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RESEARCH ARTICLE

HYDROCHEMICAL CHARACTERISTICS AND WATER QUALITY ASSESSMENT OF UNDERGROUND WATER IN THE BEACH ZONE BETWEEN QUSEIR AND SAFAGA, RED SEA, EGYPT

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ABSTRACT

Water quality is the critical factor that influence on human health, it is mostly based on the hydrochemical characteristics which reveals the suitability of water for drinking and agriculture. The beach zone of Red Sea in Egypt is considered as one of the most promising areas for development in the Eastern Desert, especially for the agricultural activities. The underground water would be one of the most important resources for such development process. The underground water in the beach zone is of great importance where it is the unique source for drinking and irrigation water. The main target of this study is to evaluate the suitability of underground water for drinking, domestic, industrial and irrigation purposes. Also, this study is to assist and outline how Egypt will safeguard its water resources in the future, both with respect to quantity and quality and how it will use its resources in the best way from a socio-economic and environmental point of view. To assess the water quality, underground water were collected and subjected to analysis for chemical characteristics. The analysis provides information on physico-chemical properties (pH, density, specific gravity, electrical conductivity, resistivity, total dissolved solids, salinity, alkalinity and hardness) as well as major and minor constituents were also determined for nine water wells selected between Quseir and Safaga cities. The results were compared with the standard permissible limits. In general, data analysis indicates that most of the studied shallow wells require treatment before using it as drinking water or as irrigation water. Different sources of pollution were detected as sea infiltration, decay of organic matter, industrial, agriculture and domestic wastewater.

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INTRODUCTION

The beach zone of Red Sea in Egypt is considered as one of the most promising areas for development in the Eastern Desert, especially for the agricultural activities. The underground water would be one of the most important resources for such development process. Most of the underground water in this area came from the water discharges from the surrounding high land areas. The plain area located to the east of the study area is recharged from the infiltrated water after irrigation and/or rain water. The underground water in the beach zone is of great importance where it is the unique source for drinking and irrigation water. The shallow Quaternary aquifer is only found in this area as a local aquifer. This aquifer ranges from 3-15 meters in thickness and exists under unconfined conditions. In fact, Egypt faces water crisis even in the Nile Delta, therefore, the overall objective of this study is to assist and outline how Egypt will safeguard its water resources in the future, both with respect to quantity and quality and how it will use its resources in the best way from a socio-economic and environmental point of view. The study area (Fig.1) is located between Safaga city in the north and Quseir city in the south. It is bounded by

latitudes 26° 00 and 27° 00 N. it covers an area of about 6000 Km². The main target of this study is to evaluate the suitability of the underground water for drinking, domestic, industrial and irrigation purposes. This area characterized by different deep and shallow aquifers, ranged in age from Cretaceous up to the Pleistocene and Holocene of Quaternary. The aquifers in the studied area are only recharged from the annual rainfall on the main highest mountains of Red Sea basement rocks, (as for example; Gebel Shayib el Banat, 2187ft. a.s.l, Gebel Abu Harba 1706ft. a.s.l, Gebel el sibai 1477ft a.s.l., Gebel Abu Hamr 1433ft a.s.l., Gebel Fatira 1355ft. a.s.l., Gebel Abu dokhan 1661ft. a.s.l. and many others). (Egypt road map, 1977) In general, the Red Sea coastal strip is characterized by hot dry summers and relatively warm dry winters. While the basement hills and mountains are characterized by rainy climate and high humidity in summer, and low winter temperature including snow on the hills. The aquifers in the studied area are only recharged from the main highest mountains in this area. Renewable underground water resources are estimated at 800 to 1000 million m³/year. Perhaps 50% of this water flows out to the sea or evaporates through sabkhas or through the main wadies in the studied area (as Wadi Safaga, Wadi Abu Ziran, Wadi Karaim, Wadi Asal, Wadi Abu shihat, Wadi Fatira, Wadi el Atrash. and many others).

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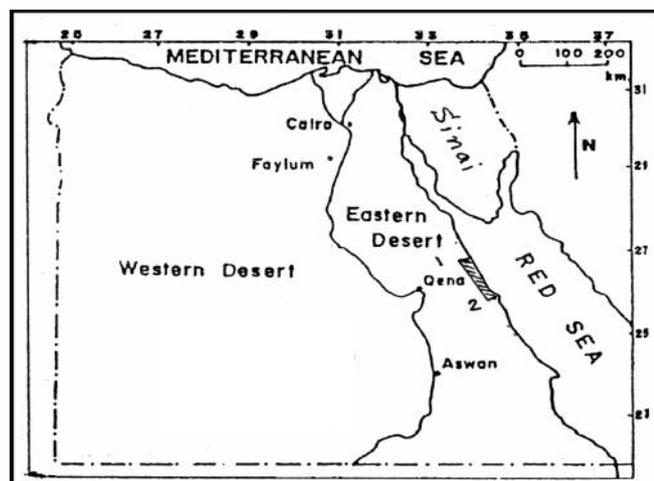


Fig. 1. Location map : 1- Safaga 2- Quseir

Geology of Red Sea shore line Basin

Based on the geological map of Egypt there is a narrow basin parallel to the Red Sea shore line. This basin extends from Ras Gharib in the North to Ras Benas in the south (Geological Map of Egypt, 1951). This basin is covered by Pliocene, Miocene and Oligocene Rocks. These rocks represent the beach and shore line cover which is composed mainly of sand dunes, gravels and flint which cover most of the low lands and plains in this area. While the Cretaceous rocks and Nubian sandstones appear on the western side of the beach zone of Red Sea. These rocks represent the highest mountains in this area specially in the area between Safaga and Quseir where Gebel El-Shayib and Gebel Mitiq represent the most famous heights in the area. Eocene rocks appear only in the western side near the Nile valley. Many of the water wells were drilled in the Nubian sandstone aquifer and thousands of people are depending on these wells in their life (Issawi *et al.*, 1971). In fact, Red Sea plain represents a unique sedimentary basin to the east of Red Sea highs where sediments of different geological ages had been deposited starting from lower Cretaceous up to Quaternary age. These formations in general increase in thickness from West to East. Red Sea plain has many underground basins such as: Lower Cretaceous basin, Miocene basin and Quaternary basin. The last one represents the best shallow aquifer in this area and its sediments comprise all the favorable conditions for accumulation and preservation of the underground water. The age of these sediments is Holocene and Pleistocene composed mainly of well – sorted and porous sandstones with some clay and calcarenite intercalations (Issawi *et al.*, 1971). The hydrogeology of the study area is mainly controlled by faults and geological formations. The structural geology of this area is characterized by two main parallel faults and many others intersect with these faults. Most of these faults are parallel to the sea shore line. This means that the water flows from West to East gathering the water from the high lands in the inland depression for extended periods of time, much of it would have seeped through the substrate, by primary and secondary porosity, to accumulate as underground water (Issawi *et al.*, 1971).

Hydrochemical characteristics of these underground water

Water quality is the critical factor that influence on human health, it is mostly based on the hydrochemical analysis which reveals the suitability of water for drinking and irrigation

purposes. Hydrochemical analysis of underground water depends mainly on the physico-chemical properties including pH, density, specific gravity, conductivity, resistivity, total dissolved solids, salinity, alkalinity, and total hardness and also on its constituents of major and minor elements. World Health Organization (WHO) published the guidelines for drinking water to protect public health, the concentrations of naturally occurring chemicals, such as chloride, iron, manganese, sodium etc. are not of health concern at levels, but may affect acceptability of drinking water (Bing *et al.*, 2012). Various hydrochemical parameters of underground water including the physico-chemical properties (pH, density, specific gravity, conductivity, resistivity, total dissolved solids, salinity, alkalinity, and total hardness), cations {lithium (Li^+), sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), aluminum (Al^{3+}), iron (Fe^{2+}), copper (Cu^{2+}), strontium (Sr^{2+})} and anions {fluoride (F^-), chloride (Cl^-), bromide (Br^-), nitrate (NO_3^-), bicarbonate (HCO_3^-), sulfate (SO_4^{2-})} were studied in details to assess the quality of these waters. This study was carried out on nine sampling sites, these samples were selected to represent Red Sea beach zone of Egypt. These sites are shown in Table 1.

Table 1. Location and Bir name of selected samples

Bir name	Location	Water sample No.
Bir Wadi Asal (1)	At km 20 south Quseir – Depth of water 16 meters.	W1
Bir Wadi Asal (2)	At km 20 south Quseir. Depth of water 7 meters.	W2
Bir Zaraieb	At km 10 south Quseir in Nubia S.S., depth of water 13 meters.	W3
Bir Wadi Nakheil	North Quseir, in Cretaceous S.S. and depth of water one meter.	W4
Bir Beida	Near phosphate mines, north Quseir and depth of water 7 meters.	W5
Bir Umm Qoeg (1)	South Quseir and depth of water 5 meters.	W6
Bir El-Arab	In Wadi Mubarak, south Quseir and depth of water 15 meters.	W7
Bir El-Agamy	In Quaternary sediments, north Quseir and depth of water one meter.	W8
Bir Umm Qoeg (2)	This well feeds one of the tourist villages on the Red Sea shore line south Quseir.	W9

Experimental Methods

All reagents employed throughout the experiments were analytical grade and all analyses had been achieved according to the standard methods of sampling techniques (Egyptian Analytical Method 1999).

1 - Physico-chemical properties

General physico-chemical properties, including pH, density, specific gravity, electrical conductivity, resistivity, total dissolved solids, salinity, alkalinity and hardness were determined for the water samples under study. The results are given in Table (2). All analyses had been achieved according to the following standard methods.

1.1 pH

The pH was determined using the electrometric method according to the ASTM D 1293 (Annual Book of ASTM

Standards 1992) and APHA 4500H⁺ (Clescrei *et al.*, 1998) methods. The pH was measured at 25°C using a digital pH-meter, Hanna model pH 213, equipped with a combination pH electrode, HI 1230 B.

1.2 Density and specific gravity

The density and specific gravity were determined using the pycnometer method according to the ASTM D 1429 (Annual Book of ASTM Standards 1992) and APHA 2710F (Clescrei *et al.*, 1998) methods. The specific gravity was measured at 60/60°F using a capillary stoppered pycnometer. The density, at 15°C of the water samples was calculated from results of specific gravity at 60/60°F.

1.3 Electrical conductivity and resistivity

The electrical conductivity was determined using the instrumental method according to the ASTM D 1125 (Annual Book of ASTM Standards 1992) and APHA 2510 (Clescrei *et al.*, 1998) methods. The conductivity of the water samples was determined at 25°C using digital conductivity meter, WTW, model cond 3301 equipped with a conductivity cell. The resistivity of the water samples was calculated from their obtained conductivity values.

Book of ASTM Standards 1992) and APHA 2320 (Clescrei *et al.*, 1998) methods. A suitable aliquot of the water sample was titrated to the pH 4.5 with a standard hydrochloric acid solution, calculations was done using Alkalinity calculator Ver 2.10. The alkalinity, as calcium carbonate, was calculated.

1.7 Hardness

The calcium, magnesium and total hardness, as calcium carbonate, of the water samples were calculated, according to the ASTM D 1126 (Annual Book of ASTM Standards, 1992) and APHA 2340 B (Clescrei *et al.*, 1998) methods from the determined calcium, magnesium and their total concentrations.

2 – Determination of Anions

Anions including fluoride F⁻, chloride Cl⁻, bromide Br⁻, nitrate NO₃⁻, and sulfate SO₄²⁻ were determined by the ion chromatography according to the ASTM D 4327 (Annual Book of ASTM Standards 1992) and APHA 4110 (Clescrei *et al.*, 1998) using Ion chromatography DX 600 gradient IC system (Dionex, Sunnyvale, CA, USA). The separated components were detected by auto suppressed conductivity using E D50 Electrochemical detector in the conductivity mode. An electrochemical self regenerated suppressor ASRS ultra II

Table 2. General Physico-Chemical Properties of the Studied Wells

Physico-Chemical Properties	Water Sample No.								
	W1	W2	W3	W4	W5	W6	W7	W8	W9
pH at 25°C	8.29	8.23	8.06	8.22	7.98	8.39	8.28	8.02	8.38
Density at 15°C, g/mL	1.0039	1.0055	1.0045	1.0053	1.0079	1.0041	1.0056	1.0081	1.0036
Specific gravity at 60/60°F	1.0049	1.0065	1.0055	1.0063	1.0089	1.0051	1.0066	1.0091	1.0046
Conductivity at 25°C, µS/cm	4.55	6.32	5.37	5.85	10.46	4.62	6.17	10.77	3.26
Resistivity at 25°C, ohm m	2.1978	1.5823	1.8622	1.7094	0.9560	2.1645	1.6208	0.9285	3.0675
Total dissolved solids at 180°C, mg/L	3180	4770	3785	4510	7850	3900	4930	8040	2355
Salinity, as NaCl, mg/L	1785.73	2241.23	2153.25	2483.27	5147.98	1824.69	2487.5	5186.13	1278.83
Alkalinity to pH 4.5, as CaCO ₃ mg/L	148	151	55	60	51	80.5	66	126	56
Hardness, as mg/L CaCO ₃ :									
- Ca	670.34	1016.68	856.92	982.62	2521.89	954.55	1065.02	2375.30	612.29
- Mg	502.81	652.12	394.56	826.15	844.68	576.82	668.72	1073.53	359.38
- Total	1173.15	1668.80	1251.48	1808.77	3366.57	1531.36	1733.74	3448.83	971.67

1.4 Dissolved solids

Total dissolved solids were determined according to the ASTM D1888 (Annual Book of ASTM Standards 1992) and APHA 2540 (Clescrei *et al.*, 1998) methods at 180°C by drying suitable aliquots of the water samples at 180°C in an oven.

1.5 Salinity

The salinity of the water samples were estimated from the determined chloride concentration to give the salinity as sodium chloride.

1.6 Alkalinity

The bicarbonate alkalinity was determined by the titration method according to the ASTM D1067 and D3875 (Annual

4-mm was used for suppression. Column used for separation was Ion Pac As 9-HC (4 x 250 mm) separation by 9.0 mmol Na₂ CO₃ solution at a Flow-rate of 1 ml/min. Integration was performed by chromeleon Ver. 6.30 Software (Dionex). HCO₃⁻ ions was determined by the titration method according to the ASTM D1067 and D3875 (Annual Book of ASTM Standards 1992) and APHA 2320 (Clescrei *et al.*, 1998) methods. A suitable aliquot of each water sample was titrated to the pH 4.5 with a standard hydrochloric acid solution. The result are given in Table (3).

3 – Determination of Alkali and Alkaline Earth cations

Alkali and alkaline earth cations, including Lithium Li⁺, sodium Na⁺, potassium K⁺, magnesium Mg²⁺, and calcium Ca²⁺ were determined in the water samples by ion chromatograph according to the International standard, ISO 14911 (ISO, 1998) using DX 600 gradient IC system (Dionex, Sunnyvale, CA, USA).

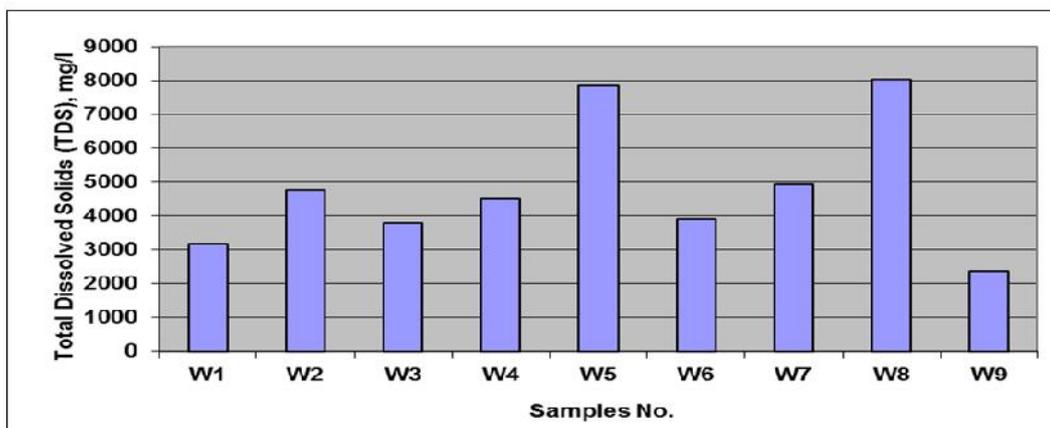
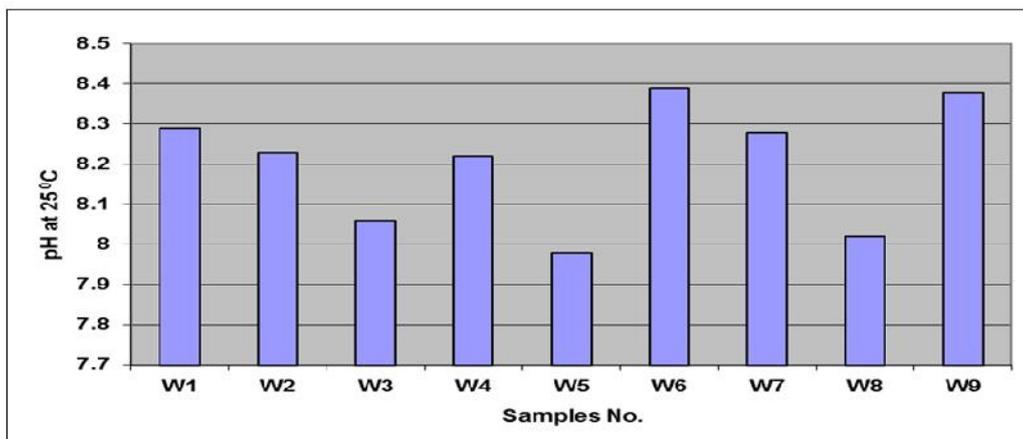
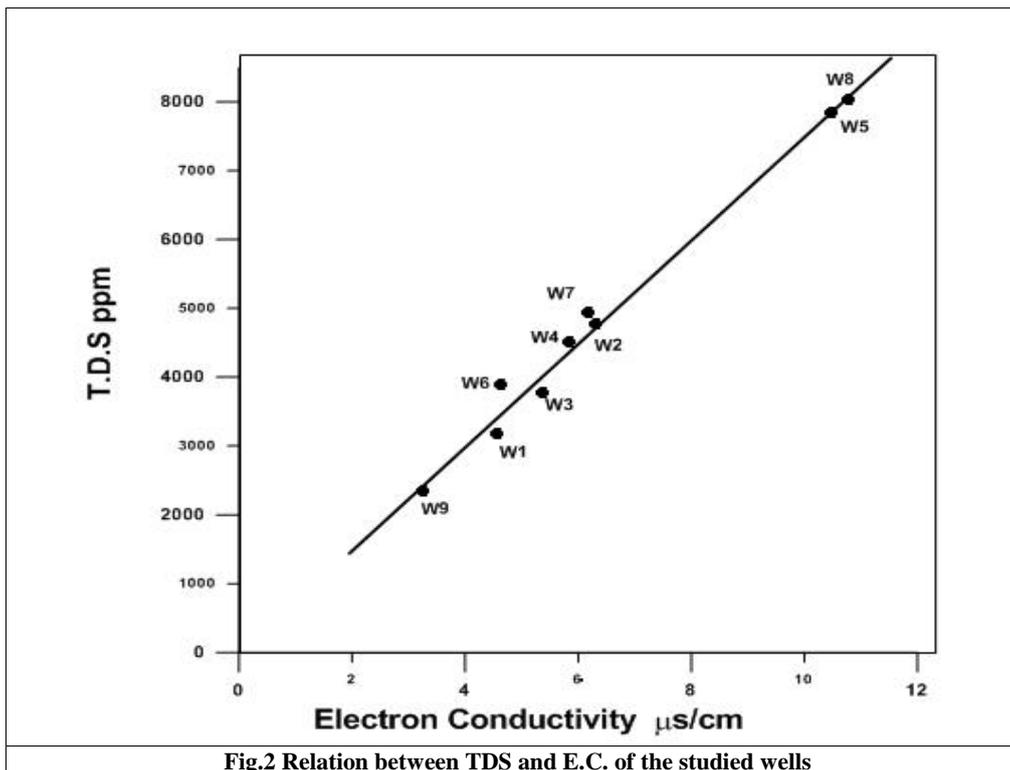
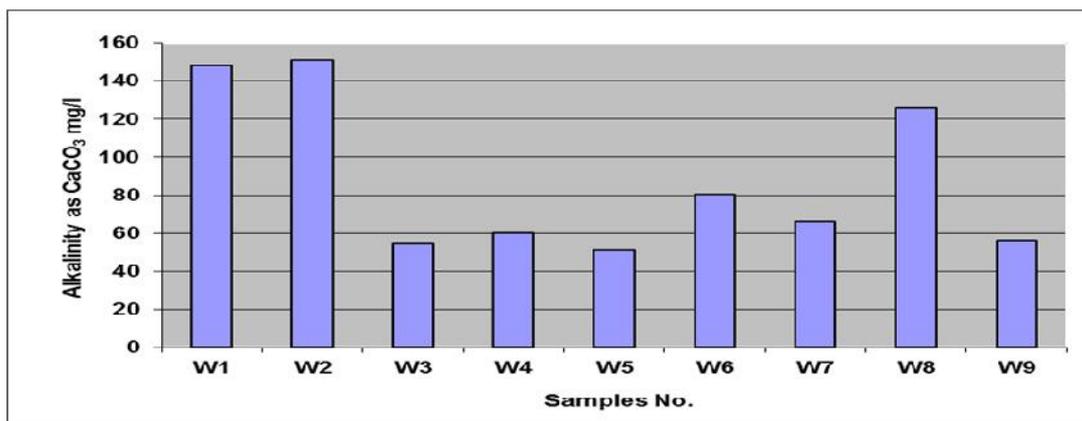
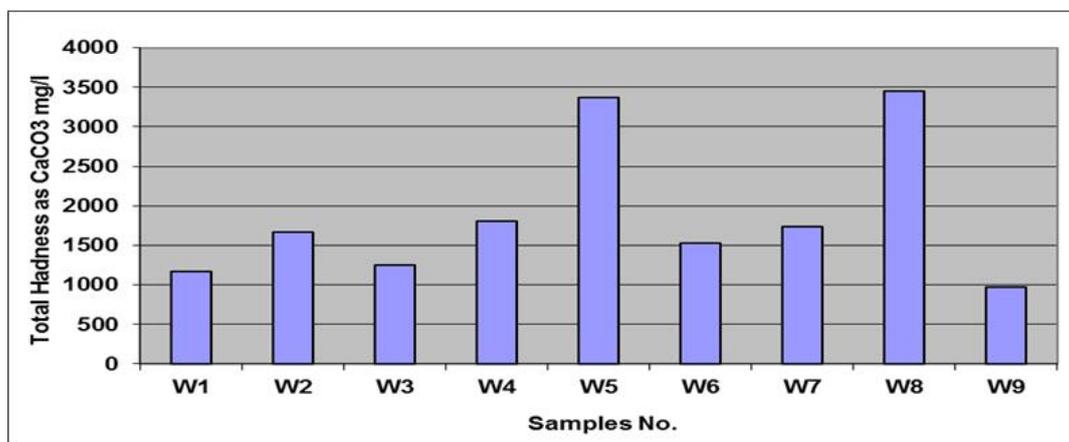


Table 3. Concentrations of Anions in Water Samples of the Studied Wells

Concentration, mg/L	Water Sample No.								
	W1	W2	W3	W4	W5	W6	W7	W8	W9
- Fluoride, F ⁻	2.441	5.805	1.519	1.982	5.904	3.14	5.83	4.83	3.18
- Chloride, Cl ⁻	1082.26	1358.32	1305	1505.02	3119.985	1105.87	1507.58	3143.11	775.05
- Bromide, Br ⁻	8.077	4.584	8.7	7.166	31.74	14.85	7.55	33.66	8.16
- Nitrate, NO ₃ ⁻	24.25	28.887	48.948	19.828	8.244	48.44	15.43	13.03	46.02
- Sulphate, SO ₄ ²⁻	835.62	1627.94	1067.5	1428.25	1944.9	1363.1	1680.7	1983.6	680.4
- Bicarbonate, HCO ₃ ⁻	180.56	184.22	67.1	73.2	62.22	98.21	80.52	153.72	68.32

**Fig. 5. Alkalinity values as CaCO₃ mg/l of the studied water wells****Fig. 6. Total Hardness as CaCO₃ mg/l of the studied water wells**

The separated components were detected by the previous auto suppressed conductivity. An electrochemical self regenerated suppressor CSRS Ultra II 4 mm was used for suppression. Column used for separation was Ion Pac CS12 A (4 x 250 mm) with Ion Pac CG 12 (50 x 4 mm) guard column using 20.0 mmol methane sulfonic acid solution at a flow-rate of 1 ml/min. Integration was performed by chromeleon Ver. 6.30 software (Dionex). The results are given in Table. 4.

4 – Determination of Heavy metals

Heavy metals including iron Fe²⁺, copper Cu²⁺, aluminum Al³⁺, and strontium Sr²⁺ were determined in acidified water samples by atomic absorption spectrometry according to ASTM D4961

(CPCB, 2000) (Annual Book of ASTM Standards 1992) using atomic absorption spectrometer ZEEnit 700P, Germany. Fe²⁺ was determined using acetylene/air flame, at wavelengths 248.3 nm, Cu²⁺ was determined by graphite furnace at wavelength 324.8 nm, Al³⁺ was determined by graphite furnace at wavelength 309.3 nm, and Sr²⁺ was determined by flame absorption at 460.7 nm using acetylene/nitrous flame, The results are given in Table. 5

RESULTS AND DISCUSSION

The present data are correlated according to the following parameters:

1- To the Egyptian standard characters of Drinking water and Ice (Analysis of Drinking water, Egypt, 1972).

2- To the World Health Organization (WHO) guidelines for drinking water (WHO, 2006).

3- To the Drinking water standards and Health Advisors (EPA, 2004).

According to these parameters the following results are concluded:

1 - Physico-chemical properties

1.1 – Color and smell

Majority of the studied water samples are clear, tasteless, odorless, in some cases the color of samples appeared slightly turbid due to the suspended materials.

1.2 pH

The pH was measured at 25°C using a digital pH-meter. The normal drinking water has pH = 7. The principle component regulating ion pH in natural waters is the carbonate, which comprises CO₂, H₂CO₃ and HCO₃⁻. Fig. 3 shows that the majority of studied water samples results were in the range (8.02 – 8.39) as measured in W8 and W6 which indicate alkaline water. This alkalinity most probably due to the presence of bicarbonate salts in these waters. The lowest value (pH = 7.98) was recorded in W5 near El-Quseir city which is slightly alkaline also. These waters may dissolve salts like Na and Ca chlorides while descending through soil and different geological beds (Barakat and Nori 2001).

1.3 Density and Specific gravity

The majority of the studied water samples have densities values between 1.0036 -1.0056 as measured in W9 and W7, except samples W5 and W8 have density values 1.0079 and 1.0081, respectively. The values of densities give indication for TDS values and conductivity results.

1.4 Electrical Conductivity

Conductivity in natural waters is the normalized measure of the waters ability to conduct electric current. This is mostly influenced by dissolved salts such as sodium chloride and potassium chloride (Sujitha *et al.*, 2011). Most of the analyzed samples have conductivity values between 3.26 μS/ cm – 6.32 μS/ cm as measured in W9 and W3 except samples W5 and W8 have 10.46 μS/ cm, and 10.77 μS/ cm, respectively. There is a positive correlation between conductivity and TDS of the water (Fig. 2).

1.5 Total Dissolved Solids (TDS)

Waters with a high TDS indicated more ionic concentration, which is of inferior palatability and can induce an unfavorable physico-chemical reactions. It was reported (Kataria *et al.*, 1996) that increase in value of TDS indicated pollution by extraneous sources. Fig. 4 shows that all the analyzed water samples have TDS over the limitation of Egyptian regularities for underground water (1000 ppm). The best water well is W9 in which TDS = 2355 ppm, while three wells (W1, W3, W6) have TDS values between 3000 – 4000 ppm. And three other

wells (W2, W4 and W7) have TDS values between 4000 – 5000 ppm. In addition, two wells (W5 and W8) have TDS values over 8000 ppm. According to (EPA, 2004) (The Drinking water standards and Health Advisors 2004), if the total dissolved solids exceeds 1000 ppm in the underground water it becomes useless for drinking but may be used for irrigation of some plants. And if TDS becomes 2000 – 3000 ppm it will be usable only for special type of desert plants and trees which can tolerate the high salinity.

1.6 Alkalinity

It is an indication of the concentration of carbonate, bicarbonate and hydroxide content in the sample. In this study, concentrations of hydroxide and carbonate were not detected in all samples, while bicarbonate were detected in all samples within the limit of Egyptian regularities (200 mg/L). The limit 500 mg/L is acceptable in the underground waters. Accordingly, all the analyzed samples are good drinking water (since the highest value is 184.2 mg/L in sample (W2) Table 3. Alkalinity resulting from naturally occurring ions like CO₃ and HCO₃⁻ are not considered as a health hazard for drinking purposes. Alkalinity is imparted by the presence of CO₂, resulting from the decay of organic matter which is the prominent activity elevating alkalinity in natural water (Sujitha *et al.*, 2011). The alkalinity, as calcium carbonate, was calculated from the concentration of bicarbonate determined. Fig. 5 shows that all the alkalinity values for the analyzed water wells are in the ranges of Egyptian regulation limits (20 – 150 mg/L). Three samples (W₁, W₂, W₈) have values over 120 mg/L, while the rest of samples have values below 80 mg/L Table 2.

1.6 Hardness

Hardness results from the presence of divalent metallic cations of which calcium and magnesium are the most abundant in underground water. The calcium, magnesium and total hardness, as calcium carbonate of the water samples were calculated from the following equation: T.H. = 2.497 Ca + 4.11 Mg. According to (Sawyer and McCarthy 1967) hardness is commonly classified in terms of degree of hardness as {(1) soft 0 – 75 mg/l & (2) moderately hard 75 – 150 mg/l & (3) hard 150 – 300 mg/l and very hard >300 mg/l. Its general acceptance level is 300 mg/l. But WHO has set allowable limit of 600 mg/l. Fig. 6 shows that the lowest value of hardness is detected in sample (W₉) which is 971.67 mg/l. while water samples No. (W₁, W₂, W₃, W₄, W₆, W₇) have hardness ranged between 1170-1800 mg/l, and the highest values are detected in samples No. (W₅, W₈) which are represented in the range 3300-3450 mg/L. In general, all wells have total hardness in the range between (1000 – 3400 mg/L). These results indicate that all the analyzed wells have very hard water and using this water in drinking may cause precipitation of Ca & Mg salts in the human body especially in kidney; however, some evidence indicates its role in heart disease (Schroeder 1960) Also, these wells are unsuitable for domestic use and cannot be used in irrigation or in different industrial uses.

2 – Anions

2.1 Fluoride (F⁻)

The major sources of fluoride in underground water are fluoride-bearing rocks such as fluospar, cryolite, fluorapatite

and hydroxylapatite. The fluoride content in the underground water is a function of many factors. Due to its strong electronegativity, fluoride is attracted by the positively charged calcium in teeth and bones causing dental fluorosis (Kapil *et al.*, 2013). The data in Table (3) and Fig. 7 show that the lowest values of fluoride are between (1.5 – 3.1 mg/L) which are detected in wells Nos. (W₁, W₃, W₄, W₆, and W₉). While the highest values are detected in samples Nos. (W₂, W₅, W₇, and W₈) which are ranged between 4.8 – 5.9 mg/L). These results indicate a very high level of fluoride in these water samples, because the (F⁻) limit is (2.0 mg/l) according to the Egyptian regulations. This level in drinking water is beneficial for dental care where the over of this limit is a harmful causing bone problem affects metabolism and the growth of cells (EPA, 1999) (Guidelines for Carcinogen Risk Assessment EPA, 1999).

as samples Nos. (W₁, W₂, W₃, W₄, W₆ and W₇). While samples W₅ and W₈ have (Cl⁻) values more than 3100 mg/L, the lowest value is recorded in water sample No. (W₉) which is 775 mg/L. Accordingly, these wells are not acceptable water supplies for drinking. The most common toxicity of chloride in irrigation water is due to that chloride is not adsorbed or held back by soils; therefore it moves with the soil-water, is taken up by the crops, moves and accumulates in the leaves (Siamak and Srikantaswamy 2009).

2.3 Bromide (Br⁻)

Bromide concentrations in natural waters depend primarily on the geochemistry of the materials in which the water has come into contact (Rodney *et al.*, 2004). The data in Table (3) and Fig. 9 indicate that (Br⁻) concentration in the analyzed samples

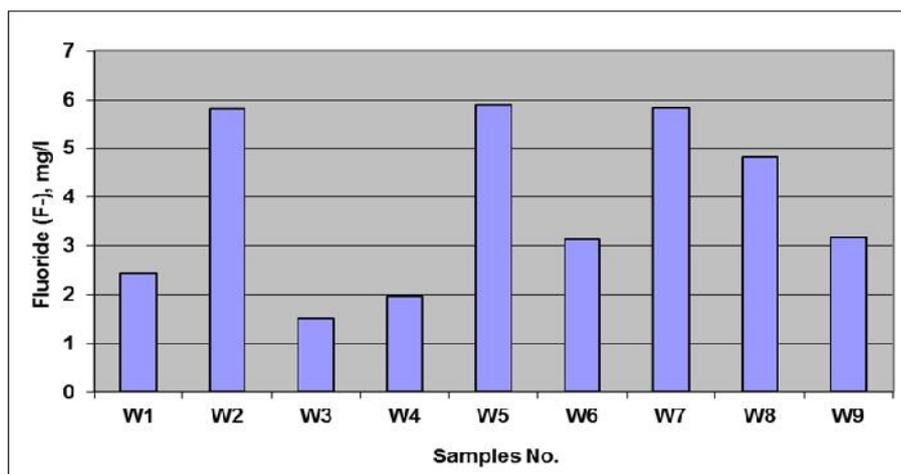


Fig. 7. Fluoride Concentrations of the Studied Water Wells

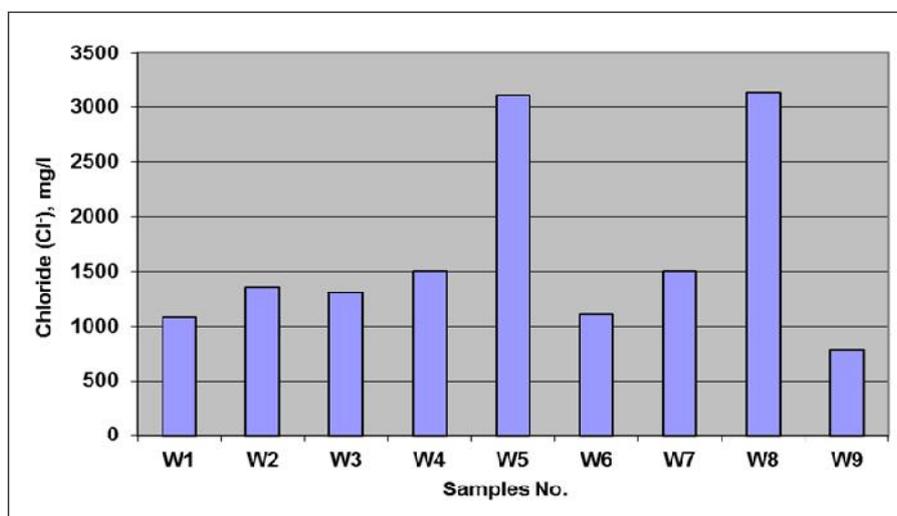


Fig. 8. Chloride Concentrations of the Studied Water Wells

2.2 Chloride (Cl⁻)

It is commonly reported as Na Cl, which causes the salty taste in potable water. According to the U.S. drinking water standards (The Drinking water standards and Health Advisors EPA, 2004) concentration of (Cl⁻) should not exceed 250 mg/L in drinking water. The data in Table (3) and Fig. 8 show that most of the analyzed samples have (Cl⁻) more than 1100 mg/L

has two groups: the first group has (Br⁻) values between (4.5 – 8.7 mg/L) in wells (W₁, W₂, W₃, W₄, W₇, W₉). While the second group has very high values of (Br⁻) ranged in wells (W₅, W₆, W₈) between (14.8 – 33.7 mg/L). The maximum permissible concentration of (Br⁻) in drinking water was set at 0.25 mg /l (Guidelines for Carcinogen Risk Assessment EPA, 1999). Accordingly, these wells are not acceptable water supplies for drinking.

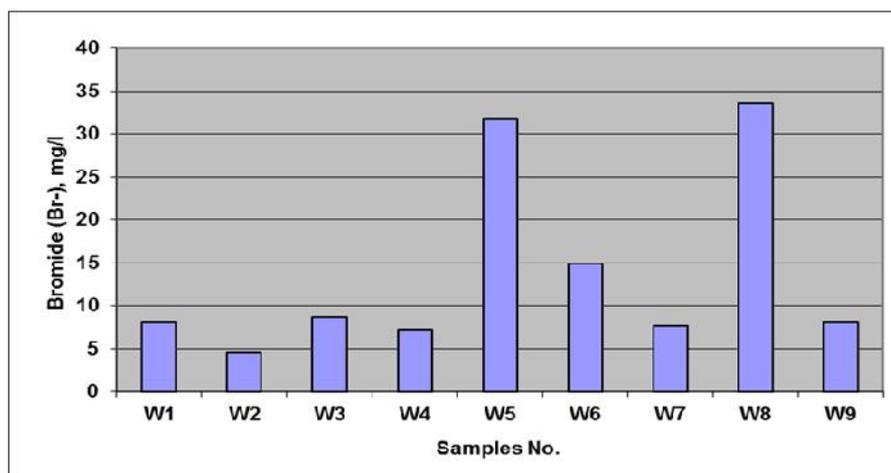


Fig. 9. Bromide Concentrations of the Studied Water Wells

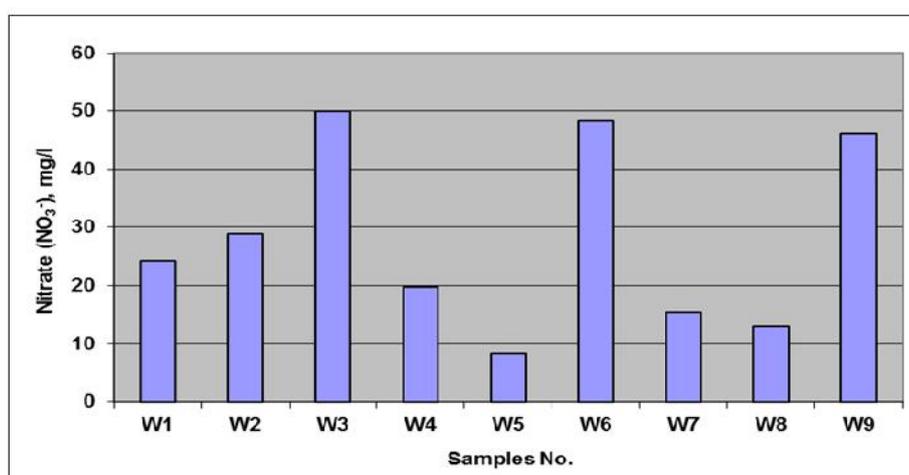


Fig. 10. Nitrate Concentrations of the Studied Water Wells

2.4 Nitrate (NO₃⁻)

Most of the analyzed samples for (NO₃⁻) were below the accepted concentration (45 mg/L) as shown in Fig. 10 for wells No. (W₁, W₂, W₄, W₅, W₇, and W₈). While samples of wells No. (W₃, W₆, and W₉) have values of nitrate between 46-49 mg/L. In general, nitrate is generated by the decay of organic matter, industrial, agriculture and domestic wastewater. It is the final form of the oxidation of decaying organic matter. Fertilizers are the major source of nitrates in the water supply (Pantnaike 1997; EEAA 2002). It generally occurs in trace quantities in surface supplies but may attain high levels in some under ground waters. The presence of nitrate usually indicate past organic pollution (Abdel Fattah and Rizk 2007).

2.5 Sulfate (SO₄²⁻)

High concentration of sulfate could cause a cathartic action on human beings, resulting in the purgation of the alimentary canal and can also cause respiratory problems (Lohani *et al.*, 2012). In this study, the data in Table (3) and Fig. 11 show that most of the analyzed samples have (SO₄²⁻) between 1000 - 2000 mg/L as samples Nos. (W₂, W₃, W₄, W₅, W₆, W₇, and W₈). While the lowest values are recorded in water samples

No. W₉ and W₁ which are 680.4 mg/L and 835.6 mg/L, respectively.

3 – Alkali and Alkaline Earth Metals

3.1 Lithium (Li⁺)

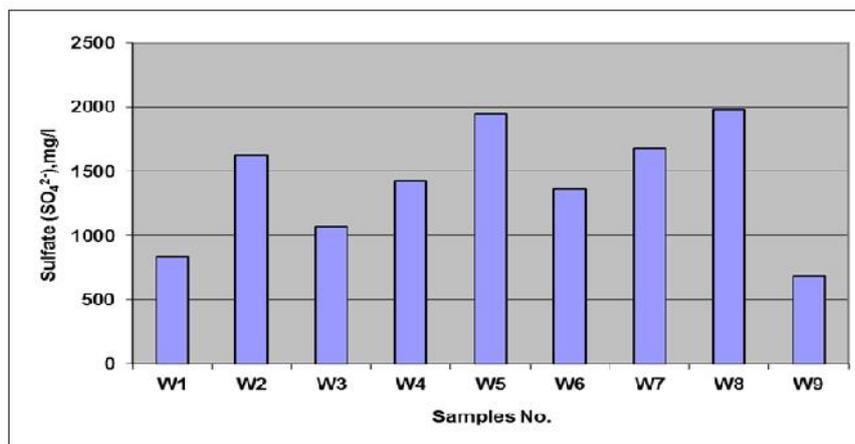
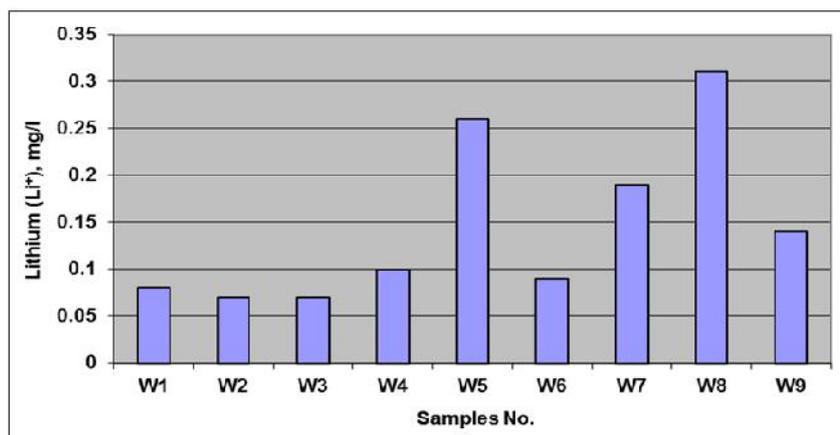
It is widely used in metallurgy in making accumulators, electric lamps, lubricants, air-conditioners, medicine, ceramics, rubber industry, nuclear technology and the production of super-pure metals. It enters the composition of 45 minerals, but only six of these are economically important. Lithium is also recovered from the brines of certain lakes (Kreiter, 1968). Also, lithium is a main component in the anhydrous phosphate rocks (Amblygonite group) (Li, AL (F, OH) PO₄). In fact, the mineral Amblygonite represents the main source for lithium in nature (Hilmy, 1964). The concentrations of (Li⁺) in the studied samples as shown in Fig. 12 ranged between (0.07 – 0.31 mg/L which are acceptable for drinking water.

3.2 Sodium (Na⁺)

It represents one of the main ions dissolved in the drinking water. (Na⁺) ions when react with (Cl⁻) ions form the (rock salt)

Table 4. Concentration of Cations in Water Samples of the Studied Wells

Concentration, mg/L	Water Sample No.								
	W1	W2	W3	W4	W5	W6	W7	W8	W9
- Lithium, Li ⁺	0.08	0.07	0.07	0.1	0.260	0.09	0.190	0.310	0.140
- Sodium, Na ⁺	626.90	961.54	801.73	851.35	1430.63	711.40	1013.96	1450.06	417.92
- Potassium, K ⁺	20.94	26.17	37.23	21.91	25.51	20.95	18.85	32.27	16.31
- Magnesium, Mg ²⁺	122.07	158.32	95.79	200.57	205.07	140.04	162.35	260.63	87.25
- Calcium, Ca ²⁺	268.46	407.16	343.18	393.52	1009.97	382.28	426.52	951.26	245.21

**Fig. 11. Sulfate Concentrations of the Studied Water Wells****Fig. 12. Lithium Concentrations of the Studied Water Wells**

or NaCl which gives salty taste for underground water. Also, this salt found in sea water and sewages with different concentrations according to the origin and path way during the formation of these waters (El-Sherbini 2007). Fig. 13 shows that (Na⁺) concentrations are above the range (250 mg/L) of the Egyptian regulations for drinking water. The highest values of (Na⁺) recorded in samples No. (W₅, W₇, and W₈) in the range (1000 – 1500 mg/L), while the lowest values of (Na⁺) recorded in samples No. (W₁, W₂, W₃, W₄, W₆, and W₉) in the range (400 – 960 mg/L).

3.3 Potassium (K⁺)

This ion is found mainly in feldspars and clay minerals, and it has high solubility in the underground water, therefore (K⁺) represents one of the most important ions for plants (EEAA 2002). As shown in Fig. 14. (K⁺) concentrations of the analyzed samples vary between 16 mg/l and 37 mg/L. These

values are not accepted in natural drinking waters, but may be useful for irrigation purposes.

3.4 Magnesium and calcium (Mg²⁺ & Ca²⁺)

Studying concentrations of (Mg²⁺ & Ca²⁺) in Table (4) and correlating these results with the international standards for drinking water (WHO, 2006), we found that (Mg²⁺) values are between (85 – 260 mg/l) Fig. 15 which indicate that only four water samples of wells No. (W₁, W₃, W₆, and W₉) are below 150 mg/L which represents the maximum contaminant level allowed in drinking water, while the rest samples are above the maximum level. On the other hand, (Ca²⁺) values are between 245 – 1000 mg/l as shown in Fig. 16, all samples are not acceptable for drinking water.

Table 5. Concentration of Heavy Metals in the Studied Water Samples

Concentration, mg/L	Water Sample No.								
	W1	W2	W3	W4	W5	W6	W7	W8	W9
- Iron, Fe ²⁺	0.119	Nil	Nil	Nil	Nil	Nil	0.027	0.341	Nil
- Copper, Cu ²⁺	0.007	0.006	0.003	0.002	0.009	0.012	0.008	0.008	0.004
- Aluminum, A ³⁺	1.175	0.468	1.073	0.619	0.007	0.824	0.649	3.17	0.693
- Strontium, Sr ²⁺	1.92	2.426	2.961	1.621	4.516	2.433	4.304	4.744	1.447

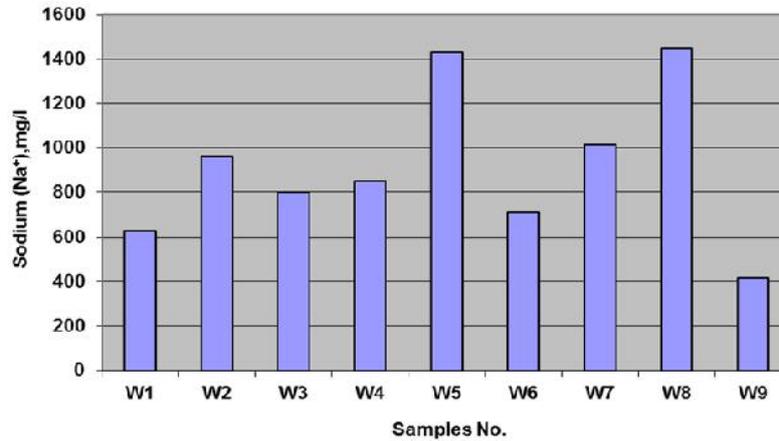


Fig. 13. Sodium Concentrations of the Studied Water Wells

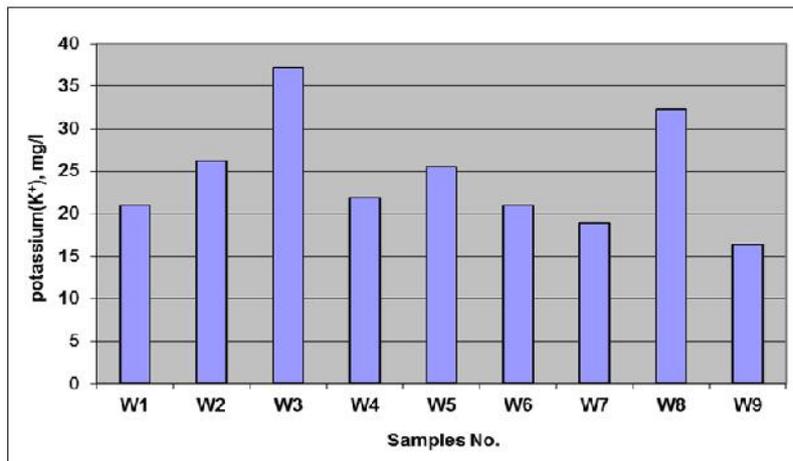


Fig. 14. Potassium Concentrations of the Studied Water Wells

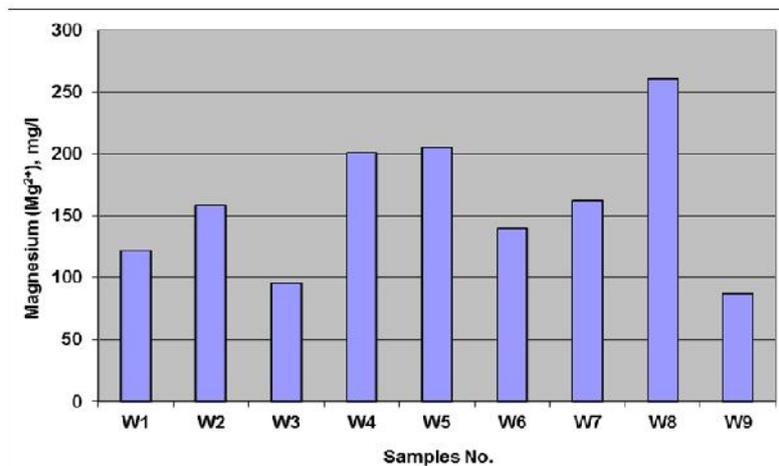


Fig. 15. Magnesium Concentrations of the Studied Water Wells

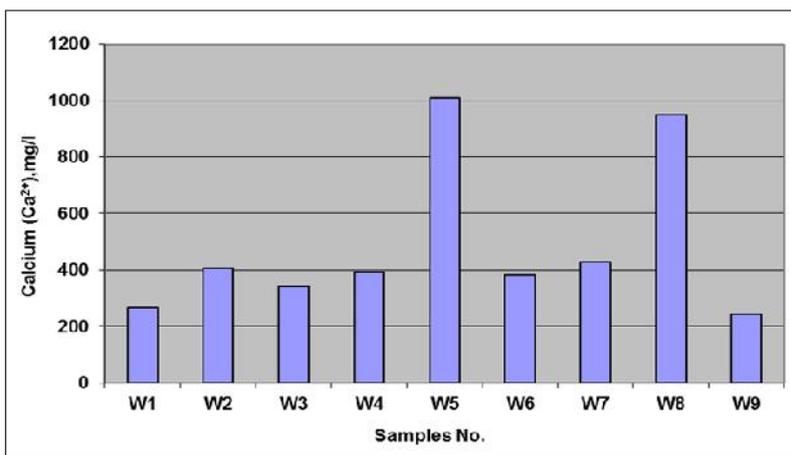


Fig. 16. Calcium Concentrations of the Studied Water Wells

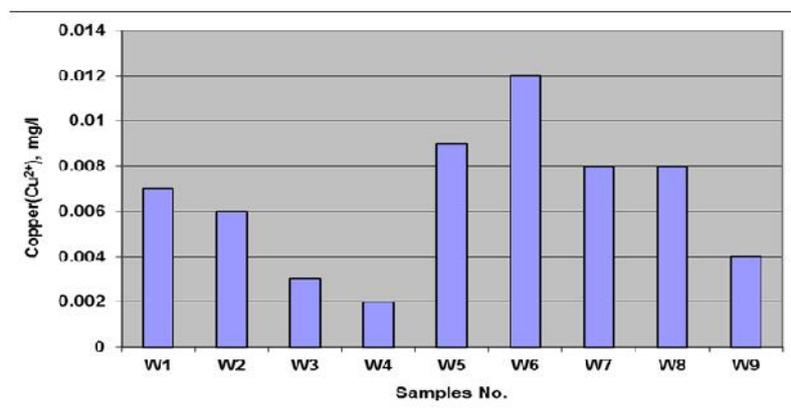


Fig. 17. Copper Concentrations of the Studied Water Wells

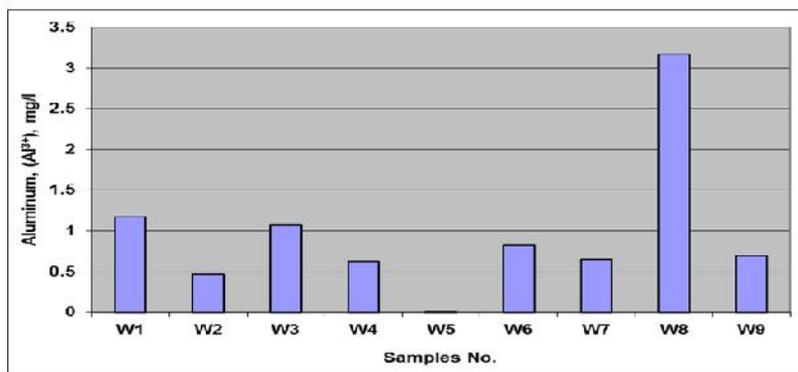


Fig. 18. Aluminum Concentrations of the Studied Water Wells

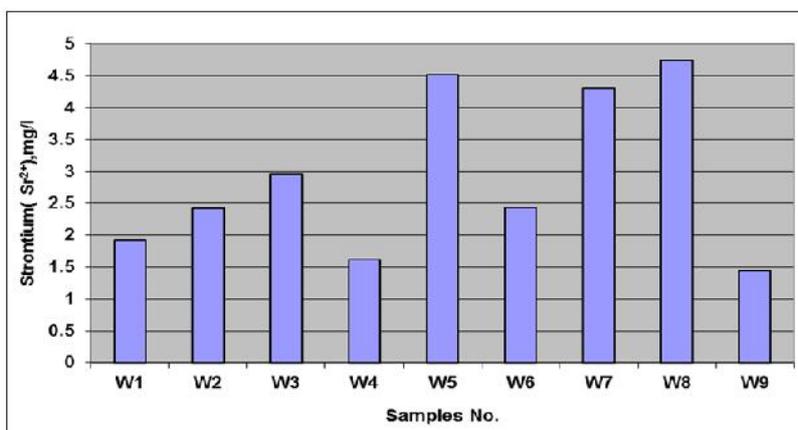


Fig. 19. Strontium Concentrations of the Studied Water Wells

4. Heavy Metals

The accumulation of heavy metals in aquatic ecosystem can lead to hazards on human and wildlife, studies have been focusing on quantifying the trace metals and their assessments on the aqueous environment (Sekhar *et al.*, 2005; Pertsemli and Voutsas 2007; Li *et al.*, 2008; Feng *et al.*, 2004; Krishna *et al.*, 2009). Heavy metals in water could be derived from both natural (weathering and erosion of bed rocks and ore deposits) and anthropogenic (mining, industrial, wastewater irrigation and agriculture activities) sources. Heavy metals may contaminate the surface and ground water resulting in deterioration of drinking and irrigation water quality. They are considered as severe pollutants owing to their toxicity, persistence and bioaccumulative nature in environment, therefore their concentrations are especially regulated in most countries (Said *et al.*, 2011). In this study, Fe^{2+} , Cu^{2+} , Al^{3+} and Sr^{2+} were determined in all filtered and acidified water samples. Table 5 and Figs (17 -19) show that the concentrations of iron in all the analyzed water samples are within the range 0.12 mg/L or nil, except sample No W8 has 0.34 mg/l. The maximum contaminant level is 0.30 mg/l. Also, copper ranged between 0.002 mg/L up to 0.012 mg/L, less than the maximum contaminant level 0.10 mg/l. Aluminum concentrations in most wells are above the accepted limit (0.2 mg/l), ranging between 0.5 up to 1.18 mg/l, except well No. (W5) has 0.007 mg/l. Strontium reference dose is 4 mg/L, therefore, all water samples are accepted as drinking water except water in three wells No. (W5, W7, and W8), where Sr^{2+} concentrations above 4 mg/L. According to (Guidelines for Carcinogen Risk Assessment EPA, 1999) Sr^{2+} is not likely to be carcinogenic to humans. In general, iron and manganese quite frequently occur together and present no health hazards at concentration of normally found in natural waters. Iron concentrations as low as 0.05 mg/L can cause color problems. In addition, some bacteria use iron and manganese compounds as an energy source and the resulting slime growth may produce taste and color problems (Abdel Fattah and Rizk 2007). Copper is essentially required for normal body growth and functions of living organisms, while high concentrations in drinking water can cause mental diseases such as Alzheimer (Said *et al.*, 2011). In drinking water only iron in concentrations above 0.3 mg/L introduces undesirable taste and stain plumbing fixtures, and also iron above 0.5 mg/L may precipitate as iron oxides in some leaves of tobacco crops (El-Sherbini 2007).

SUMMARY AND CONCLUSIONS

In general, all surface waters from rivers, lakes, many springs and shallow wells (as in the present study) require treatment before using it as drinking water. This treatment is required for removal of color, odor suspended matters, organic matters and bacteria. Also, in order to remove metals e.g. iron and manganese and for softening i.e to remove dissolved solids (e.g. Ca and Mg). Also, to neutralize acidity. The main target of all treatment methods is to obtain clear, bright, colorless, potable and whole some water, not too hard and without corrosive and solvent action on metals.

The analyzed data for the studied wells revealed that:

(1) Majority of the analyzed water wells are clear, tasteless, odorless, slightly turbid in few samples, alkaline due to the

presence of calcium and Magnesium bicarbonate in these wells. Also, all the analyzed water samples have TDS values over 1000 ppm. It ranged between 2300 ppm and 8000 ppm. Increasing TDS in these waters increase its electric conductivity.

- (2) Most drinking waters contain about 25 mg/L hardness calculated as CaCO_3 . If hardness is more than 50 mg/L, water is not allowed for domestic purposes. Since the analyzed samples have hardness ranged between 971 mg/L and 3450 mg/L. These results indicate high dissolved salts in the water of these wells. So, all analyzed water samples are undesirable for domestic use.
- (3) Fluoride (F^-) has very high level (above 2mg/L) in some of the studied wells. This level in drinking water is beneficial for dental care where the over of this limit is a harmful causing bone problem affects metabolism and the growth of cells. All studied wells are with acceptable range of fluoride, except wells No. (W₂, W₅, W₇, W₈).
- (4) Chloride in water should not exceed 250mg/L. If rise in chloride content is associated by rise in hardness (Ca^{2+} and Mg^{2+}) this may indicate sea infiltration. Thus, all the analyzed wells have very high concentrations of Cl^- which indicate sea infiltration. On the other hand, if the rise in chloride content is accompanied by rise in (NO_3^-) content, this may indicate sewage pollution. Only three wells (W₃, W₆, W₉) have high values of nitrate which may indicate pollution by the decay of organic matter, industrial, agriculture and domestic wastewater.
- (5) The water quality parameters show that the quality of the drinking water at most of the studied wells are not good and unhealthy for man use due to the different sources of pollution.
- (6) The environment affects part of this underground water and decreases its quality by increasing its salinity and also the biologic pollution reflects several environmental hazard problems in this area.
- (7) Management of wastewater is required in this area in order to control the water pollution in these aquifers.
- (8) More detailed studies and monitoring are required in many parts of the Red Sea beach zone in order to evaluate the effect of pollution on water quality.

Sources of Pollution in the underground water

Water pollution in Egypt is increasing over time. Typhoid, paratyphoid, infections hepatitis, and infant diarrhea are some endemic diseases indicating deterioration of water quality in Egypt (Hussein *et al.*, 2002). Water pollution affects not only public health but also the economic factors relevant to water quality and natural resources of reusable waters. About 90% of the rural population have no access to sewer systems or wastewater treatment facilities and they mostly depend on the on-site disposal of wastewater "septic tank". Therefore, the high level of underground water table seriously affects the infiltration and predisposes the shallow underground water to pollution (Hussein *et al.*, 2002). Many of the industrial establishments do not comply with the law, dumping their wastewater untreated into surface water bodies as well as injecting it into groundwater (Hans Catheart ICE case studies 2007). Excessive use of fertilizers and pesticides is another major source of water pollution despite the success in reducing the level of use of agro-chemicals during the past decade considerably (Gleick 1996). Extensive drainage reuse within

the Nile delta and direct drainage spillage into the Nil River along the valley increase the effect of agricultural pollution as well (Environmental Issues from US 2007).

The following summarizes the different kinds of pollutants in the underground water:

- 1- Solid materials which make water turbid with suspended particles of silt and clay.
- 2- Materials which decrease the oxygen content in water.
- 3- The mineral salts and the decayed organic matters.
- 4- The chemical pollutants such as: mercury, lead, copper, arsenic, chrome, cyanide, cadmium, Zinc, Cobalt, boron, ... and nitrate and phosphates.
- 5- Bacteria and diseased virus.
- 6- Wastewater and waste products which penetrate the soil and reach the underground aquifers.

Fertilizers, hormones, pesticides which can discharge in rivers and channels and pollute the underground aquifers.

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