HYROGEOCHEMISRTY AND RADIOACTIVITY OF GROUNDWATER IN BABA- SIDRI BASINS, SOUTHWEST SINAI, EGYPT

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ABSTRACT

The hydrogeochemistry investigations through 38 groundwater samples from Baba- Sidri basins have been done. Cations and anions distributions in all water points, as well as their trace element were content (Co, Ni, Pb, Cu, Mo, F, Mn, As, U, Ra and Th) were discussed. Also, the samples were chemically analysed for uranium (U^{238}), thorium (Th^{232}) and radium (Ra^{226}). The concentration of uranium, thorium and radium in the Quaternary alluvial aquifers is higher than those in Cambro- Ordovician sandstone aquifer and fractured basement aquifer. All ion contents have larger concentration level than the world standards, especially uranium contents in well waters of the study area. Furthermore, the water well is hydraulically connected to the storage drinking tanks, and the radionuclides analysis of samples of drinking tanks recorded the presence of very high uranium contaminant up to 3000 ppb (300 times more the maximum contaminant level). This occurs by the percolation of oxidized waters through the fractured sandstone enriched by uranium minerals, leads to the partially dissolution of the uranium and, subsequently, releasing of uranium species in groundwater.

1- INTRODUCTION

The Paleozoic succession in the southwestern Sinai (up to 320 m thick) nonconformably overlies the basement complex and in some places is covered by Permo -Triassic basalt sheet and or sill on the top. Salter (1868) reported the first identification of the Paleozoic sedimentary rocks in Sinai. Barron (1907) was the first who can subdivide the Paleozoic section in Sinai. Ball (1916) published the first map of Paleozoic rocks in southwestern Sinai.

Soliman and Abu El Fetouh (1969) subdivided the Paleozoic succession in southwestern Sinai into seven rock units from base to top as follows: Sarabit Elkhadim, Abu Hamata, Adadia, Khaboba, El-Hashash, Magharet El-Maiah and Abu Zarab formations. Weissbrod (1969) gave the term Um Bogma

Formation to the Middle Carbonate Series and in (1980) he gave the term Abu Thora Formation to the Upper Sandstone Series.

The Mn-Fe ores in the Paleozoic rock were discovered in the 2nd half of the nineteenth century. While the radioactive anomalies were discovered in the middle of the Twentieth century by Abd el Monem et al. (1958). Alshami (2004) found that the gibbsite bearing sediments extends to more than kilometer at Taleat Seleium and Abu Thora area. The study area is located in southwestern Sinai, to the east of Abu Zenima city between latitudes 28° 52 N & 29° 04'N and Longitudes 33° 18’ E & 33° 25' ' E (Fig.1).

It is accessible and connected with Abu Zenima and Abu Rudies cities with a good asphaltic roads and car tracks network. Sinai Peninsula belongs to an area lying within the arid belt, which includes the northern part of Africa and extends to southeastern Asia. The mean annual rainfall is generally less than 100 mm. The heavy rainfall during a winter season in Sinai generally occurs between November and January. The highest temperature at summer season in Sinai is in the range of 35^0- 42^0 C. The relative humidity is highest at the coastal plain and decreases in the inland direction from 69% along the coast to 60% in the inland areas. The average annual precipitation in southwestern Sinai, which includes the study area, is low (around 25 mm/y). Most of the precipitation occurs during a relatively wet period from November to March. Rains generally begin in November and attain their maximum during the second half of December, January and the first half of February. Heavy rainfall occurs in winter for very short periods and results in torrential floods in the wadies.

2- GEOLOGY OF THE STUDY AREA

The Paleozoic sedimentary rocks of south Sinai have been studied by several authors of different specializations such as geology, structure, geophysics, hydrogeologic, geochemistry, paleontology, petrography, sedimentology and REEs studies of south Sinai are numerous and diversified (Barron (1907), Ball (1916), Gindy (1961), Soliman and Abu El Fetouh (1969). Weissbrod (1969), El Aassy et al. (1986), Kora (1995), Alshami (1995), El Agami (1996), Abd El Monem et al. (1997), Shata (2002), Alshami (2003), El Aassy et al. (2006), El Aassy et al. (2011) and El –Rayes and Arnous (2015). The study area is covered by Pre- Cambrian igneous rocks, which are unconformably overlies by a thick Paleozoic sequences up to reach about 245 m (Fig. 2). The Pre-Cambrian rocks are mainly composed of granodiorites and alkali feldspar granites, while the Paleozoic sequence are mainly composed of dominant

varicolored shale, siltstone with claystone, which intercalated with dolostone rocks. The Paleozoic sequences subdivided into seven rocks units from oldest to younger as (Sarabiat El Khadim (19m) of Cambrian age, Abu Hamata

(21m) of Cambro – Ordovician age, Adadia (125m) of Cambro – Ordovician, Um Bogma (14m) of Early Carboniferous, El Hashash (33m) of Early Carboniferous, Maghareat El Maih (4m) of Early Carboniferous, and Abu Zarab (23m) of Early Carboniferous (Fig.2). The rational to select Abu Zenima area as examine area is related to since the ancient Egyptian time, that the area has been considered as an important locality for some promising ores as copper, manganese, iron, kaolin, glass sands, and recently uranium, Thorium and REEs. All these ores are incorporated in the Paleozoic rocks. Kaolin, coal and white sand are associated with Abu Thora Formation, while Mn-Fe, copper, uranium and Thorium ores are associated mainly with Um Bogma Formation. Also, it has gibbsite bearing sediments extend to several kilometers.

The Paleozoic succession represents an important rock unit in southwestern Sinai. It is mainly composed of sandstone, shale, dolostone and claystone. These rocks are well exposed at several localities (Fig. 2). The lower sandstone series, comprising Sarabit El Khadim, Abu Hamata and Adadia formations, is well developed at W. Abu Hamata, Gabal Sarabit El- Khadim, Gabal Adadia, Gabal Abu Trifia, Gabal Al Monagah, and W. Nasib.

El – Rayes, Arnous (2015) studied the hydrogeochemistry of W. Baba area. They prove that the groundwater affected by uranium mineralization is associated as a rule with low magnesium content.

Water resources in Sinai Peninsula depend on rainfall, springs and water-bearing formations. The important water-bearing formations in Sinai, as a whole, include fissured basement rocks, Nubian sandstone, Mesozoic and Tertiary carbonates and Quaternary alluvial sediments.

3- HYDROGEOLOGY

In the study area, Bir (water well) Naseib is the main source for water supply for domestic use. Bir Allouga is relatively small water well, with a depth of 15 m and represents an additional water source. There is another well located between the previously-mentioned two wells and characterized by it is brackish water.

The hydrological setting of the studied basins mainly affected by the prevailing arid climate and geomorphic setting (El-Shamy, 1983). The desert regions are characterized by scarce rainfall which represents the unique source of recharge to the existing aquifers and when exists, occasionally falls as short heavy storms causing flash flood hazard. The studied basins receive great part of runoff, most which goes to the Gulf of Suez, while the other part evaporates or percolates downward through the pore spaces and/or fractures to feed the different aquifers.

Thirty-eight (38) water points representing the groundwater of the different aquifers (Fig. 3) represent the distributions of the collected groundwater samples in the studied area.

3.1- Water - bearing Formations:

The water- bearing formations that detected in the studied area will be described in the following paragraphs:

3. 1. 1- The Quaternary Alluvial Deposits Aquifers:

The Quaternary aquifers represent the important water sources in the arid terrains such as Eastern Desert and Sinai, they are exploited in drinking and irrigation purposes because the easy and cheap digging of shallow wells in such aquifers. The alluvial deposits are diversified in their texture and composition along the course of the hydrographic basin. They consist of poorly sorted sands, silts, clays and gravels with boulders and cobbles derived from the exposed rocks.

The thickness of the Quaternary alluvial aquifer in the study area ranges from 8m to 13m. At W. Baba, area fourteen wells are present. Six of them are located at W. Baba itself, (B.1, 2,3,4,5 and 6). Another six wells occur at W. Kharige (Kh.1, 2,3,4,5 and 6) and two wells are recorded at Ramsa area (R.1 and 2). Generally, all the groundwater samples collected in the summer seasons (dry and hot). Quaternary aquifers reflect higher ability for transmitting and sorting water and good groundwater potentialities in west Sinai. The groundwater flow and accumulation in the alluvial aquifer are controlled by the aquifer thickness and the existence of irregularities in relief of the underlying basement rocks such. In addition, the successive resistant dikes dissect the alluvial deposits into several semi-isolated reservoirs. Connection between these reservoirs may take place by the overflow after heavy rainy seasons (Kassem, 1981).

3.1.2-TheCambro- Ordovician sandstone aquifer:

The most collected samples of the study area were represented in these Formation Sixteen water points. The Cambro- Ordovician sandstones (Abu Hamata and Adadia Formations) have a wide distribution in the study area. Nine wells in Adadia Formation (Ag.1, 2, 3, 4, 5, At.1, Nb.1 and Sh.1 and 2. Seven in Abu Hamata Formation (S.S. 4, 5, 6, 7, 8, 9 and 10) most wells in W. Nasib (Nb) and Allouga (Ag) were existing in Abu Hamata Formation, while nine wells exist in Adadia Formation.

3.1.3-ThePrecambrianfracturedbasement aquifer:

The basement rocks are widely distributed in the study area especially in W. El Shallal, Baba, Seih Sidri and Iqna. They are represented by metagabbro, diorite complex, older and younger granites. Eight (8) wells are tapping this aquifer, one at W. Seih (S.1), one at W. Zobier (Z.1), two at W. Seih Sidri (S.S.1-2), two at W. Shallal (Sha1-2), one at W. Iqna (S.S.3) and one at Bedda locality B.1). The fractures, the dikes and the sinuosity are the main factors controlling groundwater occurrences (Aggour et al, 2008). The fractured granites represent the main water bearing Formation in study area. Rocks are generally impermeable except through fractures (faults- joints). El- Shazly et al. (1985) stated that, in igneous and metamorphic rocks porosity occurs primarily in the form of joints and fractured. Joints porosity may be large than 2% of the total rock volume. On the other hand, the porosity of the weathered igneous and metamorphic rocks may exceed on 10%, El- Rayes (2004), El –Shamy et al. (1889) and El –Shamy, El- Rayes (1992).

4- HYDROGEOCHEMISTRY

The main objectives of the present study are to determine the chemical characteristics for the groundwater for the existing aquifers to conclude the conditions or the environments of the surrounded rocks. Thirty-eight water samples were collected from the different water wells in the study area (Fig. 3). Eight water samples from the Pre-Cambrian fractured basement aquifer, sixteen water samples from the Cambrian sandstones aquifer and fourteen water samples from the Quaternary alluvial aquifer. The chemical analyses of the collected water samples are listed in tables (1, 2 and 3). A complete chemical analysis of the groundwater includes the determination and trace elements contents. The major dissolved components in the groundwater that constitute the bulk of the mineral matters contributing to total dissolved solids (TDS) are cations of Sodium (Na^+), Potassium (k^+), Magnesium (Mg^{++}), Calcium (Ca^{++}), and anions of Chloride (Cl^-), Sulfate ($SO4^{-2}$), Carbonate (CO_3^{-2}) and Bicarbonate (HCO_3^-). Also, groundwater contains some minor and trace elements such as Lead (Pb^{+2}), Cobalt (Co), Uranium (U), Thorium (Th), Copper (Cu), Molybdenum (Mo), Chromium (Cr), (As), Cadmium (Cd^+), Manganese (Mn^{++}) and Iron (Fe^{++}).

The hydrochemichal properties of groundwater of the study area are discussed here in the below:

4. 1. Salinity distribution:

Total dissolved salts (TDS) or Salinity include all dissolved, salts ionized and non-ionized, in water and do not include organic materials and gases. Total salinity distribution is represented in (Fig.4) which shows the variation in groundwater salinity. In general, total salinity increases from upstream highlands to the downstream.

The total dissolved salts of the groundwater samples issued from the fractured basements rock aquifers that vary from 342 ppm (Bd.1) to 5800 ppm (Z.1).

The total dissolved salt of the groundwater issued from the Quaternary alluvial aquifers varies from 1810 ppm (Kh.6) to 10470 ppm (B.5). The high TDS values may referred to the dissolution of evaporate minerals enriching the source rocks.

The total dissolved salts of the groundwater issued from the Cambro-Ordovician sandstones varies from ppm 307 (S.S.10) to 3995 ppm (Ag.1). The total salinity distribution reveals that the groundwater from the Cambro-Ordovician sandstone aquifer has lower salinity than those of the fractured basement aquifers and the Quaternary alluvial aquifer. This is because the groundwater flowing through the fractured developed in the sandstone aquifer dissolves very small quantities of the minerals due to their relative insolubility, unless mineralization zone exists. This can be attributed to the following reasons:

1- The longer flow path of groundwater in the Quaternary alluvial aquifers than the basement aquifer. The surface area of contact in alluvial aquifers is more than in the fractured basement rock aquifer. The alluvial sediments have more soluble minerals and individual elements than the basement rocks.

2- The presence of the local sources of pollutions near the water points in the alluvial aquifer (Ghodief et al., 1999).

4. 2. Magnesium (Mg^{++}):

Magnesium derived principally by the weathering of rocks containing ferromagnesium minerals and form some carbonate rocks such as dolomite ($MgCO_3.CaCO_3$) and magnesite ($MgCO_3$), Figure (5) shows the distribution of magnesium in the different aquifers, the figures shows that:

I) The concentrations of magnesium in the fractured basement aquifer vary from 12.16 ppm (Sha.1) to 145.92 ppm (Z.1).

II) The concentrations of magnesium in the Quaternary alluvial aquifers vary from 48.64 ppm (Kh.6) to 486.4 ppm (B.6).

III) The concentrations of magnesium in the Cambro- Ordovician sandstones aquifer vary from 12.16 ppm (most samples) to 194.56 ppm (Ag.2).

4. 3. Calcium (Ca^{++}):

The main source of calcium in the natural water is the carbonates rocks. Calcium is readily dissolved from rocks rich in calcium bearing minerals, particularly of the carbonate rocks and sulfates minerals such as (Gypsum). Calcium and magnesium are responsible for hardness of the water. According to Hem, (1989), the average content of calcium in some major earth crust is: 22400 ppm in sandstones, 22500 ppm in shale and 27200 ppm in carbonate rocks. Figure (6) represents the distribution of calcium in the aquifers of the study area. It is concluded that:

I) The concentrations of calcium in the fractured basements aquifer vary from 4.08 ppm (Sha.1) to 400.8 ppm (Z.1).

II) The concentrations of calcium in the Quaternary alluvial aquifer vary from 160.32 ppm (Kh.6) to 1282.56 ppm (B.5).

III) The concentrations of calcium in the Cambro- Ordovician sandstones aquifer vary from 20.04 ppm (At.1) to 681.36 ppm (Ag.2).

4. 4. Sodium (Na^+):

Sodium is considered as one of the most abundant elements in the earth. Sodium content is almost related to salinity of the groundwater. The source of sodium in natural water is the weathering of Na- bearing rocks and principally depending on the components of water bearing formation, where sodium may be presented as impurity or as soluble sodium salts. According to Hem (1989), the average content of sodium in some sedimentary rocks is 4850 ppm in shale, 3870 ppm in sandstone and 393 ppm in carbonate rocks. Figure (7) shows the distribution of sodium in the different water bearing aquifers. It shows that:

I) The concentrations of sodium in the fractured basements aquifer vary from 55 ppm (Bd.1) to 1481 ppm (Z.1).

II) The concentrations of sodium in the Quaternary alluvial aquifer varies from 373.33 ppm (Kh.6) to 2000 ppm (B.5).

III) The concentrations of sodium in the Cambro- Ordovician sandstones rock aquifer vary from 55 ppm (S.S.10) to 840 ppm (Ag.1).

4. 5. Potassium content (K+):

Potassium is the more abundant element in all sedimentary rocks where these rocks contain relatively high percentage of K- bearing minerals. According to Hem (1989), shale contains 24900 ppm, sandstone 13200 ppm and carbonate 2390 ppm in average. Figure (8) shows the distribution of potassium in the different aquifer of the study area. It shows that’s:

I) The concentrations of potassium in the fractured basements aquifer vary from 3.7 ppm (Bd.1) to 16.66 ppm (Sha.1).

II) The concentrations of potassium in the Quaternary alluvial aquifer vary from 7.77 ppm (Kh.6 and 4) to 23.45 ppm (B.5).

III) Cambro- Ordovician sandstone aquifer varies from 3.88 ppm (At.1) to 15.74 ppm (Ag.2).

4. 6. Carbonate and bicarbonate (HCO_3^-):

Carbonate and bicarbonate ions presented in water are mainly derived from rocks composed mainly of calcium carbonate rocks. The concentration of bicarbonate in water is greatly depending on amount of CO_2 in water. The formation of carbonate and bicarbonate is related to the following equation:

$$CO_2 + H_2O \text{ ------------- } HCO_3^- + H^+$$

$$CaCO_3 + H^+ \text{------------- } HCO_3^- + Ca^{++}$$

Figure (9) shows the distribution of bicarbonate in the different aquifers.

I) The concentrations of bicarbonate in the fractured basements aquifer vary from 122 ppm (Sha.1, S.S.2 and S.S.1) to 224 ppm (S.S.3).

II) The concentrations of bicarbonate in the Quaternary alluvial aquifer varies from 152.5 ppm (Kh.5) to 549 ppm (Kh.3).

III) The concentration of bicarbonate in the Cambro- Ordovician sandstones rock aquifers vary from 61 ppm (S.S.10) to 305 ppm (Ag.4).

With respect to carbonate content of the studied samples, the results of the water analysis indicate that the carbonate is presented in all samples with the same level of 31 ppm.

4. 7. Chloride content (Cl^-):

Chloride is the most common major ion in the earth crust. The main sources of chloride are the evaporation processes and dissolution of sedimentary rocks of marine origin, such as shales. The occurrences of the chloride depend on the environmental condition during deposition, where they are present in high concentrations in marine sediments. According to Hem (1989), some sedimentary rocks contain chloride, such as shale 423 ppm, sandstone 120ppm and carbonate 7.1 ppm. Figure (10) represents the distribution of chloride in the different aquifers of the study area.

I) The concentrations of chloride in the fractured basements aquifer vary from 56.72 ppm (Bd.1) to 7222.6 ppm (Z.1), which could be attributed to evaporation.

II) The concentrations of chloride in the Quaternary alluvial aquifer vary from 514.02 ppm (Kh.6) to 5643.64 ppm (B.5).

III) The concentrations of chloride in the Cambro- Ordovician sandstone aquifer vary from 35.45 ppm (S.S.10) to 1751.23 ppm (Ag.2).

According to the study of Taylor and Oza (1954) the chloride in groundwater were classified into four classes:

1- Small chloride content <200 ppm that's include (S.S.6- S.S.7- S.S.9- S.S.10- Ag.5- Nb.1- At.1- Sh.1- Sh.2- Bd.1).

2- Medium chloride content ranged between 200 and 500 ppm that is include (Sha.1- S.S.2- S.S.2- S.S.3- S.S.4- S.S.5- S.S.8- Ag.3- Ag.4- S.1).

3- High chloride content ranged from 500 to 1000 ppm that is including (Kh.1- Kh.4- Kh.6- Sha.2- S.S.1).

4- Very high chloride content with >1000 ppm that is include (Z.1- Ag.1- Ag.2- Kh.2- Kh.3- Kh.5- R.1- R.2- B.1- B.2- B.3- B.4- B.5- B.6)

4. 9. Sulfate content (SO_4^{--}):

The main source of sulfate is generally gypsum and anhydrite dissolution. It also forms as a result of the oxidation of sulfide ores. Gypsum is easily dissolved in water at ordinary temperature where it gives about 1500 ppm sulfate concentration at the saturation point. Sulfate is widely distributed in reduced form both in igneous and sedimentary rocks as sulfide. Industrial discharges and atmospheric precipitation can also add a considerable amount of sulfate to surface water. Under anaerobic conditions, bacteria convert sulfate to hydrogen sulfide. Figure (11) represents the distribution of sulphate in the different aquifers of the study area.

I) The concentrations of sulfate in the fractured basements aquifer vary from 86.4 ppm (Bd.1) to 742 ppm (Z.1).

II) The concentrations of sulfate in the Quaternary alluvial aquifer vary from 164 ppm (Kh.4) to 2286 ppm (Kh.1).

III) The concentration of sulfate in the Cambro- Ordovician sandstones aquifer varies from 72.48 ppm (S.S.10) to 765 ppm (Ag.2).

4. 8. Ion dominance:

The ion dominance within the studied water samples of the different aquifers are arranged in a decreasing order of abundance of the main soluble ions as following (Schoellers, 1962):

Anions: They are accumulated in the following groups:

1) **Cl > SO_4> HCO_3:** that is includes most the water samples.
2) **Cl> HCO_3 >SO_4:** that is includes samples of (Kh.2- Kh.3- Kh.4- R.2- S.S.3- S.S.5- Sh.1- Sh.2- Sha.1).

Cations: They are accumulative in the following group:

1) **Na >Ca > Mg:** that is includes (main group in different aquifers).
2) **Na > Mg > Ca:** that is includes (Sha.1- Bd.1- B.1- B.6)
3) **Ca > Na >Mg:** that is includes (S.S.3- S.S.9- Ag.2).

4. 9. Classification of groundwater:

Pipers Classification Diagram:

The trilinear diagram is one of the more widely graphical method used for classification of natural waters (Piper, 1953). This type of classification is based on the percentage equivalent per millions of cations and anions. Pipers diagram defines groundwater genesis and the characters of groundwater through the relationship among the alkali (Na, K), alkali earths (Ca, Mg), alkalinity (CO_3, HCO_3) and salinity (SO_4, Cl). Piper’s diagrams for the groundwater of the quaternary alluvial aquifer (Fig. 12), indicates that all the samples have the same origin and of the same aquifer. On the other hand both of the Cambro- Ordovician aquifer (Fig. 12) and the fractured Precambrian basement aquifer (Fig. 14) shows that the groundwater samples do not have the same conditions, that indicate existence of two types of water and a type of mixing in between is existed causing dilution and or contaminations due to the increasing of trace elements ranges than the world standards.

4. 9. 2. Schoellers Diagram:

On the other hand, the Schoellers diagram is linear diagram based on a system developed in part by the French investigator Schoellers, (1962). Schoellers diagrams for the quaternary alluvial aquifer shows that all the groundwater samples lay in one pattern, indicating that it has the same origin (Fig. 15) where the Cambro - Ordovician aquifer (Fig. 16)

and Fractured Precambrian basement aquifer (Fig. 17) show that all the groundwater samples are separated into two patterns according to their sources that reflect the different water type.

4. 10. Trace element distributions:

4. 10. 1. Copper (Cu^{++}):

Copper are relatively insoluble, so little copper found in natural water. The toxicity of copper depends upon the hardness and pH of water and therefore, it is more toxic in soft and low alkalinity water (Jones, 1964).

The toxic level of copper in aquatic samples varies from 1 to 1.5 mg/l (Hem, 1986). Copper is an essential element in human metabolism, but it can cause anemia, disorders of bones, connective tissue and liver damage at excessive level. So, drinking water shouldn’t have more than 1 mg/l Cu^{++} (Bouwer, 1978). Figure (18) represents the distribution of copper in the different aquifers. The copper value in the Cambro- Ordovician sandstones aquifers range from 2.35 ppb (Ag.2) to 73.28 ppb (S.S.5), while it ranged in the quaternary alluvial aquifer from 1.29 ppb (B.2) to 99.2 ppb (Kh.5) and varying in the fractured Precambrian basement aquifer from36 ppb (Bd.1) to 107.8 ppb (S.1).

4. 10. 2. Lead (Pb^{++}):

Lead is one of the main trace elements that occur in natural water when accumulated, lead causes poison impacts to human and animals. Lead concentration in water is limited and controlled by the solubility restrictions. The lead toxicity appears to be greater in soft water than hard water (Pickering and Henderson 1960). Lead concentration in rain and river water ranges from 0.1 ppm or more in areas that subjected to substantial air pollution that down to 0.001 ppm or less in more remote areas (Lazarus et al. 1970). Lead limit in drinking water is 0.05 mg/l (W.H.O standard 1963). Figure (19) shows the distribution of lead in the different aquifers of the study area. The lead value in the Cambro- Ordovician sandstones aquifer range from 4.85 ppb (Ag.3) to 34.89 ppb (Sh.2), while it ranges in the quaternary alluvial aquifer from 10.6 ppb (Kh.4) to 29.4 ppb (Kh.2) and varied in the fractured Precambrian basement aquifer from 3.49 ppb (Sha.1) to 32.8 ppb (S.S.3).

4. 10. 3. Cadmium (Cd++):

Generally, cadmium exists in zinc bearing minerals such as sphalerite and is recovered from some copper ores during smelting and refining. It is rarely found in natural water. Cadmium is sometimes toxic if its concentration exceeds 0.01 mg/l (Hem, 1986). The effects of increasing in human body cadmium are kidney damage, destruction of testicular tissue as well as destruction of red blood cells. Figure (20) shows the distribution of cadmium in the different aquifers in the study area. The cadmium value in the Cambro-Ordovician sandstones aquifers range from 10.62 ppb (S.S.8) to 612.46 ppb (S.S.5), while it ranged in the quaternary alluvial deposits from 9.56 ppb (B.1) to 21.2 ppb (Kh.5) and varying in the fractured Precambrian basement aquifer from 10.2 ppb (Z.1) to 18.26 ppb (S.S.3).

4. 10. 4. Cobalt (Co^{++}):

As shows at table (6) the cobalt values in the Cambro- Ordovician sandstones aquifer ranges from 2.62 ppb (At.1) to 27.63 ppb (S.S.10), while they ranged in the quaternary alluvial aquifer from 8.2 ppb (Kh.3) to 22.6 ppb (R.1) and varying in the fractured Precambrian basement aquifer from 2 ppb (S.1) to 16.98 ppb (S.S.2). (Figure 21).

4. 10. 5. Chromium (Cr^{++}):

The chromium values in the Cambro- Ordovician sandstones aquifers ranges from 13.2 ppb (Sh.1) to 44.69 ppb (S.S.5), while it ranged in the quaternary alluvial aquifer from 16.76 ppb (B.3) to 25.7 ppb (Kh.6) and varied in the fractured Precambrian basement aquifers from 15.3 ppb (Sha.2) to 31.2 ppb (Bd.1). (Figure 22).

4. 10. 6. Arsinic (As^{++}):

The arsinic value in the Cambro- Ordovician sandstones aquifers ranges from 27.14 ppb (Ag.2) to 242.2 ppb (Ag.4), while it ranged in the quaternary alluvial aquifer from 16.9 ppb (Kh.4) to 301.1 ppb (B.4) and varying in the fractured Precambrian basement aquifers from 77.3 ppb (Z.1) to 242.2 ppb (Sha.1). (Figure 23).

4. 10. 7. Manganese (Mn^{++}):

Manganese value in the Cambro- Ordovician sandstones aquifer ranges from 44.9 ppb (Ag.4) to 2.7ppb (S.S.6), while it ranged in the quaternary alluvial aquifer from 406.8 ppb (B.2) 1.7to ppb (Kh.1) and varying in the fractured Precambrian basement aquifers from 12 ppb (Z.1) to 0.51ppb (S.1). (Figure 24).

4. 10. 8. Iron (Fe^{++}):

Abundant source of iron exists in the earth’s crust. Some of the important minerals and mineral groups that contain large amount of iron are pyroxenes, amphiboles, magnetite, pyrite, biotite and garnets. The weathering of these minerals releases large amounts of iron, which are usually converted to the relatively insoluble and stable iron oxides. The common form of iron in the groundwater is the soluble ferrous iron (Fe^{+2}). Corrosion of well casing and other pipes may also contribute iron to the groundwater. Bacterial activity could increases iron concentration in groundwater. If pH of groundwater is below 3, the iron should occur in the ferric state (Fe^{+3}) but above this pH ferric iron may be present as a complex compounds. If the Ec is not too high, water contains ferrous iron (Hem and Cropper, 1959). The presence of iron in drinking water leads to a metallic taste. So, the recommended maximum concentration of iron in drinking water is 0.3 mg/l. Iron value in the Cambro-Ordovician sandstones aquifers range from 1291.6 ppb (S.S.9) to 4.95 ppb (Ag.3), while it ranged in the quaternary alluvial aquifer from 939.6 ppb (Kh.6) to 65.3 ppb (B.3) and varied in the fractured Precambrian basement aquifer from 20.2 ppb (Sha.1) to 400.8 ppb (S.1), Fig. (25).

4. 11. Radioactivity of groundwater:

The radioactivity of the groundwater is generally attributed to the penetration of water through the fractured anomalous country rocks. The uranium content in the world mineralized aquifers is 100 – 460 ppb, (Judson and Osmend 1955). Fix (1956) notes that in the uraniferous areas, uranium content in the groundwater ranged from 20 – 200 ppb and ranged typically from 15 – 400 ppb. Uranium mines and uranium in surface water ranging from 1 – 10ppb as general in uraniferous area. Denson et al. (1956) stated that the mineralized aquifers contain 10 -250 ppb uranium.

In the present study thirty eight groundwater samples were chemically analysis for uranium (U^{238}), thorium (Th^{232}) and radon (Ra^{226}), (Tables. 6, 7and 8).

4. 11. 1. Uranium (U^{238}):

The concentration of uranium in the different aquifers (Tables. 7, 8 and 9) can be graphically represents in Figure (26):

I) The concentration of uranium in the fractured basements aquifer vary from 1824 ppb (Sha.2) to 385.6 ppb (Bd) with an average of 934.37 ppb.

II) The concentration of uranium in the Quaternary alluvial aquifer varies from 3336 ppb (B.5) to 679.4 ppb (B.1) with an average of 1382.8 ppb.

III) The concentration of uranium in the Cambro- Ordovician sandstone aquifer varies from 1684 ppb (Nb) to 472.1 ppb (S.S.6) with an average of 981.20 ppb.

4. 11. 2. Thorium (Th^{232}):

The distribution of thorium in the different aquifers (tables 7, 8 and 9) can be illustrates as show in figure (27):

I) The concentrations of thorium in the fractured basements aquifer are not defined because thorium is not soluble in water in general.

II) The concentration of thorium in the Quaternary alluvial aquifer varies from 2.23 ppb (Kh.3) to 1.54 ppb (R.1) with an average of 1.88.

III) The concentration of thorium in the Cambro- Ordovician sandstone aquifer varied from 2.88 ppb (Ag.3) to 1.67 ppb (Sh.1).

4. 11. 3. Radium (Ra^{226}):

The distribution of radium in the different aquifers (Tables 7, 8 and 9) can be illustrated as following (Figs. 28 and 29):

I) The concentration of radium in the fractured basements aquifer varies from 0.06 Bq (1.5 pci) in (SS3 - S) to 0.01Bq (0.33 pci) in (Z- Sha1) with an average of 0.0387 Bq (1.03 pci).

II) The concentration of radium in the Quaternary alluvial aquifer vary from 0.12 Bq (3.37 pci) in (Kh.5) to 0.02 Bq (0.47 pci) in (Kh.6) with an average of 0.077 Bq (2.098 pci).

III) The concentration of radium in the Cambro- Ordovician sandstone aquifer that varies from 0.13 Bq (3.57 pci) in (At) to 0.01Bq (0.26 pci) in (S.S.5) with an average of 0.057 Bq (1.55 pci).

5. SUMMARY AND CONCLUSIONS

The Paleozoic succession in the southwestern Sinai (up to 320 m thick) nonconformably overlies the basement complex and is covered by Permo-Triassic basalt sheet and or sill on the top. The Paleozoic succession in the study area composed of Sarabit El Khadim, Abu Hamata, Adadia, Um Bogma, El Hashash, Magharet El Maih and Abu Zarab Formations.

The area under study comprises three main aquifers, the Quaternary alluvial, Cambro-Ordovician sandstones and Precambrian fractured basement aquifers. All cations (Mg, Ca, Na and K) and anions (Cl, SO_4 and HCO_3) maximum permissible limits are larger than the world standards.

All the trace elements (Cu, CO, Cd, Cr, Ni, As, Pd, Mn and Fe) maximum permissible limits are larger than the world standards for all elements, especially uranium contents in drinking water wells digged in the area. Uranium recorded very high contaminant up to 3000 ppb (300 times more the maximum contaminant level). The anions dominance in most samples were Cl > SO_4> HCO_3, where the dominance cations were Na >Ca > Mg.

The water wells located at W. Baba are more contaminated than other one. It is recommended to not use as drinking water for human's activities and even for animals.

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Table (1): Results of chemical analysis of grounwater of the Quaternary Alluvial aquifer.

Well No.	Code	TDS	Cations				Anions			
			NA++	K^+	Ca^{++}	Mg^{++}	Cl^-	SO_4^{--}	CO_3^{--}	HCO_3^{---}
1	B.1	4607	1050	13.88	200.4	291.84	2183.7	642	31	183
2	B.2	4015	910	13.88	400.8	97.28	1946.2	426	31	183
3	B.3	3468	813	12.03	280.56	97.28	1534.9	446	31	244
4	B.4	3100	675.5	11.11	320.64	72.96	1361.2	439	31	183
5	B.5	10470	2000	23.45	1282.5	364.8	5643.6	830	31	244
6	B.6	7000	1446	17.59	400.8	486.4	3658.4	765	31	183
7	R.1	3390	682	15.74	300.6	145.9	1503.1	452	31	244
8	R.2	2565	630	10	200.4	48.64	1047.5	289	31	305
9	Kh.1	2550	525.5	14.81	260.52	48.64	864.98	2286	31	4888
10	Kh.2	3600	980	21.29	200.4	48.64	1435.7	314	31	549
11	Kh.3	3390	761	12.96	220.44	133.7	1425.9	248	31	549
12	Kh.4	1960	412.5	7.77	180.36	48.64	716.09	164	31	366
13	Kh.5	3692	980	13.88	280.56	97.28	1651.9	480	31	152.5
14	Kh.6	1810	373.3	7.77	160.32	48.64	514.02	419	31	244

Table (2): Results of chemical analysis of groundwater of the Cambro-Ordovician Sandstones aquifer.

Well No.	Code	TDS	Cations				Anions			
			NA^{++}	K^+	Ca^{++}	Mg^{++}	Cl^-	SO_4^{--}	CO_3^{--}	HCO_3^{---}
15	S.S.4	1420	317.7	7.77	100.2	24.32	261.26	410	31	244
16	S.S.5	1060	200	5.55	80.16	36.48	223.33	202	31	244
17	S.S.6	680	110	5.55	60.12	24.32	90.04	208	31	122
18	S.S.7	825	200	12.96	40.08	12.16	133.64	202	31	183
19	S.S.8	1090	170	7.77	140.28	36.48	347.17	226	31	122
20	S.S.9	715	59.7	5.55	100.2	36.48	70.9	221	31	183
21	S.S.10	307	55	6.66	20.04	12.16	35.45	72.48	31	61
22	Ag.1	3995	840	18.51	360.72	145.92	1726.41	681	31	183
23	Ag.2	3120	440	15.74	681.36	194.56	1751.23	765	31	183
24	Ag.3	1100	330	5.55	20.04	12.16	237.51	235	31	183
25	Ag.4	1350	344	6.66	60.12	24.32	251.69	314	31	305
26	Ag.5	1100	317	7.77	20.04	12.16	173.7	278	31	244
27	Sh.1	650	140	5.55	40.08	12.16	74.44	144	31	183
28	Sh.2	715	120	6.66	60.12	24.32	106.35	111.84	31	244
29	At.1	780	220	3.88	20.04	12.16	198.52	139.7	31	122
30	Nb.1	820	187.5	5.55	60.12	12.16	152.43	238	31	122

Table (3): Results of chemical analysis of groundwater of the fractured Precambrian basement aquifer.

Well No.	**Code**	**TDS**	**Cations**				**Anions**			
			NA++	**K+**	**Ca++**	**Mg++**	**Cl-**	**SO4--**	**CO3--**	**HCO3--**
31	S.1	1920	391	7.77	80.16	48.64	436.1	423	31	183
32	Z.1	5800	1481	13.88	400.8	145.9	7222.6	742	31	183
33	Bd.1	432	55	3.7	6.12	12.16	56.72	86.4	31	122
34	Sha.1	710	180	8.88	4.08	12.16	207.4	96	31	122
35	Sha.2	1990	630	16.66	40.08	24.32	786.9	260	31	183
36	S.S.1	1515	330	8.88	160.3	24.32	577.5	251	31	122
37	S.S.2	1190	220	5.55	160.3	12.16	379.3	236	31	122
38	S.S.3	980	120	3.88	140.3	36.48	269.4	127	31	224

Table (4): Trace element distributions of groundwater of the quaternary alluvial aquifer.

Well No.	**Code**	**Cd**	**Co**	**Cr**	**Fe**	**Mn**	**As**	**Pb**	**Cu**
1	B1	9.56	9.05	17.07	287.6	44.9	48.64	23.13	n.d
2	B2	10.75	17.6	17.9	422.3	406.8	212.7	15.76	1.29
3	B3	11.92	16.56	16.76	65.3	13.3	122.2	14.49	n.d
4	B4	14.1	13.3	22.3	n.d	141.6	301.1	21.3	n.d
5	B5	12.2	6.91	26	247.6	196.1	143.7	26.85	13.1
6	B6	11.7	16.5	18.8	n.d	n.d	282.7	22.71	1.92
7	R1	19.8	22.6	21.1	247.6	196.1	139.2	18.1	4.46
8	R2	10.3	9.1	18.8	427.5	n.d	n.d	18.1	16.3
9	Kh1	14.5	6.7	24.7	99.5	1.7	128.2	17.3	87.5
10	Kh2	11.8	3.92	21.9	516.7	34.1	132.4	29.4	98.9
11	Kh3	16.3	8.2	18.1	422.3	81	108.1	27.2	91.1
12	Kh4	19.7	10.5	22.2	205	56.7	16.9	10.6	18.3
13	Kh5	21.2	9.08	22.8	81.6	3.7	138.4	28.2	99.2
14	Kh6	17.8	11.01	25.7	939.6	91	121.1	24.8	78.1

Table (5): Trace element distributions of groundwater of the Cambro-Ordovician sandstone aquifer.

Well No.	**Code**	**Cd**	**Co**	**Cr**	**As**	**Fe**	**Mn**	**Pb**	**Cu**
15	SS4	183.4	26.08	28.4	214.76	355.4	3.8	27.97	38.74
16	SS5	612.46	19.91	44.69	126.75	117.5	n.d	19.06	73.28
17	SS6	41.21	18.9	39.15	159.87	258	2.7	23.45	17.82
18	SS7	27.05	26.72	29.46	241.08	n.d	n.d	33.71	4.09
19	SS8	10.62	4.46	24.26	183.35	58.5	n.d	30.99	63
20	SS9	34.87	18.45	24.97	176.38	1271.6	n.d	29.81	51.74
21	SS10	14.7	27.63	16.86	158.4	314.4	25	26.7	48.9
22	Ag1	11.98	21.39	19.56	198.06	n.d	35	12.8	n.d
23	Ag2	13.35	15.47	30.41	27.14	96.2	41.6	n.d	2.35
24	Ag3	11.8	7.52	38.03	232.02	4.95	n.d	4.85	26.87
25	Ag4	11.31	11.12	20.87	242.2	82.2	44.9	n.d	n.d
26	Ag5	12.8	18.7	37.8	232.8	176.7	40.6	7.85	32.08
27	Nb1	34.99	18.25	27.88	85.99	63.1	n.d	23.89	10.44
28	At1	72.53	2.62	16.11	113.2	54.5	19.1	n.d	n.d
29	Sh1	10.8	8.6	13.2	195.8	98.6	2.8	n.d	n.d
30	Sh2	187.3	16.33	38.96	18.08	59.6	14.6	34.89	33.44

Table (6): Trace element distributions of groundwater of the fractured Precambrian basement aquifer.

Well No.	**Code**	**Cd**	**Co**	**Cr**	**Fe**	**Mn**	**As**	**Pb**	**Cu**
31	Z1	10.2	4.05	18.7	111.17	12	77.3	12.1	101.1
32	S1	11	2	21.4	113.4	0.51	81.5	13.2	107.8
33	Bd1	9.08	14.1	31.2	106.7	2	143.2	24.1	36
34	Sha1	13.8	11.2	19.7	20.2	n.d	242.2	3.49	n.d
35	Sha2	12.2	4.92	15.3	36.9	n.d	113.2	18.9	n.d
36	SS1	12.87	12.28	16.55	400.8	21.1	111.73	6.28	n.d
37	SS2	10.9	16.98	21.05	226.1	n.d	153.1	19.08	64.04
38	SS3	18.26	13.83	17.27	143.9	n.d	97.32	32.8	n.d

Table (7): Radiometric distributions of the quaternary alluvial aquifer of the study area.

Well No.	**Code**	**U ppb**	**Th ppb**	**Ra**	
				Bq	**Pci**
1	B1	679.4	n.d	0.02	0.56
2	B2	853.7	2.10	n.d	n.d
3	B3	1447.9	n.d	n.d	n.d
4	B4	1450.1	n.d	n.d	n.d
5	B5	3335.5	1.68	0.11	3.04
6	B6	936.8	n.d	n.d	n.d
7	R1	1362.3	n.d	n.d	n.d
8	R2	1285.3	n.d	n.d	n.d
9	Kh1	1231.4	n.d	0.11	2.94
10	Kh2	1827.7	n.d	0.10	2.57
11	Kh3	1115.81	2.23	n.d	n.d
12	Kh4	928.64	n.d	n.d	n.d
13	Kh5	927.15	n.d	0.12	3.73
14	Kh6	728.1	n.d	0.02	0.47

Table (8): Radiometric distributions of the fractured Precambrian basement aquifer of the study area.

Well No.	**Code**	**U ppb**	**Th ppb**	**Ra**	
				Bq	**Pci**
15	SS4	824.8	n.d	n.d	n.d
16	SS5	517.94	n.d	0.01	0.26
17	SS6	472.1	n.d	n.d	n.d
18	SS7	621.57	n.d	0.04	1.02
19	SS8	695.59	1.98	n.d	n.d
20	SS9	784.2	n.d	n.d	n.d
21	SS10	649.21	n.d	n.d	n.d
22	Ag1	1852.1	1.78	n.d	n.d
23	Ag2	705.9	n.d	0.05	1.32
24	Ag3	677.78	2.88	0.12	3.26
25	Ag4	1683.6	n.d	0.06	1.52
26	Ag5	1228.6	1.69	n.d	n.d
27	Nb1	1683.6	n.d	0.01	0.38
28	At1	787.7	2.01	0.13	3.58
29	Sh1	1195.6	1.67	0.01	0.33
30	Sh2	955.8	n.d	n.d	n.d

Table (9): Radiometric distributions of the Cambro – Ordovician sandstone aquifers in the study area.

Well. No.	**Code**	**U ppb**	**Th ppb**	**Ra**	
				Bq	**Pci**
31	Z1	1601.3	n.d	0.01	0.33
32	S1	1560.8	n.d	0.06	1.57
33	Bd1	385.6	n.d	n.d	n.d
34	Sha1	513.6	n.d	0.01	0.33
35	Sha2	1823.6	n.d	n.d	n.d
36	SS1	532.6	n.d	0.05	1.32
37	SS2	485.2	n.d	0.05	1.45
38	SS3	431.12	n.d	0.06	1.50

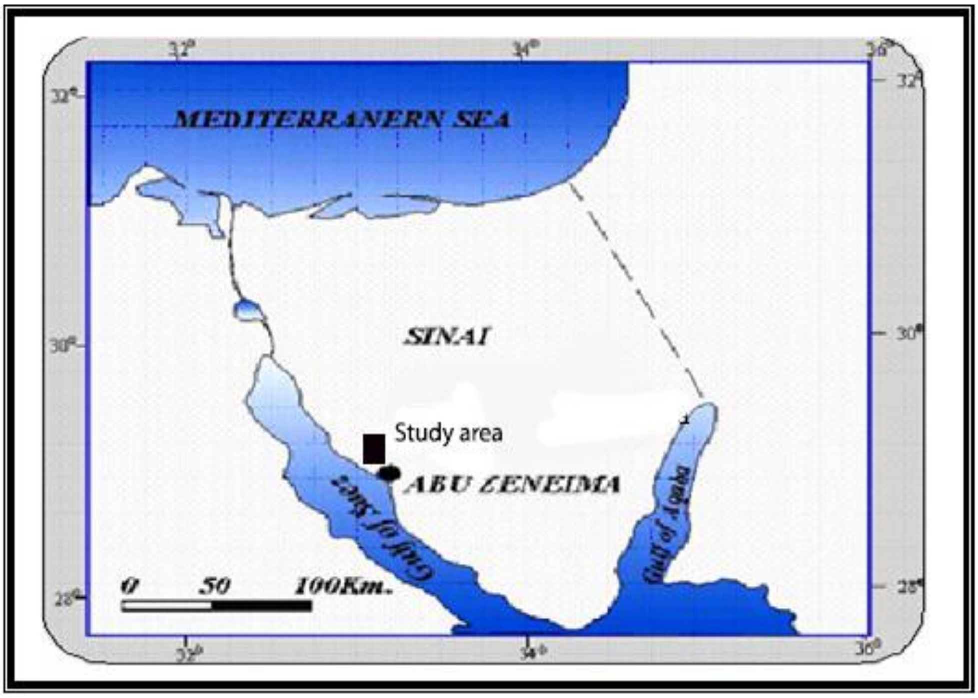

Fig. (1): Location map of the study area.

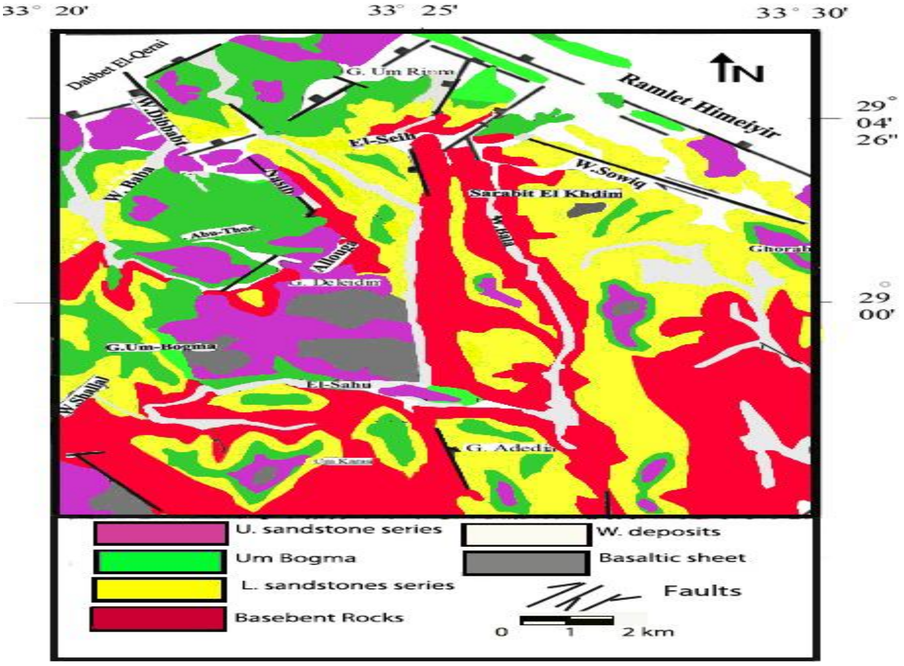

Fig. (2): Geological map of the studied area (modified after, Aita, 1996).

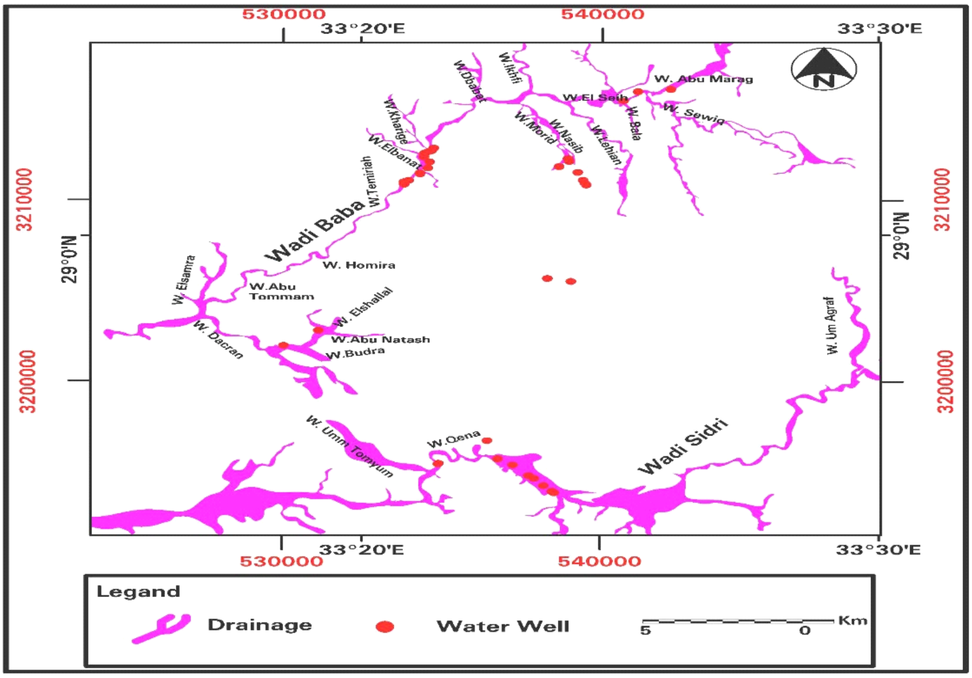

Fig. (3): Location map of the studied groundwater.

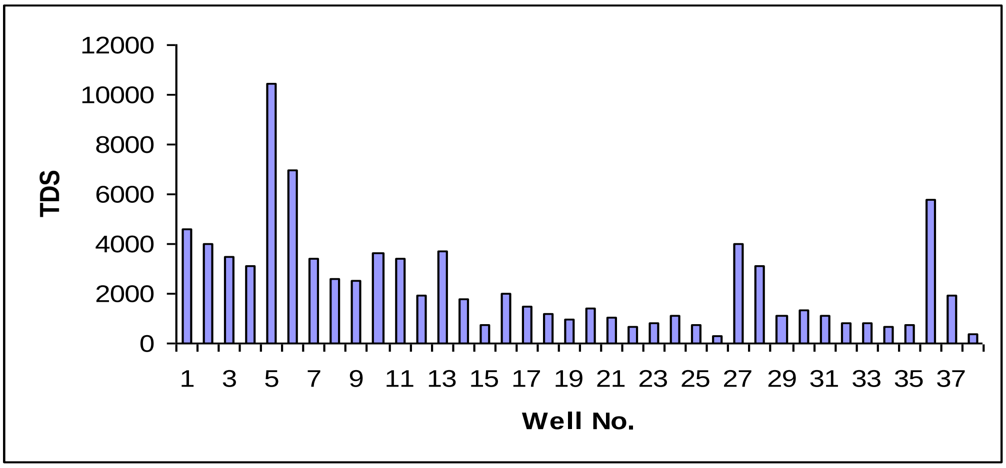

Fig. (4): Distribution of total salinity in groundwater of the study area.

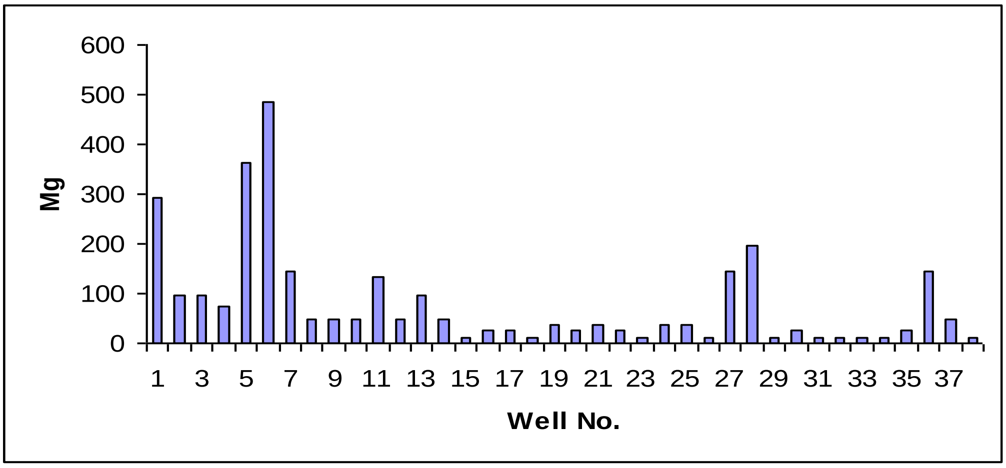

Fig. (5): Distribution of magnesium in groundwater of the study area.

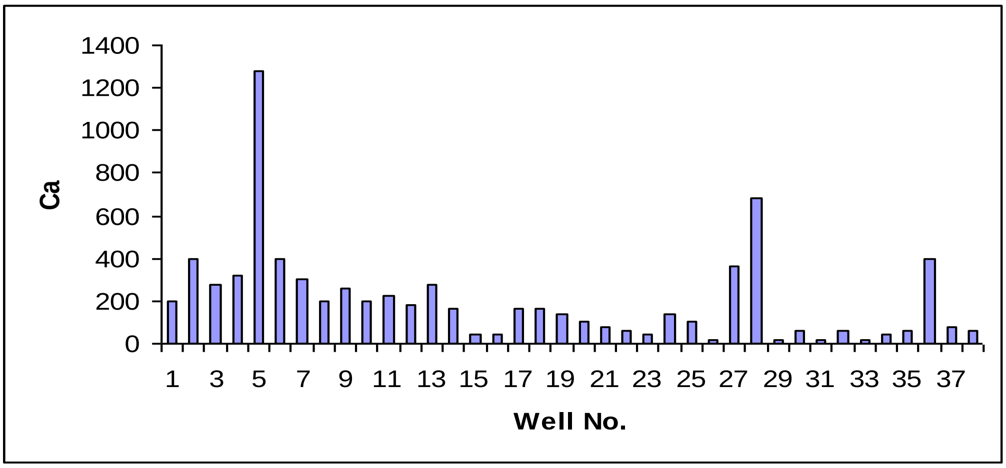

Fig. (6): Distribution of calcium in groundwater of the study area.

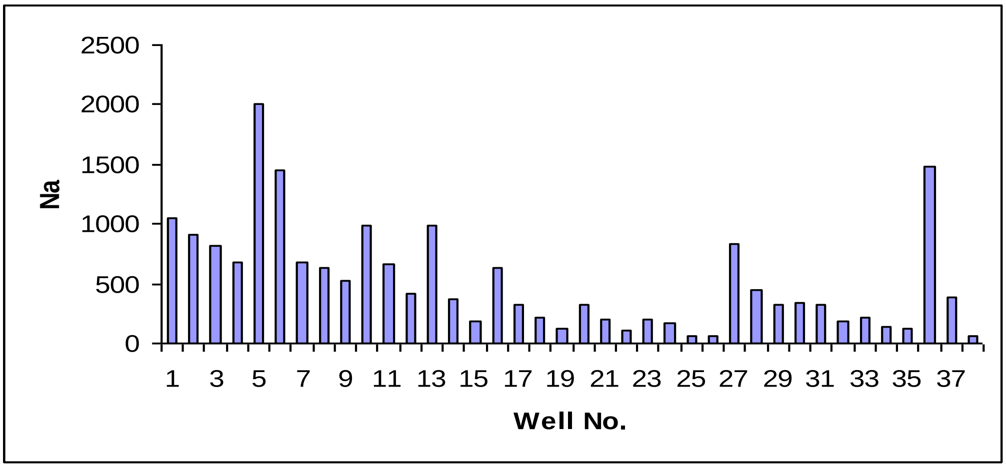

Fig. (7): Distribution of Sodium in groundwater of the study area

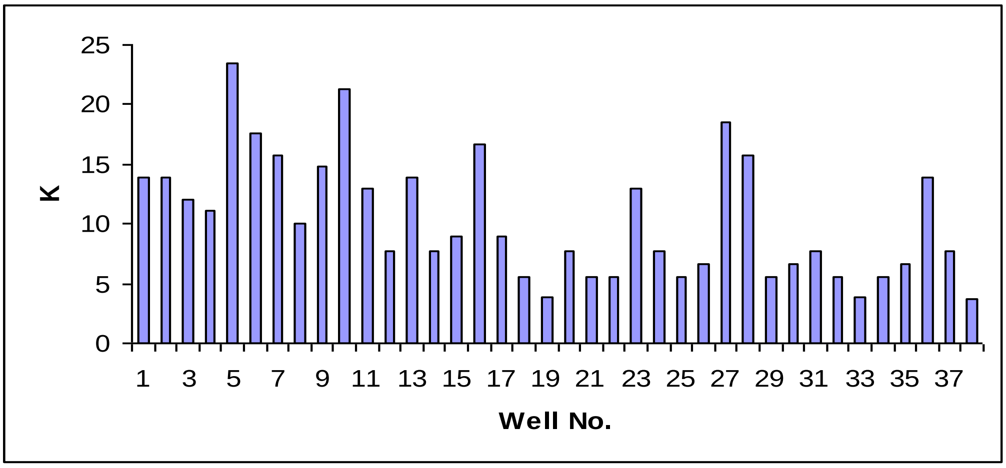

Fig. (8): Distribution of potassium in groundwater of the study area.

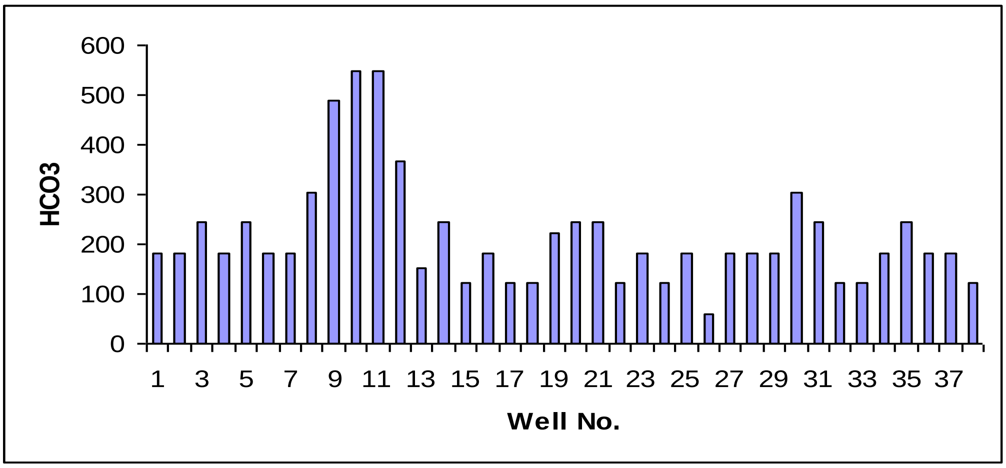

Fig. (9): Distribution of bicarbonate in groundwater of the study area.

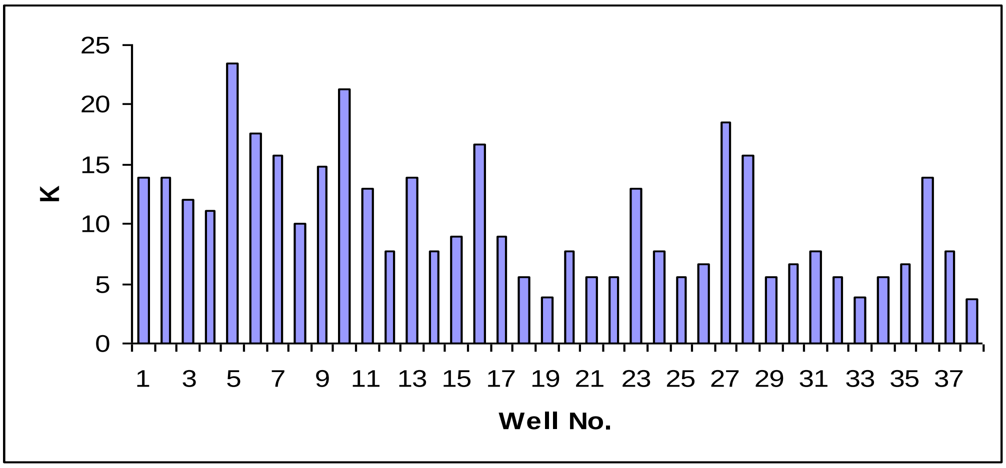

Fig. (10): Distribution of chloride in groundwater of the study area

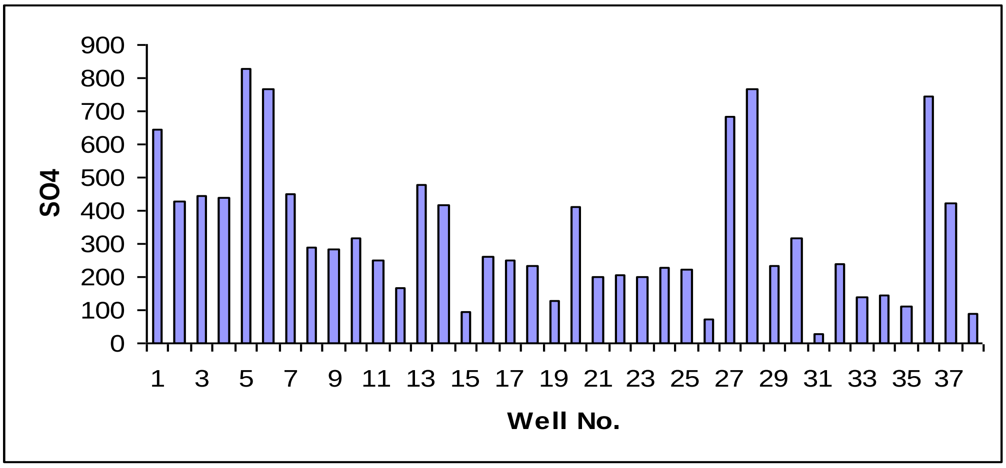

Fig. (11): Distribution of Sulphates in groundwater of the study area

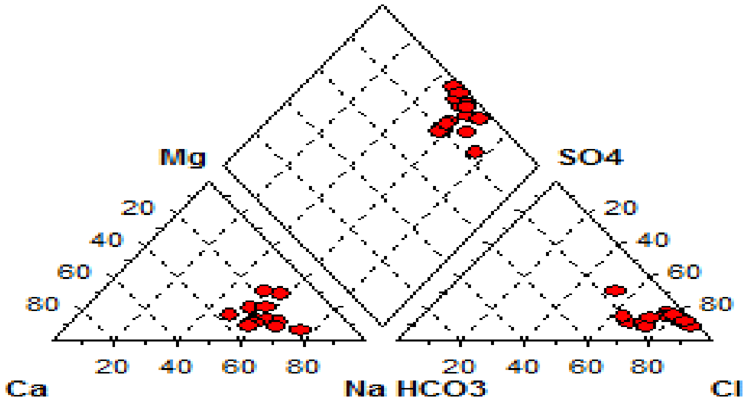

Fig. (12): Geochemical classification (Pipers diagram) of the Quaternary Alluvial aquifer

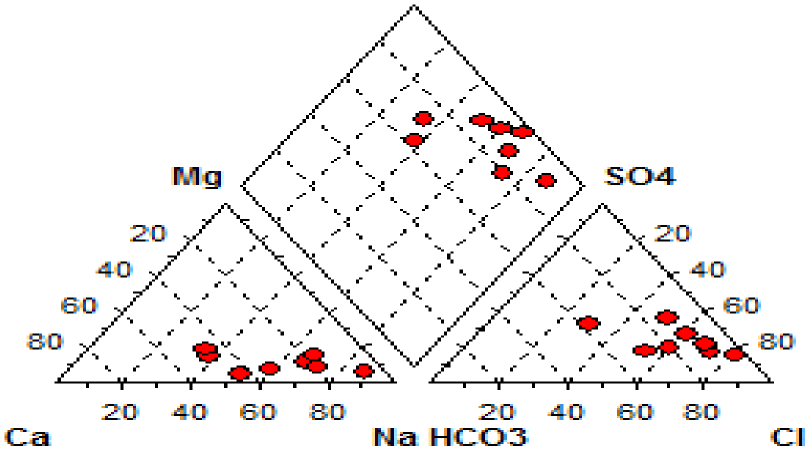

Fig. (13): Geochemical classification (Pipers diagram) of the Cambro-Ordovician aquifer

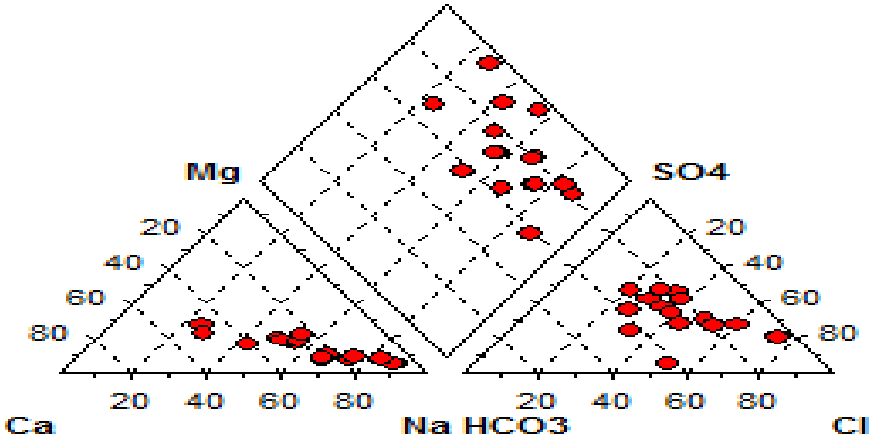

Fig. (14): Geochemical classification (Pipers diagram) of the Precambrian Fractured basement aquifer

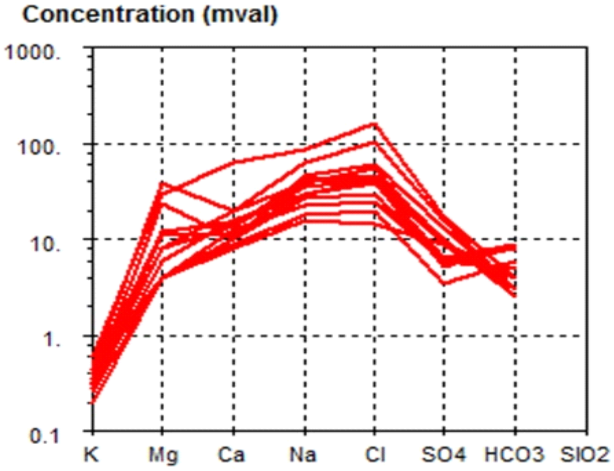

Fig. (15): Geochemical classification (Schoellers diagram) of the Quaternary Alluvial aquifer in the study area

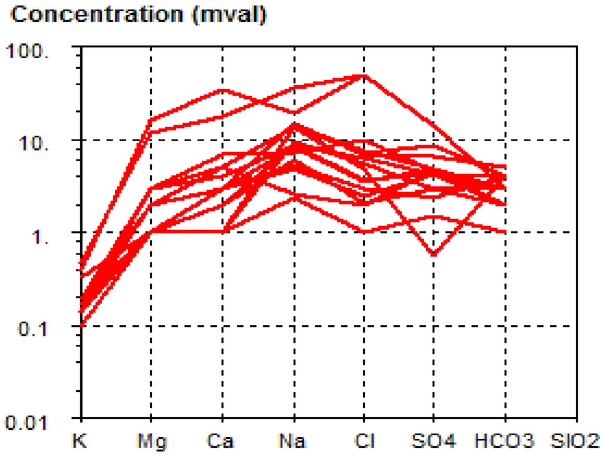

Fig. (16): Geochemical classification (Schoellers diagram) of the Cambro-Ordovician aquifer in the study area

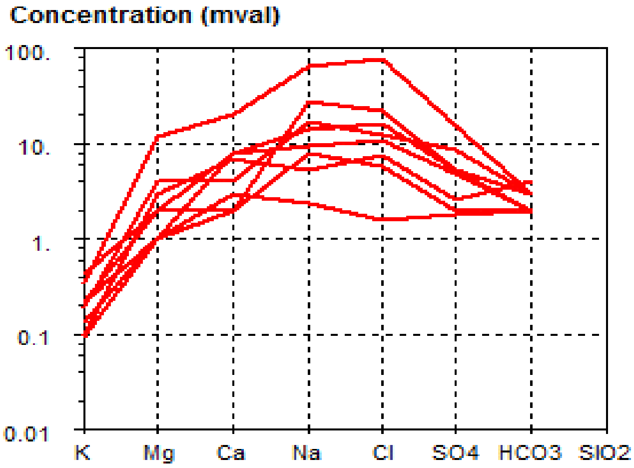

Fig. (17): Geochemical classification (Schoellers diagram) of the Precambrian Fractured basement aquifer in the study area

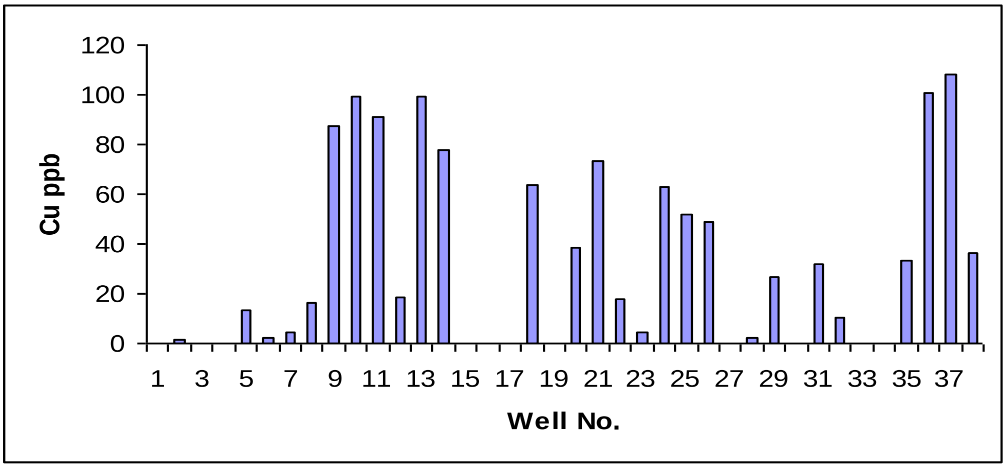

Fig. (18): Distribution of copper in groundwater of the study area

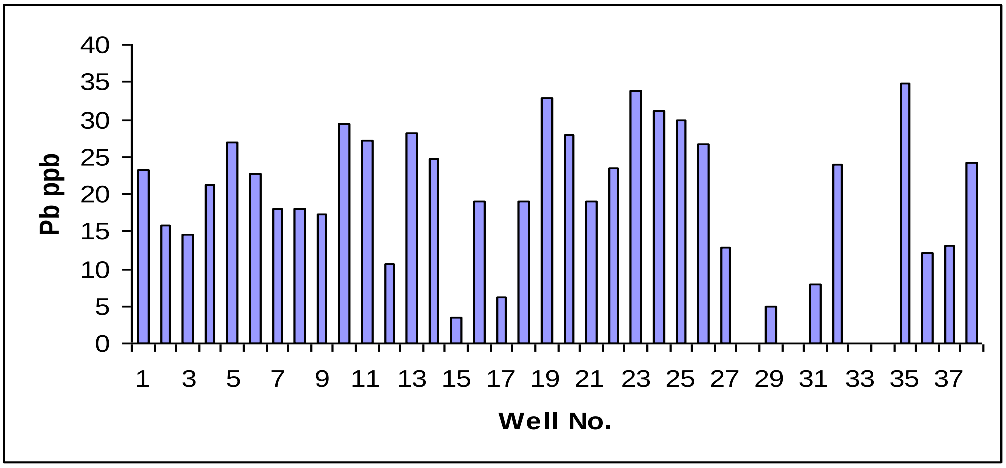

Fig. (19): Distribution of lead in groundwater of the study area

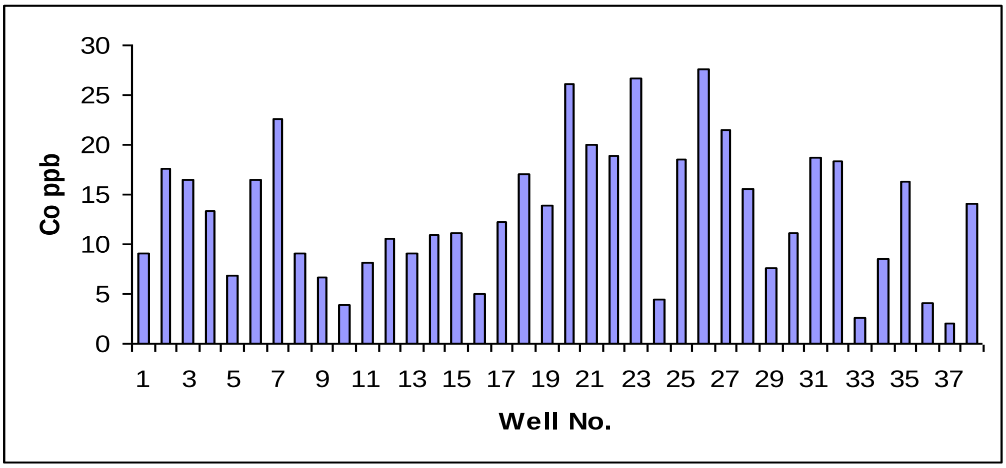

Fig. (20): Distribution of Cadmium in groundwater of the study area

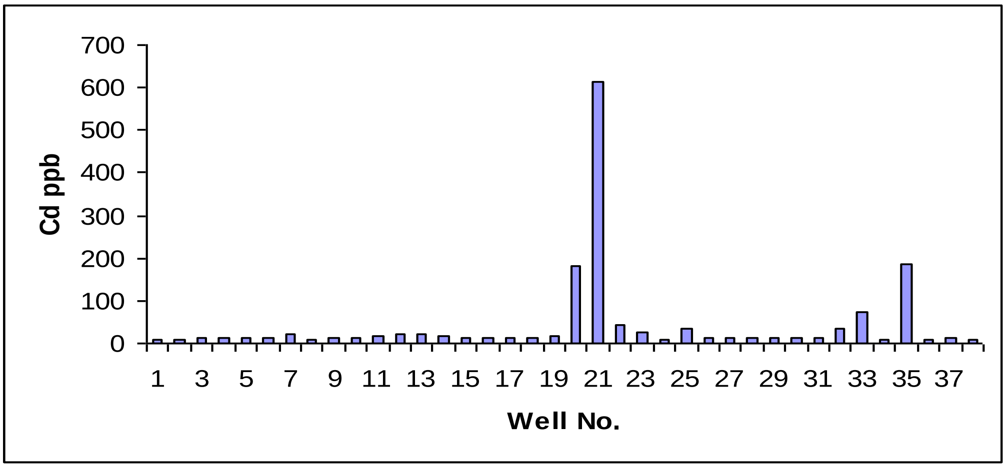

Fig. (21): Distribution of Cobalt in groundwater of the study area

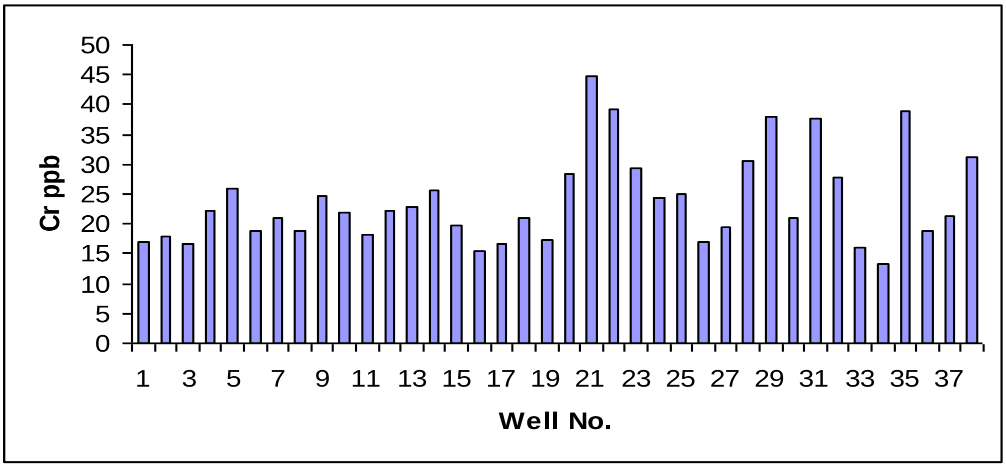

Fig. (22): Distribution of Chromium in groundwater of the study area

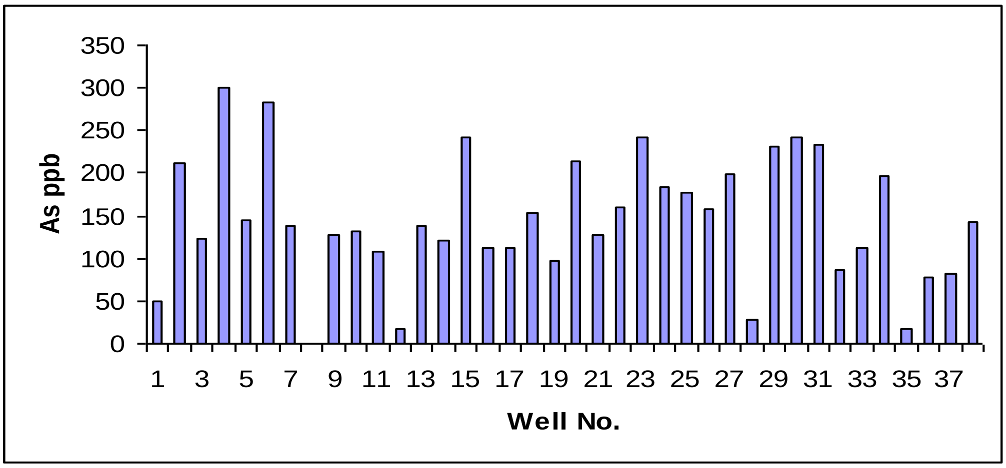

Fig. (23): Distribution of Arsinic in groundwater of the study area

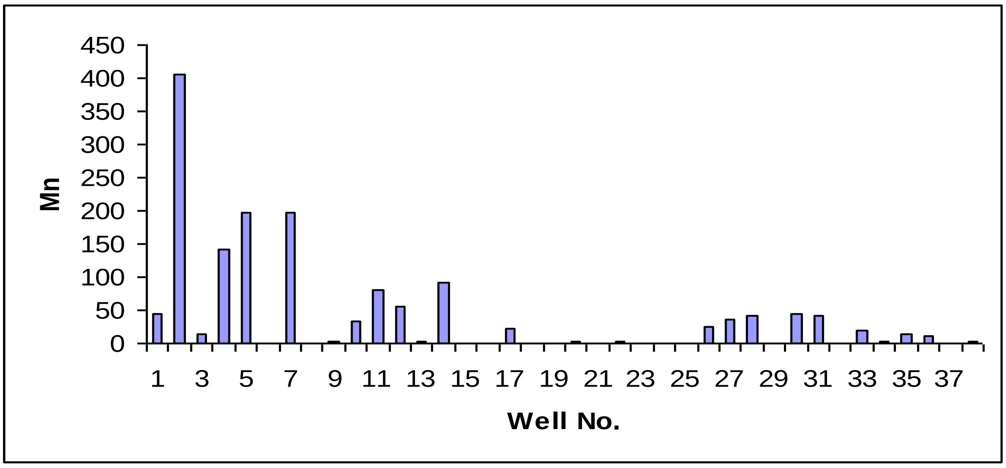

Fig. (24): Distribution of Manganese in groundwater of the study area

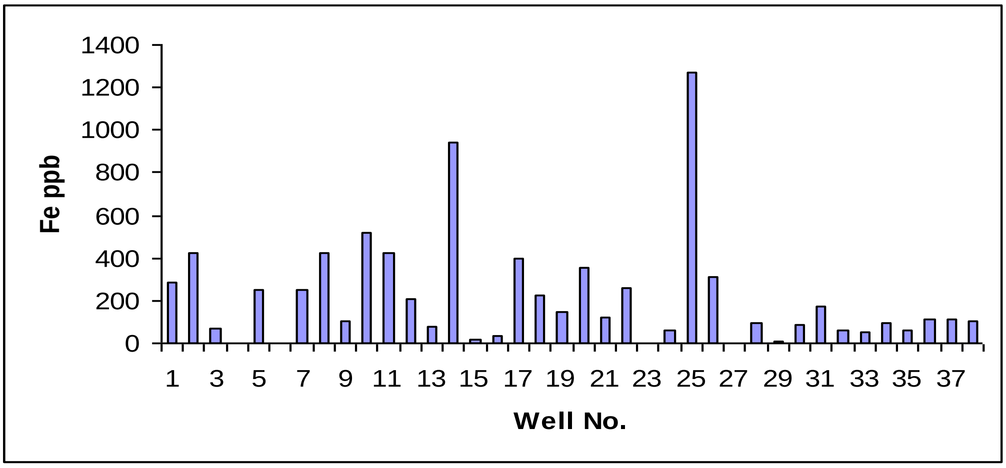

Fig. (25): Distribution of Iron in groundwater of the study area

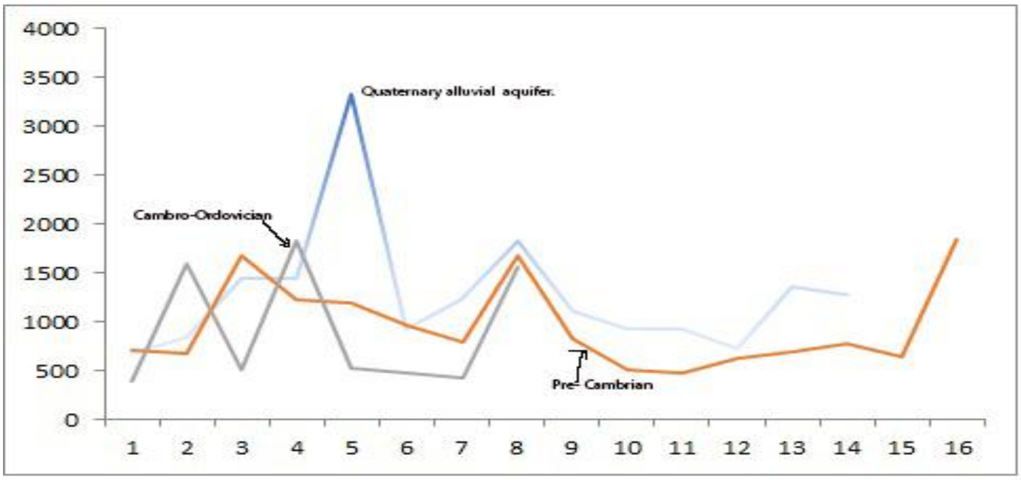

Fig. (26): Distribution of uranium in groundwater of the study area

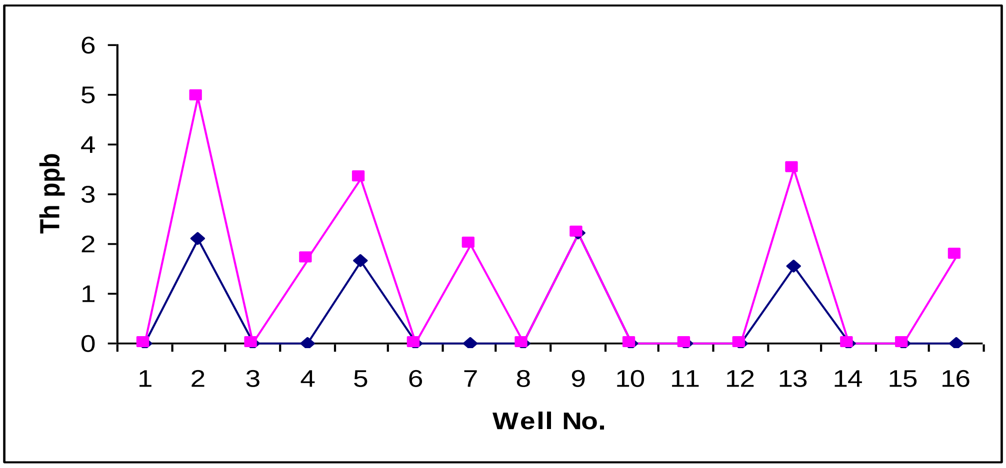

Fig (27): Distribution of thorium in groundwater of the study area

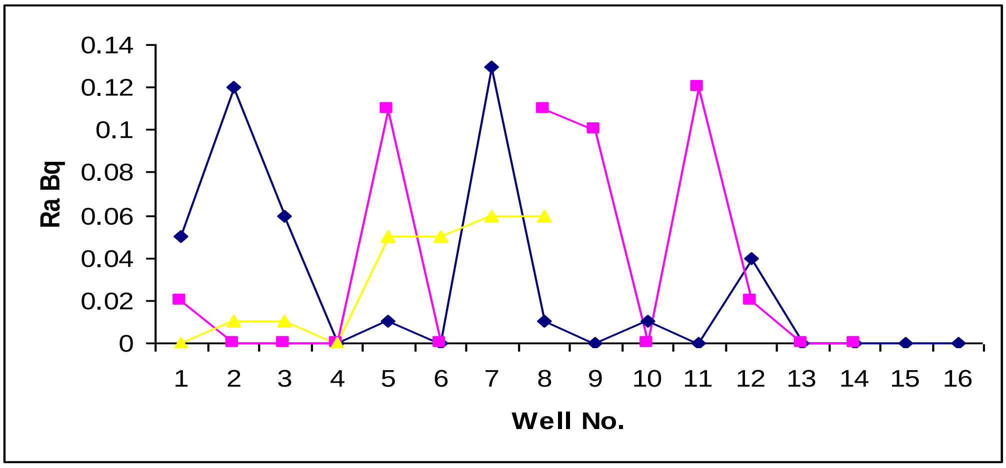

Fig. (28): Distribution of radium in groundwater of the study area (pci).

دراسات هيدروجيوكيميائية واشعاعية على حوض بعيع- سدري
جنوب غرب سيناء، مصر

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تقع منطقة الدراسة فى شرق مدينة أبو زنيمة. تمت الدراسة من خلال تجميع ٣٨ عينة مياه من حوض بعبع – سدري، وقد تم إجراء جميع التحاليل الكيميائية (الكاتيونات – الانيونات) وقد وجد ان جميع النتائج اعلي من المعدلات العالمية بكثير،وهذا يؤكد العلاقة القوية بين السحن الصخرية وتأثيرها على المياه، كارتفاع مجموع الاملاح الذائبه وذلك نتيجة لوجود السبخات وتمعدنات الاملاح فى الصخور المحيطة بالخزانات، وبناءا عليه تم معرفة الكاتيونات والانيونات السائده فى المياه. كذلك تم عمل تحاليل للعناصر الارضية النادرة مثل (النحاس – النيكل- الرصاص – الكوبلت – القصدير - الكادميوم – الحديد – المنجنيز)، وقد تبين من النتائج ان جميع التحاليل اعلي بكثير من المعدلات العالمية مما ترتب عليه تغيير الكثير من الخواص الفيزيائية والكيميائية للمياه وهذا ما بدا واضحا من خلال دراسة نوعية المياه من خلال تطبيق بيبر وشولر. كذلك تم دراسة المحتوى الاشعاعى فى المياه الجوفيه وقد بينت الدراسة وجود تلوث اشعاعى بنسب عالية جدا تصل فى بعض الآبار الى اكثر من ٣٠٠٠ جزء في البليون، اي ما يعادل ٣٠٠ ضعف المعدلات العالمية، لذا ينصح بعدم استخدام المياه وخاصة فى حوض بعبع لاى اغراض سواء آدميه او حيوانية.