorly sorted sand and conglomerates
Neogene	Miocene	Sidi Salem	700	Bathyal	Shales, few sand intercalations (turbidites), more sandy upper part, more sandy to NE, NW.

Fig. (3): Stratigraphic sequence of the Nile Delta (modified after El Menayar, 1999 and Atwia *et al.*, 2006).

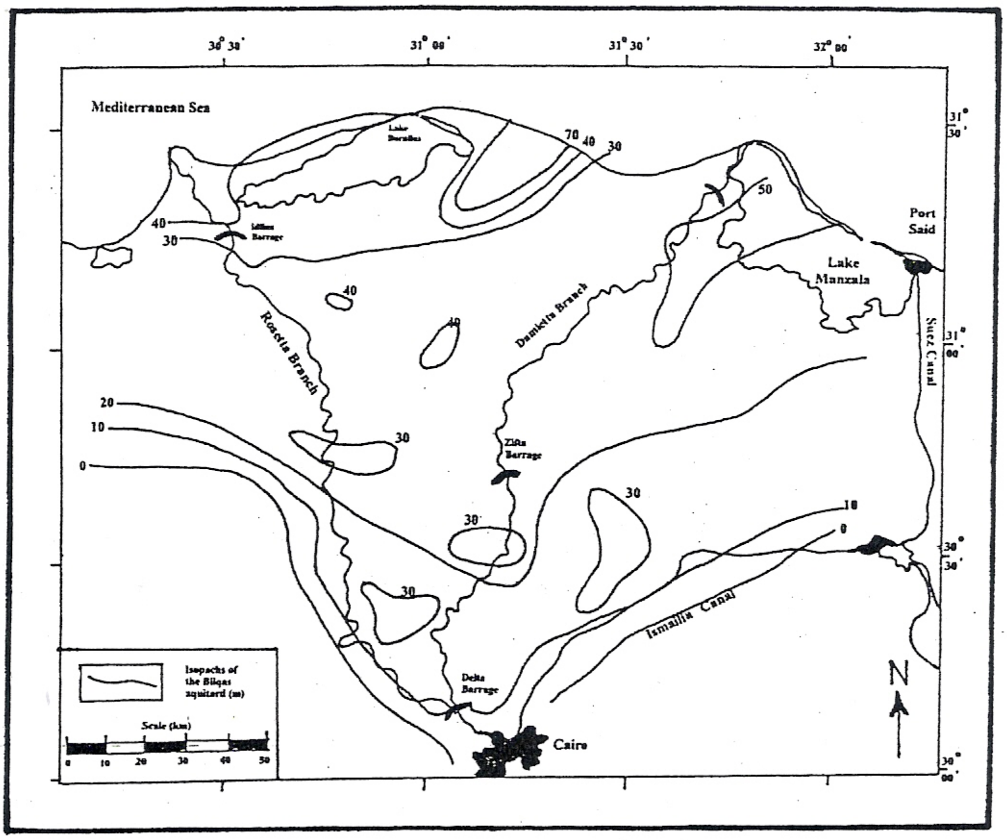

Fig. (4): Isopach map of the Bilqas Formation (after Atwia *et al.*, 2006).

3. HYDROGEOLOGICAL SETTING

The water resources of the area west of Nile Delta comprise surface water system and groundwater system. The surface water system in the area west of Rosetta Branch comprises the Rosetta Branch and various canals such as El Rayah El Beheiri, El Rayah El Naseri, El Nubariya, El Mahmoudia, and Hosh Isa canals. Most of this surface water system runs through sand and gravel of Holocene age, which are characterized by high effective porosity. Therefore, groundwater of the aquifer can easily be contaminated by the infiltrated surface waters which may have high amounts of agricultural wastes. These irrigation and drainage canals form the main source of groundwater recharge.

The groundwater of the study area is available in water-bearing formations belonging to Quaternary. The water-bearing formations in the area west of Rosetta Branch have been differentiated based on lithology into two formations: Mit-Ghamr Formation and Bilqas Formation (Rizzini *et al*., 1978).

As mentioned before, the Mit-Ghamr Formation is belonging to Late-Pliocene-Early Pleistocene times; it constitutes the main aquifer of the Nile Delta region. It consists of sand and gravel with thin interbeds of clay. The main aquifer is divided by clay layers into several connected and disconnected aquifers (Kashef, 1983).

Alternating clay and sand with gravel which exist predominantly in the northern and north eastern parts reflect the progradation cyclicity sequences of Delta (Dahab, 1993).

Bilqas Formation is belonging to Holocene time; it mainly comprises fine detrital materials ranging between the two clastic end members; clay and silt including some sand tracks and sand dunes in the northern coastal area (El Fayoumy, 1987). The thickness of these cap sediments become thinner and their grain sizes become coarser southward, its thickness ranges between 20-25 m in the southern and central parts, therefore, it acts as aquitard for groundwater aquifer in these parts. In the northern part it becomes thick and fine, attaining 50 m thickness, therefore it acts as aquiclude for groundwater aquifer (Dahab, 1993).

The upper Holocene deposits (Bilqas Formation) act as aquitard for the Plio-Pleistocene aquifer in the southern and central parts of Nile Delta. Therefore, the lower thick sand sequence of the Plio-Pleistocene (Mit-Ghamr Formation) forms a huge aquifer of the Nile Delta. It is considered as leaky aquifer in south and middle of Nile delta and as a free aquifer in the western and eastern borders of the Nile Delta, where the thickness of the upper Holocene deposits decreases. To the north, the Holocene deposits act as aquiclude for the Plio-Pleistocene aquifer, therefore the aquifer becomes a confined one.

Two hydrogeological cross-sections running north-south and east-west were constructed (Figs. 5 and 6) based on the detailed lithologic descriptions of BWADC (2005) for the water wells in the study area. The cross-sections gave a complete picture for the subsurface succession where the geologic formations are mainly coarse sand and gravel comprising the main aquifer with few clay and fine sand lenses and the top layer is a clay cap. The water depths range between 1 to 5.13 m (BWADC, 2005).

The constructed water-table contour map for the Bilqas Formation (Fig. 7) shows that the groundwater flow is mainly towards north and northwest. There is a local flow in the vicinity of well 11 may be due to over pumping.

The groundwater of the study area is discharged through pumping of scattered water wells.

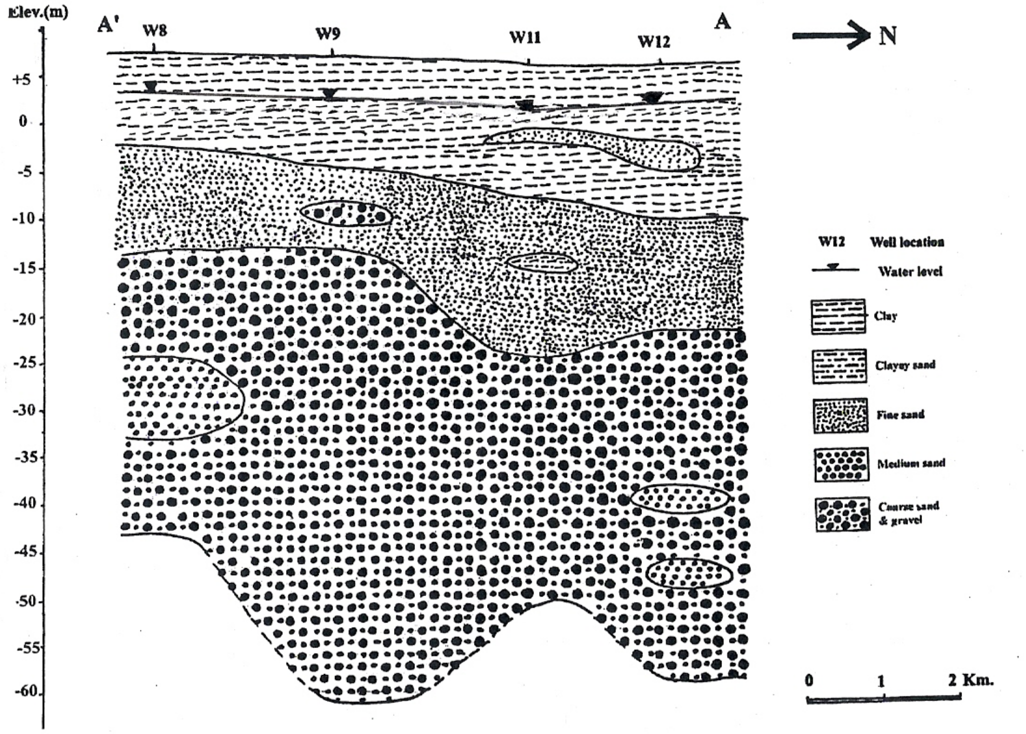

Fig. (5): A-A' Hydrogeological cross-section in the area of study (after BWADC, 2005). **Fig. (5): A-A' Hydrogeological cross-section in the area of study (after BWADC, 2005).**

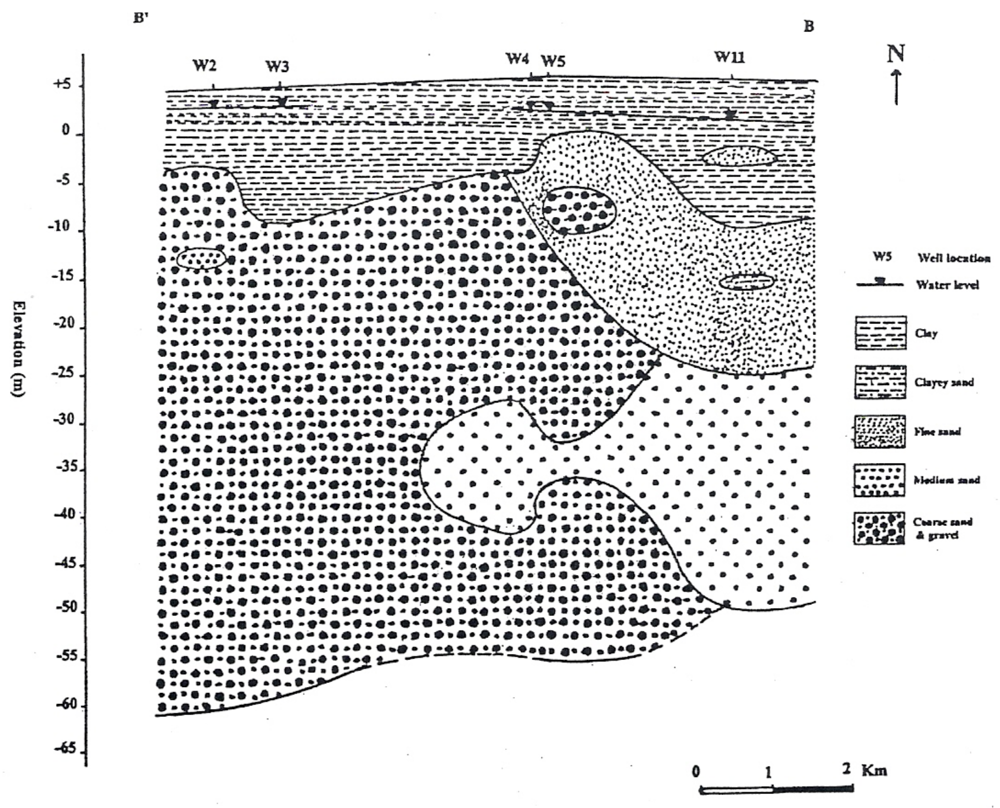

Fig. (6): B-B' Hydrogeological cross-section in the area of study (after BWADC, 2005).

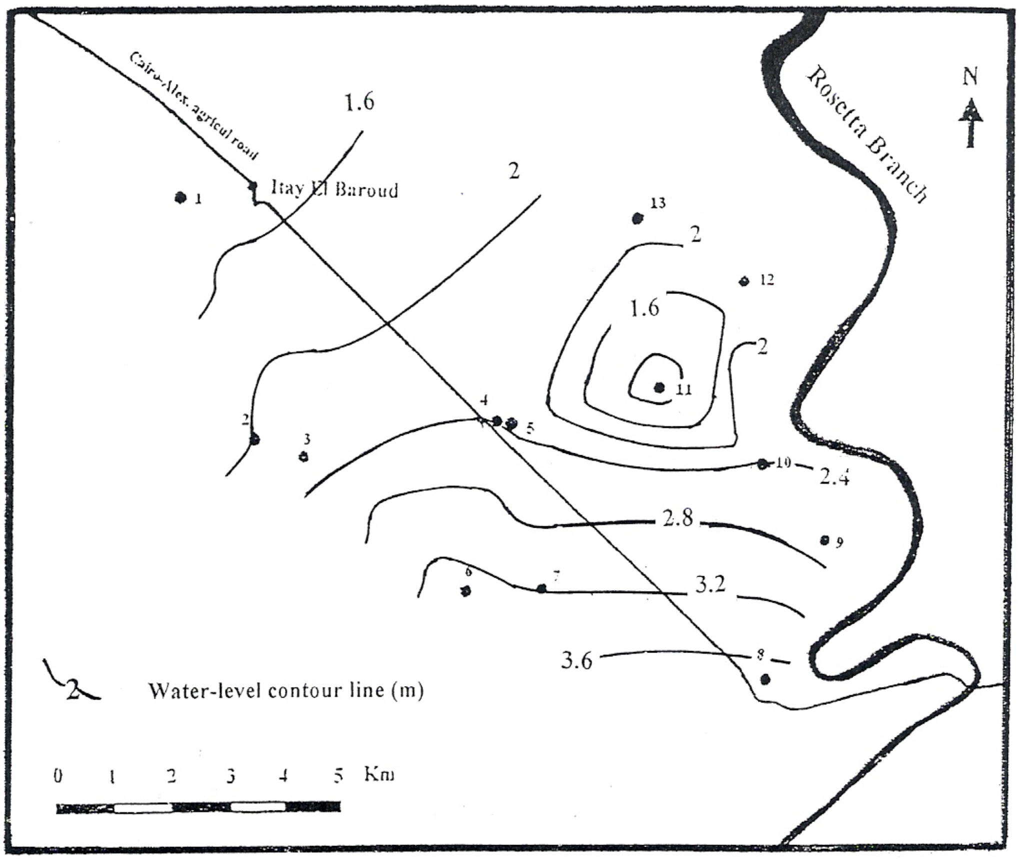

Fig. (7): Water-level contour map of the Itay El Baroud area, west of Rosetta Branch.

4. HYDRAULIC PARAMETERS

The wells are partially penetrating formations. The total depths of these wells are ranging between 48 to 67 m. The top of the Holocene water-bearing formation plays an important role in groundwater management of Nile Delta aquifer, where it affects greatly on the vertical leakage to and from the aquifer (El Menayar, 1999).

The transmissivity of the area west of Rosetta Branch is ranging between 3.5 and 3000 m^2/d. The variation in transmissivity values is mainly due to variation in lithology, where silt and clay intercalations predominate the sand and gravel (Dahab, 1993).

The hydraulic conductivity in the study area ranges between 60 and 70 m/day in southwestern and northern parts of the Nile Delta. The effective porosity of the study area ranges between 30 and 40%, indicating that the aquifer is composed mainly of coarse sand and gravel (Serag El Din, 1983).

The storage coefficient of the Plio-Pleistocene aquifer varies between 0.01 and 0.001 in southern and southwestern parts (Dahab, 1993) reflecting semi-confined condition.

5. METHODOLOGY

Groundwater was sampled from thirteen wells, two samples were taken from Rosetta Branch, and four samples from agricultural canals in order to study the mutual relation between surface water and groundwater in the Itay El Baroud area, Beheira Governorate, during March 2006. Sampling for this study was carried out at the end of the rainy winter season. The wells were purged until water-quality indicator parameters had stabilized. The samples were collected directly from the wells in acid-cleaned polyethelene bottles. The bottles were rinsed twice with sample water before the sample was collected, then filled with water. All the samples for laboratory analyses were filtered through 0.45 μm membrane filters. The samples were acidified to pH 1.5-2.0 using concentrated HNO_3 for analysis of metals.

EC and pH were measured in the field. Ca, Mg, HCO_3 and Cl were determined titrimetrically as described in APHA (1995). Na and K were measured using Corning Flame Photometer 410C. SO_4, SiO_2, B, NO_3, PO_4 and NH_3 were determined spectrophotometrically using Perkin-Elmer Lambda 3B UV/VIS Spectrophotometer. Fe, Mn, Ni, Pb, Zn, Cu, Cd, and Cr were determined using Perkin-Elmer 2380 Atomic Absorption Spectrophotometer. All the chemical analyses were performed in Geology Department and Central Laboratory of Faculty of Science, Alexandria University.

6. HYDROCHEMISTRY

Thirteen groundwater samples and six surface water samples were collected and analyzed for major and some minor and trace constituents from the Itay El Baroud area (Tables 1 and 2). The analyses are used to clarify the hydrochemical characteristics of the groundwater and to investigate the effect of pollutants on the groundwater, where this water is mainly used for drinking purposes. The surface water samples were analyzed to identify their relationship with groundwater.

The pH values of the groundwater range between 7.3 and 8.1 and between 7.35 and 8.25 for surface water indicating slightly alkaline water conditions. The salinity of groundwater ranges between 397.6 mg/L in the center of the study area to 751.2 mg/L in the northwestern part of the area of study and 753 mg/L in the northeastern part. On the other hand, the salinity of surface water ranges between 247.05 and 383.9 mg/L. The iso-salinity contour map (Fig. 8) of the groundwater shows that low values are observed in the center of the study area near surface irrigation water canals (e.g. El Rayah El Beheiry, El Rayah El Nasery) and at the extreme southeastern part near the Rosetta

Branch reflecting possible recharge from these surface water bodies. The groundwater salinity increases towards northwest, west and east, which coincides more or less with the groundwater flow direction (Fig. 7). Moreover, increase of salinity (751.2 -753 mg/L) coincides with the flow direction which may also be attributed to local environmental conditions such as leaching from soil zone of the cultivated lands. Increase of salinity may be due to leakage of waste water from septic tanks that are used for its disposal.

6.1. MAJOR CONSTITUENTS

The ion dominance of the groundwater from the Pleistocene aquifer of the study area (Table 1) shows the predominance of bicarbonate ion over chloride and sulfate. Whereas, the cations show two types of predominance: Ca>Na>Mg (9 samples) and Na>Ca>Mg (4 samples). This ionic dominance suggests meteoric origin of groundwater.

Accordingly, groundwater of the Itay El Baroud area can be classified into two water types: HCO_3>Cl>SO_4, Ca>Na>Mg (9 samples), and HCO_3>Cl>SO_4, Na>Ca>Mg (4 samples).

On the other hand, surface water of the Itay El Baroud area shows two water types: HCO_3>Cl>SO_4, Ca>Na>Mg (4 samples), and HCO_3>Cl>SO_4, Ca>Mg>Na (2 samples).

Schoeller's diagram (1962) revealed the close relationship between groundwater and surface water (Fig. 9).

The results of major ion concentrations were plotted on Piper diagram (Fig. 10). It shows that all groundwater and surface water samples are more or less located in the same field where Ca, Na as well as HCO_3 are greater than 50%, indicating that secondary alkalinity exceeds 50%, that is, the chemical properties of water are dominated by alkaline earths and weak acids; which also reflect good relationship between groundwater and surface water.

6.2. HYDROCHEMICAL COEFFICIENTS

The calculated values of the dominant hydrochemical coefficients (rNa^+/rCl^-, $rHCO_3^-/rCl^-$, rCa^{++}/rMg^{++}) revealed wide range of values (Table 1). The computed rNa^+/rCl^- values for the groundwater samples are more than unity (1-1.4); these values are close to that of the surface water (1.33-2.76) that reflects the influence of fresh water recharge mainly from surface water. The computed $rHCO_3^-/rCl^-$ values (1.13-2.34) reflect the dominance of bicarbonate over chloride proving the meteoric origin, where the hydrochemical composition are essentially developed by leaching process of the percolating meteoric water from surface water canals through soil zone. The calculated rCa^{++}/rMg^{++} values (1.55-2.48) for the groundwater samples of the study area revealed the abundance of calcium over magnesium. These coefficients reflect the influence of surface water recharge on the groundwater.

6.3. NUTRIENTS

Nitrate ions are detectable in soils and consequently are wide spread in the environment from food to atmosphere and water. The Nitrate concentration in groundwater and surface water is normally low but can reach high levels as a result of agricultural activities and/or contamination from human or animal wastes (WHO, 2006).

The sources of nitrate in surface water and groundwater may be due to use of nitrogenous fertilizers in agriculture (Chettri and Smith, 1995); input of organic nitrogen into soil; biological dinitrogen fixation by microorganisms (Barnes *et al*., 1992) and inputs of human and animal waste in village and urban environments.

Table (1): Results of chemical analysis of major constituents and hydrochemical coefficients in the Itay El Baroud area. (concentrations in mg/l).

	Well No.	Site Name	pH	EC[a]	TDS (mg/l)	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	rNa/rCl	$rHCO_3/rCl$	rCa/rMg
Groundwater	1	14	7.85	1000	751.20	81.90	29.50	95.00	3.00	0.00	360.10	38.00	143.70	1.02	1.46	1.68
	2	28	7.54	830	601.98	65.12	21.67	70.00	4.00	0.00	312.65	46.00	82.54	1.31	2.20	1.82
	3	25	7.50	550	397.60	45.80	11.20	50.00	3.00	0.00	220.70	12.00	54.90	1.40	2.34	2.48
	4	R4	7.84	820	591.25	67.21	24.90	63.00	4.00	0.00	283.71	52.00	96.43	1.01	1.71	1.64
	5	R5	7.51	670	496.03	53.30	19.50	55.00	4.00	0.00	257.89	37.00	69.34	1.22	2.16	1.66
	6	37	7.58	1000	691.70	68.43	24.22	95.00	10.00	0.00	295.54	62.00	135.77	1.08	1.26	1.71
	7	38A	7.61	1000	696.59	81.20	28.90	80.00	7.00	0.00	311.79	66.00	121.70	1.01	1.49	1.70
	8	44A	7.85	700	494.63	56.39	18.45	60.00	4.00	0.00	249.28	14.00	92.51	1.00	1.57	1.85
	9	33	7.72	890	631.15	71.98	28.11	66.00	4.00	0.00	320.51	48.00	92.55	1.10	2.01	1.55
	10	30	7.54	1050	707.87	83.13	21.65	98.00	5.00	0.00	289.43	61.00	149.11	1.01	1.13	2.33
	11	26	8.10	830	586.30	63.70	19.80	80.00	4.00	0.00	280.70	22.00	116.10	1.06	1.40	1.95
	12	22	7.30	1100	753.00	89.30	25.30	95.00	5.00	0.00	382.60	11.00	144.80	1.01	1.54	2.14
	13	16	7.74	700	549.60	69.40	19.20	60.00	4.00	0.00	303.60	5.00	88.40	1.05	2.00	2.19
Surface Water	R1	Rosetta Br.	7.35	500	343.50	30.00	16.00	34.00	6.50	0.00	220.00	18.00	19.00	2.76	6.73	1.14
	R2	Rosetta Br.	7.75	460	336.50	34.00	16.00	32.00	6.50	0.00	213.00	16.00	19.00	2.60	6.51	1.29
	S1	Surface Canal	8.25	350	247.05	25.64	10.56	28.00	4.00	0.00	115.40	31.00	32.45	1.33	2.07	1.47
	S2	Surface Canal	7.97	550	382.12	39.81	20.40	37.50	5.00	0.00	210.39	38.00	31.02	1.86	3.94	1.18
	S3	Surface Canal	8.05	550	383.90	41.50	19.40	37.50	5.00	0.00	214.70	28.00	37.80	1.53	3.30	1.30
	S4	Surface Canal	8.20	500	371.72	35.40	18.70	34.50	5.00	0.00	231.54	20.00	26.58	2.00	5.06	1.15

[a] EC : in µmohs/cm at 25°C

Table (2): Results of chemical analysis of minor and trace constituents and nutrients in the Itay El Baroud area (concentrations in mg/l).

	Well No.	Site Name	Fe	Mn	Pb	Cu	Cd	Cr	Ni	Zn	B	SiO_2	NO_3	NH_3	PO_4
Groundwater	1	14	0.02	0.02	0.15	0.02	0.02	0.02	0.00	0.00	0.10	18.00	<1	0.00	0.00
	2	28	0.14	0.59	0.66	0.00	0.00	0.00	0.00	0.03	0.05	19.00	<1	0.20	0.10
	3	25	0.11	0.16	0.11	0.00	0.01	0.00	0.17	0.00	0.04	18.00	<1	0.10	0.10
	4	R4	0.03	0.00	0.20	0.00	0.02	0.02	0.00	0.03	0.06	17.00	<1	0.00	0.10
	5	R5	0.01	0.03	0.24	0.02	0.02	0.02	0.00	0.05	0.05	17.00	<1	2.00	0.10
	6	37	0.16	0.02	0.58	0.00	0.01	0.09	0.22	0.12	0.13	15.00	1.45	0.00	0.10
	7	38A	0.02	0.15	0.48	0.00	0.04	0.00	0.00	0.01	0.07	16.00	1.75	0.10	0.10
	8	44A	0.21	0.69	0.94	0.00	0.02	0.00	0.00	0.00	0.08	17.00	<1	0.00	0.10
	9	33	0.14	0.59	0.61	0.00	0.05	0.06	0.00	0.00	0.03	16.00	<1	0.90	0.10
	10	30	0.58	0.66	0.09	0.12	0.00	0.01	0.29	0.05	0.00	15.00	<1	nd[a]	0.11
	11	26	0.01	0.38	0.57	0.03	0.00	0.00	0.00	0.00	0.12	17.00	<1	0.20	0.20
	12	22	0.25	0.05	0.10	0.04	0.03	0.02	0.25	0.01	0.07	20.00	<1	nd	0.04
	13	16	0.59	0.62	0.21	0.00	0.00	0.02	0.00	0.12	0.12	21.00	<1	0.70	0.20
Surface Water	R1	Rosetta Br.	0.12	0.04	0.00	0.00	0.00	0.00	nd	0.01	nd	3.00	<1	1.80	nd
	R2	Rosetta Br.	0.14	0.05	0.06	0.00	0.00	0.00	nd	0.01	nd	4.00	<1	0.50	nd
	S1	Surface Canal	0.67	0.10	0.06	0.00	0.02	0.01	0.11	0.01	0.15	1.00	<1	nd	0.01
	S2	Surface Canal	0.61	0.59	0.00	0.01	0.02	0.01	0.00	0.01	nd	nd	0	0	nd
	S3	Surface Canal	0.32	0.13	0.09	0.05	0.01	0.09	0.17	0.00	nd	nd	0	0	nd
	S4	Surface Canal	0.49	0.05	0.15	0.06	0.02	0.04	0.00	0.02	nd	nd	0	0	nd
Guideline (WHO, 2006)			NGL[b]	0.4	0.01	2	0.003	0.05	0.07	3	0.1-0.3	NGL	50	0.5	0.4-0.5[c]

[a] nd: not determined.
[b] NGL: No guideline
[c] (Carney, 1991).

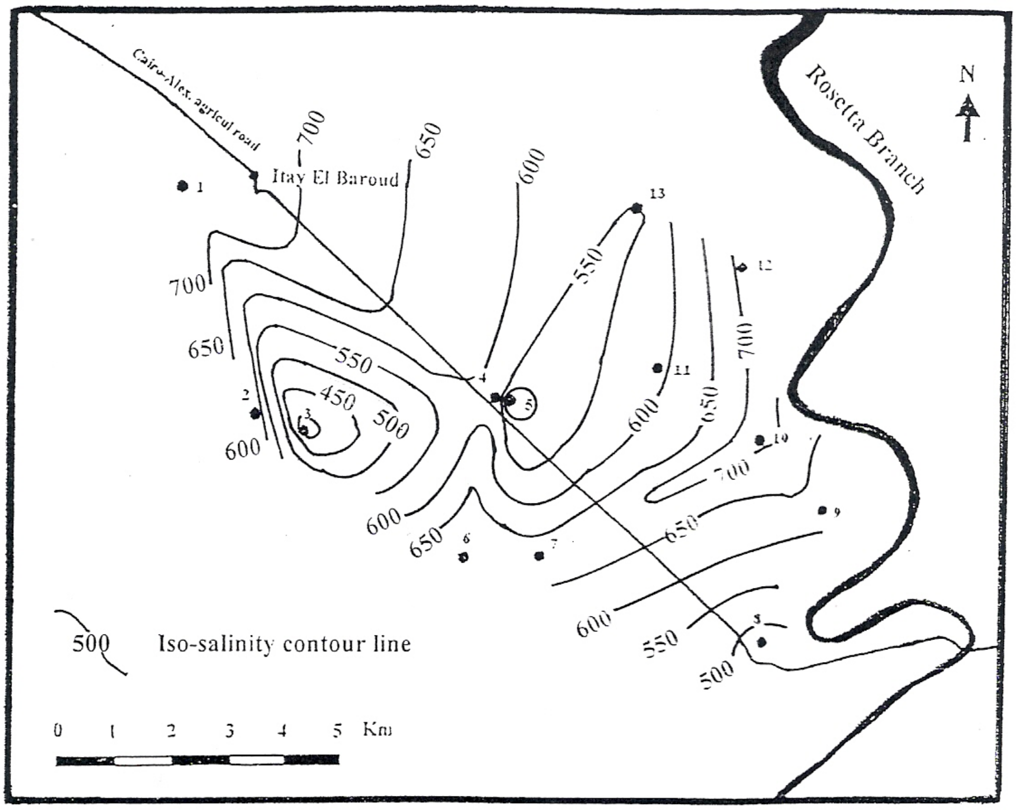

Fig. (8): Iso-salinity contour map of the Itay El Baroud area, west of Rosetta Branch.

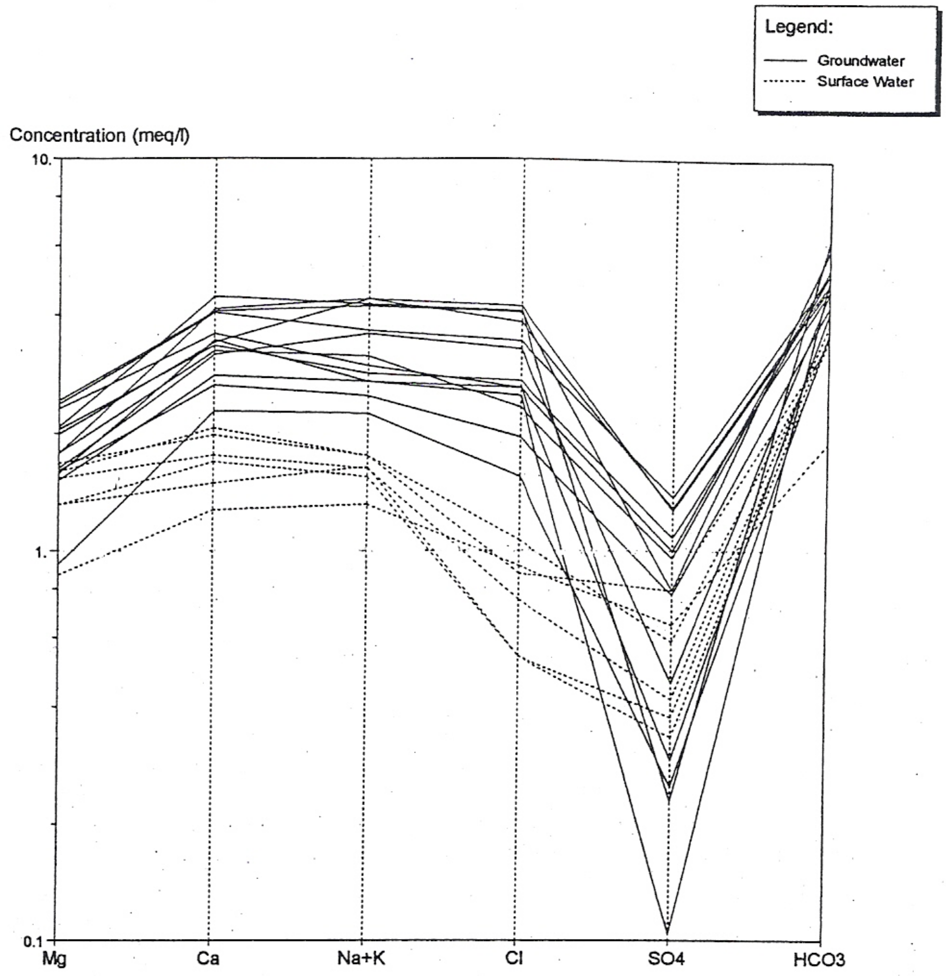

Fig. (9): Schoeller diagram of the groundwater and surface water samples of the study area.

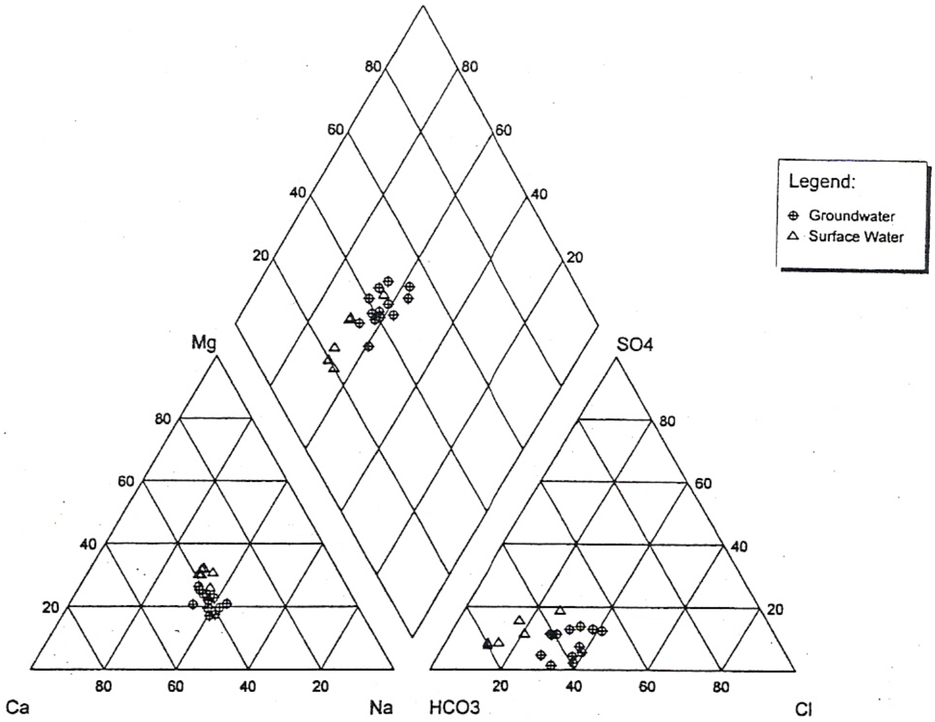

Fig. (10): Piper trilinear diagram for the surface water and groundwater samples in the Itay El Baroud area, west of Rosetta Branch.

The variation in the concentration of nitrates in groundwater is due to the soil drainage (Hill, 1982). So, the low concentrations of nitrate in the groundwater have been attributed to slow oxidation of nitrogenous compounds and to the difference in the rate of manure and nitrogen compounds application.

Concentrations of nitrate (NO_3) are in suitable range (Table 2) in both groundwater and surface water of the area of study for drinking purposes.

Pollution of groundwater and surface water by inorganic phosphorous is due to fertilizer application. The main sources of phosphates in water could be the minerals in parent material or from pollution caused by the application of fertilizers, sewage and industrial wastes (Notodarmojo *et al*., 1991).

The decrease of phosphate concentrations in groundwater may be due to strong soil absorption of phosphate ions. While the increase in phosphate ion concentrations in the surface water can be attributed to agricultural activities (Seiler *et al*., 1988).

The maximum permissible limit of phosphate in water for drinking purposes ranges between 0.4– 0.5 mg/L (Carney, 1991). The phosphate ion concentration in the groundwater and surface water samples of the study area (Table 2) is below the maximum permissible limit for drinking purposes.

Ammonia in the environment originates from metabolic, agricultural, and industrial processes. This may be also due to presence of wells in urban areas with domestic wastewater disposal using septic tanks. Natural levels of ammonia in groundwater and surface water are usually below 0.2 mg/L (WHO, 2006).

The decrease in ammonia concentrations may be due to adsorption to clay particles of the soil, and also due to the rapidly oxidation of ammonia in water to nitrite and nitrate by bacterial action (APHA, 1995).

The concentrations of nitrogen compounds were relatively low due to the following:

i) The plant utility from nitrogen compounds through direct fixation (Driscoll, 1989). Generally nitrogen compounds play an important role in plant physiology and soil metabolism (Seiler *et al*., 1988).

ii) The increase of the clay layer, where it can adsorb ammonia and so ammonia is not easily leached from the soils (APHA, 1995).

iii) The clay layer is at the surface; however, the water is abstracted from the low coarse sand layers.

Three groundwater samples (5, 9 and 13) have higher concentration of ammonia (NH_3) more than the safe limit (<0.5 mg/L), whereas the rest of samples are in the safe limits.

Boron is found naturally in groundwater, but its presence in surface water is frequently a consequence of the discharge of treated sewage effluent to surface water.

For most of the world, the concentration range of boron in drinking water is judged to between 0.1 and 0.3 mg/L (WHO, 2006).

The boron concentration ranges between 0 and 0.15 mg/L in the groundwater and surface water samples. This concentration ranges are, more or less, suitable for drinking purposes.

6.4. MINOR AND TRACE CONSTITUENTS

The silica content of natural water most commonly is in the 1 to 30 mg/l range, although concentrations as high as 100 mg/l are not unusual and concentrations exceeding 1000 mg/L are found in some brackish water and brines (Bailey *et al*., 1978).

Silica in water is undesirable for a number of industrial uses because it forms scales in equipment, particularly on high pressure steam blades. Silica is removed most often by the use of strongly basic anion exchange resins in the deionization process, by distillation, or by reverse osmosis. Some plants use precipitation with magnesium oxide in either the hot or cold lime softening process (APHA, 1995).

The silica content ranges between 15 and 21 mg/l in the groundwater samples and between 1 and 4 mg/L in the surface water samples (Table 2).

Most of water contains minor and trace constituents, either in acceptable or unacceptable limits. The sources of these constituents are much variable. For example, cadmium is released to the environment in wastewater, and diffuse pollution is caused by contamination from fertilizers. Copper is both an essential nutrient and a drinking-water contaminant. Copper concentrations in treated water often increase during distribution, especially in systems with an acid pH or high-carbonate waters with an alkaline pH. Iron is one of the most abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/l. Iron may also be present in drinking-water as a result of corrosion of steel and cast iron pipes during water extraction and distribution. The presence of lead in water is primarily from household plumbing systems containing lead pipes, solder, fittings or the service connections to homes. The amount of lead dissolved from the plumbing system depends on several factors, including pH, temperature, water hardness and standing time of the water, with soft, acidic water being the most plumbosolvent. Manganese is one of the most abundant metals in the Earth's crust, usually occurring with iron. Manganese is naturally occurring in many surface water and groundwater sources, particularly in anaerobic or low oxidation conditions, and this is the most important source for drinking-water. Nickel may be naturally occurring in groundwater where there is use of certain types of non-resistant material in wells; in such case the nickel contribution may be significant. Zinc is an essential trace element found in virtually all potable water in the form of salts or organic complexes. Although levels of zinc in surface water and groundwater normally do not exceed 0.01 and 0.05 mg/l, respectively, concentrations in tap water can be much higher as a result of dissolution of zinc from pipes (WHO, 2006).

The analysis of minor and trace constituents of groundwater samples of the study area are shown in Table 2. According to the WHO (2006) standards for drinking purposes, Cu, Ni and Zn concentrations show normal content; whereas, Mn, Pb, Cd and Cr concentrations show high content over the limits of drinking purposes. This indicates contamination either from agricultural resources (e.g. fertilizers, pesticides) or from dissolution processes from the sediments under reducing conditions or from industrial sources. Additionally, presence of these constituents in the surface water samples coincides with those of groundwater indicating the relationship between groundwater and surface water.

Most of the contaminated wells are located near the Rosetta Branch where many industrial plants dispose their wastes, especially those near Kafr El Zayat directly to the east of the study area.

The groundwater of the study area is within the safe limits for drinking purposes relative to major constituents, nitrate, phosphate, boron, Cu, Ni and Zn, whereas; it is above the permissible limit for drinking in some water samples relative to ammonia, Mn, Pb, Cd and Cr.

7. CONCLUSIONS

The Itay El Baroud area depends for drinking purpose on groundwater from the Pleistocene aquifer which is made up of sand and gravel with few clay lenses. These sediments are capped by clay and loam that leads to the development of semi-confined condition. The agricultural activities are concentrated on this soil cap because of its high fertility. The accompanying activities; such as fertilizers application, have led to contamination of groundwater. The depth of groundwater ranges between 1 and 5.13 m. and the groundwater flow is mainly towards north and northwest. Most of groundwater and surface samples have the water type: HCO_3>Cl>SO_4, Ca>Na>Mg. From the calculated hydrochemical coefficients and the constructed Schoeller and Piper diagrams, it can be concluded that surface water irrigation system is the main source of recharge to groundwater.

Consequently, the groundwater in the area of Itay El Baroud requires special treatment to be suitable for drinking.

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