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Geochemical Signatures of Bara Basin Aquifers, Kordofan State, Sudan

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Abstract

Purpose: In this paper, geochemical investigation has been carried out to study the concentrations of major cations; Sodium (Na^+), Potassium (K^+), Magnesium (Mg^{2+}), and Calcium (Ca^{2+}), and major anions; Chloride (Cl^-), Bicarbonate (HCO_3^-), Nitrate (NO_3^-) and Sulphate (SO_4^{2-}), other parameters such as (pH), Electric conductivity and T.D.S were also studied in all water samples taken from wells in Bara basin.

Methodology: Forty five (45) water samples have been collected from wells. Lab works were done at Groundwater and Wadis Directorate (GWD), Khartoum State according to Sudanese Standards and Metrology Organization, (2002), to study the major cations and major anions.

Findings: The results revealed that the average value of pH was (7.9) E.C values were (843.4 µS/cm) and T.D.S values were (59 mg/l). The average concentrations of the major cations obtained were; Na^+ (126.3), K^+ (5.22), Mg^{2+} (28.30), Ca^{2+}(66.41) and the major anions (mg/l) were; Cl^- (159.00), HCO_3^- (165.30), NO_3^- (156.70) and SO_4^{2-} (164.70). The (Na/Cl) ratio is (2.47) is also high which reflects the abundance of (Na^+) ions relative to the Chloride (Cl^-) ions which confirmed the light-salty nature of groundwater. Geochemical mass balance calculations indicate that upper aquifer is mainly affected by the dissolution and dolomitization processes of major anions.

Unique Contribution to Theory, Policy and Practice: This process is highly developed in the central west part of the basin due to the abundance of Sulphate ($SO_4^{2-)}$, Bicarbonate ($HCO_3^{-)}$, Magnesium ($Mg^{2+)}$, and Calcium (Ca^{2+}) ions. High values of E.C, T.D.S, Ca^{2+}, and SO_4^{2-} are mainly presents as a saline water resource in some villages. Two types of water are classified here these are : i). Na-HCO_3 type and ii). Ca- Cl -SO_4 type. The study concluded that water samples from Almakser, Hamdan-2, Um-Zeeraga-2, and Al-Zareeba-2 villages have very high concentrations of E.C, T.D.S Ca^{2-}, Cl^-, NO_3^- and $SO_4^{2-,}$ which may suggest that water samples are not fit for human consumption, according to guidelins by W.H.O (1984). This paper recommends further study on water quality.

Keywords: *Anions, Bara Basin, Cations, Groundwater, Hydrochemistry*

INTRODUCTION

Due to the long dry season and high evaporation over most of the country, groundwater has always been a vital supply source for people and livestock. Even along the Nile River, wells were and are used for domestic water due to the deteriorating quality of Nile water. North of the country, away from the rivers, groundwater resources will be a governing factor in developing areas of the Sudan. It is also used for irrigation especially for the schemes laying far away from the rivers. These resources will be used in many multipurpose projects, industrial, irrigation, and livestock (H. G. Nash, 1979) [1]. In the western part of Sudan, there is no permanent surface runoff, thus, domestic and pastoral water supply depends on groundwater and water harvesting from seasonal streams water. Currently, the sustainability of these resources is threatened by the high demand for water due to increasing population (almost 3 % ⁄ year), climatic changes, and drought periods have been occurring since the 1970s (National Bureau of Statistics, Khartoum, 2008) [2] .

Sudan depends upon groundwater aquifers for domestics uses, animal consumption, and irrigation(in some areas) most of the year (Abdeen M. Omer, 2013) [16]. Just few kilometers from the Nile, groundwater aquifers provide the only permanent stocks of water.

The present study focused on the hydrogeochemical facies of the shallow aquifer of the Bara sub-basin, which occupies the north western part of the Bara Um- Rawaba-basin, and supplies most of the current water demand to the Bara region for domestics and agricultural uses.

Description of the study area

Bara basin is about 60 Km North of Al-Obeid city covering an area of about 6800 km^2 of semi desert terrain with sparse vegetation , (Ali , H. O., & Whitly, R.J. 1981). [7]. The basin occupies a trench running North-West / South-East in central Kordofan region and eastward as far as the White Nile south of Kosti (U.N, 1988). Bara basin comprises mainly the localities of Bara and Um-Rauwaba villages in Kordofan state. It extends between latitudes 12˚ and 14 ˚ North and longitudes 29° 30 ´ and 31 50° East, (Intenational Fund for Agricultural Developmrnt (IFAD Report, 1993[3].

Soil and Rainfall

About (75%) of the northern kordofan area is mainly covered by sandy soil or Goz deposits (it is a small hilly area covered with sand like sandune). This type of soil is characterized by its high permeability, poor water-holding capacity, low clay and organic matter content, (H. G.Nash, 1979) [1]. The sandy nature of the area along with low rainfall amounts and limited drainage patterns into a few sparse disconnected channels dispersed at the centre and the eastern regions of the area. The

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rainfall increases in amount and duration due south; it ranges from 200 mm/y in the north to 300 mm/y in the south. The mean temperature is about (27° C) with the lowest value of (10° C).

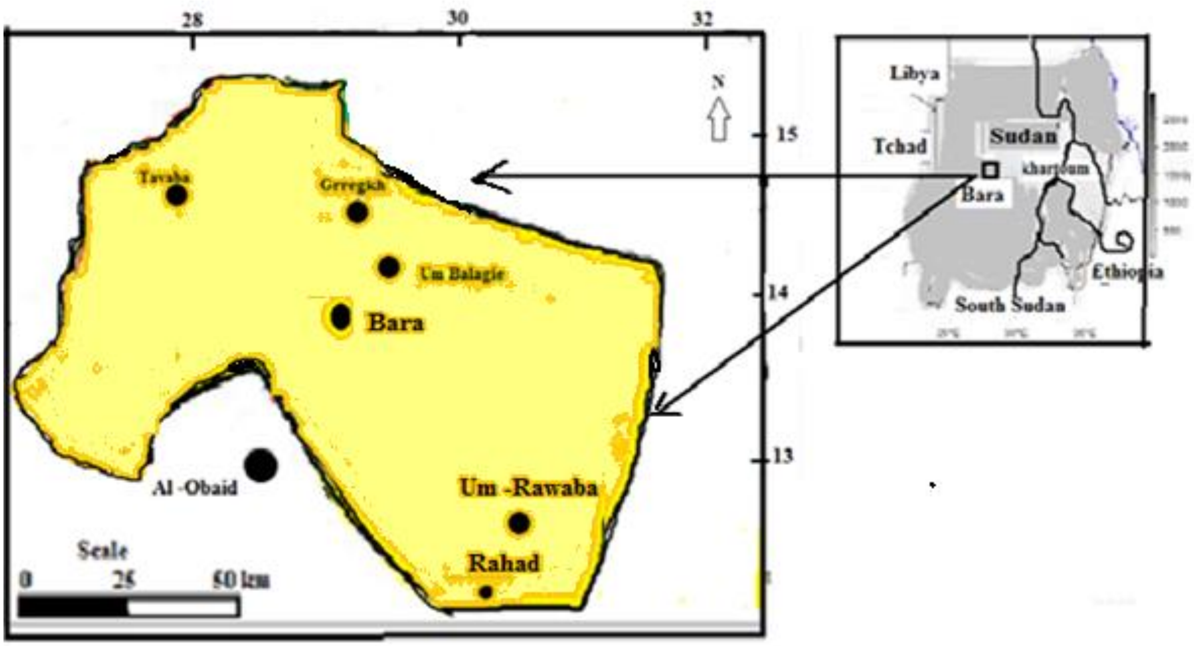

Fig.(1): Location map of the Bara basin

Source : Modified after Elmansour A.A., et.al (2019)

Geology of the area

North Kordofan state –western Sudan chacterized by semi –arid and poor savannah climatic zone,where acute shortages of water are experienced. The study area is covered by the Basement Complex (Pre Cambrian age) which is overlain by superficial deposits (Tertary to Quaternary age), Elzien S.M. et al. (2013) [13].

The Basement Complex that consists of various igneous and metamorphic rocks formed during the pre-cambarian time and was followed by a period of prolonged erosion.

Geologically the bulk of the basin is composed of relatively fine consolidated sediments known as Um -Ruwaba formation and overlain by thin superficial deposits of wind blown sands. The sediments are bounded from the Western and Southern parts by the Basement Complex formation and from the north by the Jurassic Cretaceous Nubian Sandstone Formation,the geological map is given in (Fig.1), quantitative geophysical survey has revealed that the basin is narrow elongated depression and about 45 km wide. The basin is semi closed with an outlet only at the south-east end. Around the central part the basin a maximum thickness of about 1.4 km. To the North and South,

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the basin has steep side walls suggested that the basin is bounded by the faults which may well be related to the African rift system, (Ali , H. O., & Whitly, R.J. ,1981) [7].

Um-Ruwaba formation sediments are probably tertiary to Pleistocene in age and may be related to the early Nile drainage system (Vail, 1978). They are enclosed to the West and South by a metamorphic and igneous rocks and to the North by relatively thin sediments of the Nubian Sandstone Formation, (Whiteman, A. J. ,1971) [6] . Intenational Fund for Agricultural Developmrnt , (IFAD Report, 1993) [3] described the geological system structure of Bara basin as a result of rifting process, which gave rise to fracturing faulting and subsidence of Basement rocks. Bara trough is controlled by three systems of faults mainly striking North East-South West, North West-South East and East West. The North East - South West and North West – South East faults formed the Western and North-Eastern boundaries of the trough.

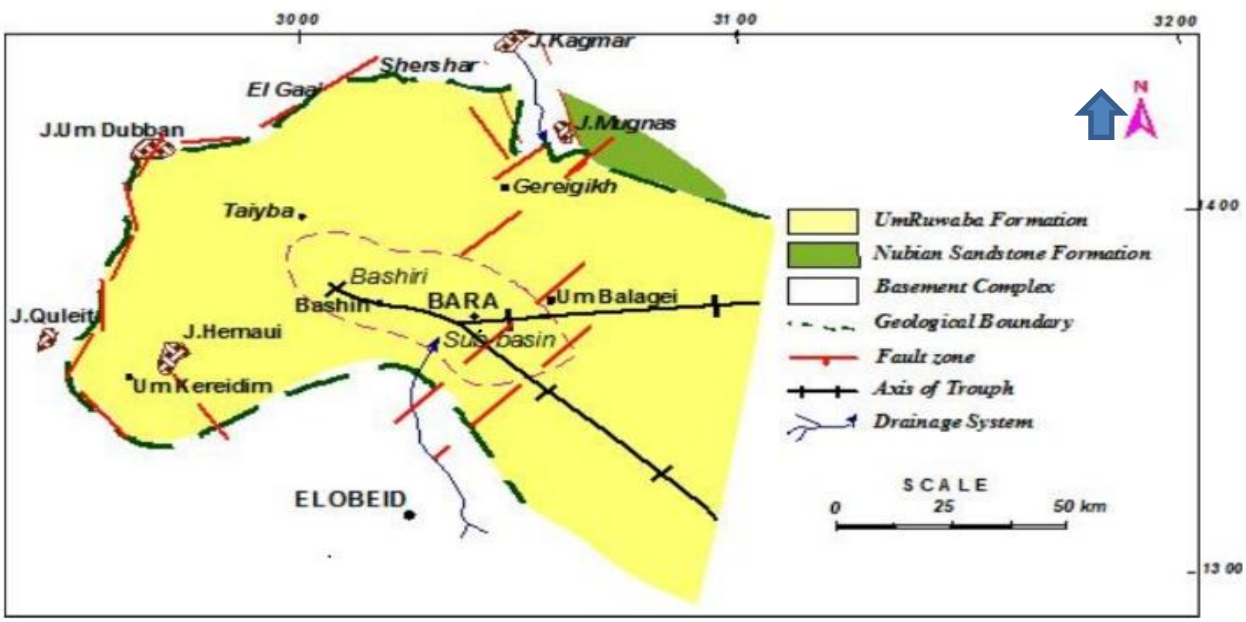

Fig.(2): Geological map of the area

Source: (Almansour A.A, et.al (2019).

The Basement Complex partly bounding the sedimentary basin, forms its lower limits and acts as an impervious hydrogeological boundary to the aquifers. It consist of different metamorphic and igneous rocks mainly gneisses, schists, granites, syenites, and other metamorphic and igneous rocks. The Nubian Sandstone Formation and Basement Complex rocks are followed by Nawa Formation, which is limited in extent, and not outcropping. Cross sections contain alternating cross-bedded sandstone, grit and mudstone consecutively. Finally, the Nubian Sandstone overlays the basement rocks and it consists of well-stratified sediments ranging from clay stone to conglomerates. It is of fluviatile continental origin and flat-lying or gently dipping northwards, (Intenational Fund for Agricultural Developmrnt (IFAD Report, 1993) [3].

Hydrogeology

Groundwater in the Bara sub-basin is mainly found in the Um-Rawaba formation of the late tertiary (Pleistocene age), the sand dunes of Quaternary (recent), and some parts of Nubian sandstone of Mesozoic age (Cretaceous). Two main aquifer types can be distinguished in the Bara sub-basin : free water table aquifer and semi-confined one.

Some authers referred to the presence of two aquifers zones within Bara basin. One deep and extends under most of Bara and Um-Rawaba provinces and the other is shallow and extends under the Northern part of the basin and along Abu Habil system.

The Northern part of the basin is underlain by Nubian sediments While the Western part is formed mainly from Um-Ruwaba sediments with Nubian sediments filling the base of structural depressions. Both areas are covered by Goz deposits, (Omer Adam,M. Gibla et.al, 2016) [15]. Ground water occurs in the three formations (Bara, Nawa and Abu-Habil) as a single hydrolic unit and under free water table conditions. Based on the lithological logs from nine observation wells and seven boreholes in the study area, the geological formations was found to be Um- Rawaba formation composed of two aquifers one shallow and other deep aquifer. The transimissivity of the deep aquifers was found to be 0.17 m^2/ min, which is good, and the average of hydraulic conductivity was found to be 0.0014 m/ min., which is high, (Muhamed, Ghadah M. Hamid Abd al-Magid (2007) [19].

The average depths to the water table in the area occupied by the two aquifers are almost slight variation between 0.5-1 m. depending on the exploitation condition either it is from the shallow or deep aquifer. The shallow aquifer restricted to the northwestern region is a water table aquifer overlain by a homogeneous layer of Qoz sands. The aquifer shows a reduction in thickness southwards due to the declined nature of the water table.

Its thickness in the northeast part is controlled by the depth of the Basement rocks (Abdel Khalig O, 2000) [8] (Whiteman, A. J. (1971) [6], (Ali , H. O., & Whitly, R.J. ,1981)[7] agreed with the Al-Obied Water Supply Project finding that the variation in the shallow aquifer thickness varies from 8 to 150 m. However, water table for the shallow aquifer can get closer to the ground surface under recharging conditions (in El Khearan area). The depth of water increases from west to east. It is approximately 15 m below ground surface in the North-West direction and reaches more than 100 m. in the South.

The total effective thickness of the Bara shallow aquifer exceeds 150 m. in the Bara and El-Khearan area. Many attempts have been conducted to estimate the hydraulic properties of Bara Um- Rawaba sub-basin aquifers. The average transmissibility reach about 225 and 1692 m2 day and hydraulic conductivity was estimated to be 2.3 m day. The fluctuation in static water level depending mainly on the annual recharge and discharge rates range between 0.5 to 3.0 m , (Elzien S.M. et al. (2013) [13].

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Bara – Um- Rawaba basin extends over North Kordofan state and the White Nile State, and today it is considered an arid region with rainfall mainly below 200 mm/year.

It is underlain by two major aquifer systems, unconfined shallow aquifer and semi-confined deep aquifers, which contain mainly fresh water. Depth to water varies from 4 m. to 70 m. depending on topographical elevations and proximity to recharging sources.

In Bara basin there are two aquifer exist:

1). The upper aquifer (shallow) is confined to the Qoz deposits and upper Um-Ruwaba sediments. Here, ground water occurs in well sorted sand , Qoz deposits and the coarse sandy layers of Um-Ruwaba formation. Ground water occurs under free water table conditions at depths varying from 10 meters at Bara town to a maximum of 48 meters along Qoz El-hagiz, south of Um-Dam village.

2). The deeper aquifer is separated from the upper one by a clay layer of Um-Ruwaba sediments acting as an aquiclude. The thickness of the aquiclude varies from 70 m. at Bara town to >150 m. around Um-Ruwaba town, (Omer Adam,M. Gibla e.t.al, 2016) [15].

The shallow aquifer extends across the North and Western part of North Kordofan State, and the principal areas of recharge to the shallow aquifer are the El Khearan, Greagikh, and Bara town areas through direct rainfall , infiltration and from recharge induced by seasonal streams. Sandy soil or Goz deposits cover about 75% of the Northern part of the area and are found naturally by sand dunes. This soil is characterized by its high permeability, poor water-holding capacity, low clay and organic matter content.

Excessive agricultural, industrial practices, and petroleum activities supported by the high vulnerability of the shallow aquifer will lead to the formation of pollution, especially around Bara town. High Salinity and high concentrations of nitrates were also recorded in some parts of the area. In addition, most of the agricultural plans in N.Kordofan state lie on the shallow sedimentary aquifer of Bara-basin. The impact of these conditions has raised attention towards groundwater quality deterioration, (Intenational Fund for Agricultural Developmrnt (IFAD Report, 1993) [3]. Bara basin is structurall depressionthat elongates northwest to southeast. This depression is filled mainly by Um-Rawaba Formation and superficial deposits. Depth to Basement Complex generally increases from west to east and from the basin periphery towards the center where the deepest area is more than 600 m. around Bara town, (Elmansour A. A, et. al (2019) [20].

MATERIAL & METHODS

Water samples were collected in polyethene bottles from 45 water wells. At each location, temperature, pH and electrical conductivity were measured using a glass thermometer, pH metre and E.C meter respectively. Major cations and anions were analyzed in the laboratory of Groundwater and Wades Directorate in Khartoum. All samples were analyzed according to

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Sudanese Standards and Metrology Organization, (2002) [18], and the Standard Methods of Examination of Water and Waste water (American Public Health Association, (A.P.H.A ,1984))[10]. In addition, Standard Classical Methods Jackson (1958) , Trivedy and Goel, (1984) were also used. Bicarbonate (HCO_3) was estimated by titrating the samples with HCl Sulphate (SO_4) is measured by a gravimetric method using a Barium Chloride to precipitate the salt. Magnesium (Mg^{+2}) was calculated from the Total Hardness. Calcium(Ca^{+2}), Sodium (Na^{+})and Potassium (K^{+}) were measured by a Flame photometer device. All parameters are expressed in milli grams per litre (mg/ l) except E.C in µS/cm^3 and pH express in pH unit. The analysed precession for the measurement of cations (Ca^{+2}, Mg^{+2}, Na^{+} and K^{+}) and anions (HCO_3, Cl and SO_4) were indicated by the ionic balance error which is observed to be within the stipulated limit of + 5%.

RESULTS & DISCUSSIONS

Results of physical and chemical parameters of the water samples from 45 wells from Bara Basin, Kordofan State, Sudan were presented in Table (1). Hydrogen ion concentration (pH) ranged from (6.9 - 9.1), and Electrical Conductivity (E.C) ranged from (50 - 4930 µS/cm^3). Cations concentrations ranges were: $K^{+} < Mg^{2+} < Ca^{2+} < Na^{+}$ where the anions ranges are: $HCO_3^{-} < SO_4^{2-} < Cl^{-} < NO_3^{-}$.

1. pH: The pH of water affects treatment processes, especially coagulation and disinfection with chlorine-based chemicals. Changes in the pH of source water should be investigated as it is a relatively stable parameter over the short term, and any unusual change may reflect a major event. The results of pH in the area ranging from (6.9 to 9.1) which indicates an alkaline nature of water, which agrees with the permissible range of W.H.O, (1984) [9]. Fig(3) shows that the range of pH throughout the area is vary between 7 to 9 , which indicates the alkaline nature of all samples.

2. E.C: All cations and anions in the present study considered as a main factors affecting electrical conductivity (American Public Health Association, (A.P.H.A ,1984)[10].

Ahigher concentrations of electrical conductivity values were found in sample collected from Al-Makser village (4930 µS/cm^3). Other high values were also found in Al-Zareeba-2 (3180 µS/cm^3) and in Um-Zeeraga-2 (2380µS/cm^3). Al- Ryad-1 (1720 µS/cm$^{3,)}$, Hamdan-2 (1720 µS/cm^{3,}), Um-Tagoor, (1760 µS/cm^{3,}), Um-Ushara (1690 µS/cm^3) and Khabur Khali villages (1700 µS/cm^{3,}).

3. Sodium ion: Considered harmful to persons suffering from Cardiac disease and high blood pressure. The recommended limit of sodium given by W.H.O., (1984) was 200 mg/l for drinking water and only 8 samples has a higher concentrations (more than 200 mg/l). These are Al- Ryad-1 (233 mg/l), Al-Zareeba-2 (799 mg/l), Um-Zeeraga-2 (487 mg/l), Hamdan-2 (226 mg/l), Um-Ushara-2 (355 mg/l), Wad Al-Zaki (275 mg/l), Meleeha

(203 mg/l) and Miema (276 mg/l). The rest i.e. 37 samples showed less than 200 mg/l.

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4. Potassium ion: The study showed less value of potassium ions throughout of the study area, The results of Potassium ion in the ranging from (0 to 29 mg/l) with average concentration of (5.22 mg/l).

5. Magnesium ion: The high values of magnesium ions were found in Um-Dayoka village (530 mg/l) and Al-Makser village (145 mg/l) and this may mainly be due to the presence of olivine and pyroxene rocks that covering small area.

6. Calcium ion: The highest values of Calcium ion concentrations were found in Makser village (377 mg/l. Other higher values are found in Al- Ryad-1 (211 mg/l), Al-Zareeba-2

(189 mg/l), Um-Zeeraga-2 (117 mg/l), Um Tagoor (276 mg/l), Hamdan-2 (219 mg/l), Um-Namil -2 (214 mg/l) and Um-Sot-2 (110 mg/l). No harmful effects from calcium normal values. According to E.E.C. (European Economic Community /European Union,1970) [17],

the recommended value is up to 50 mg/l, whereas the I.S.I. (Indian Standard Institution) recommended value is up to 30 mg/l.

7. Chloride: The highest value of Chloride concentration were found in Makser village (1718 mg/l). High values have also been found in some samples at Al-Ryad (493 mg/l), Khabur Khali (448 mg/l), Al –Zeeraba-2 (1200 mg/l) , Um-Zeeraga-2 (775 mg/l), and Hamdan-2 (225 mg/l). A higher values may be due to some contamination in water. High concentrations make too salty water. About 21 samples are restricted in range (less than 55 mg/l). in water.

8. Bicarbonate: The highest value of Bicarbonate ion concentrations were found in Wad -Alzki village (403 mg/l), whereas the lowest were found in Miema village (13.3 mg/l). Most of the wells vales were below 380 mg/l.

9. Nitrate: A very high concentration of Nitrate was found in Al-Makser village (1328 mg/l). High values have also been found in some samples at Um-Sot-1 (117 mg/l), Um- Dam (168 mg/l), Al-Zareeba-2 (204 mg/l), Khabur Khali (203 mg/l), Um- gigi (202 mg/l),Um- Sot (237 mg/l). The maximum nitrate concentration permitted by the W.H.O. (1984).[9] in waters for human consumption is 50 mg/l. High concentrations of nitrate from 31 samples were found throughout the study area.Ahigh values may be related to agricultural activities (such as the intensive use of synthetic fertilizers). In addition, high nitrate concentrations cause methahemoglobine disease in children and babies, and there is evidence that nitrogenous compounds formed inside the stomach act as human cancer promoters (Mageed and Barnes, 1956) [11]. In a research done by (Muhamed , Ghadah Hamid Abd al-Magid (2007) [19], wrote about the average of nitrate concentration which were found to be 74.1, mg l, which is above the permissible limit of W.H.O. standards [.

10. Sulphate: The highest value of Sulphate concentration were found in Makser village 2096 mg/l . High values of Sulphate have also been found in some samples : Al- Ryad-1 (408 mg/l), Al-Zareeba-2 (734 mg/l), Um-Zeeraga-2 (521 mg/l), Wad –Alzki (111 mg/l), Hamdan-2 (733 mg/l), Um-Tagoor (425 mg/l), Um Ushara-2 (421 mg/l) . About 26 samples fell within the permissible limit (less than75 mg/l), whereas 19 samples shows high concentrations of Sulphate ion.

11. Cation / Anion Relationship

a). Sodium / Chloride Relationship

The Na^+/Cl^- relationship graph (Fig.3) is often used to identify the mechanism of the dissolution evaporation. A parallel enrichment in both ions indicates the dissolution of chloride salts or a re-concentration process by evaporation (Appelo, C. & Postma, D. Balkema, (1993) [12].

The graph shows that the Sodium ion is in excess of Chloride due to the cluster of the points above the equity line as an indication for the multi-sources for Sodium.

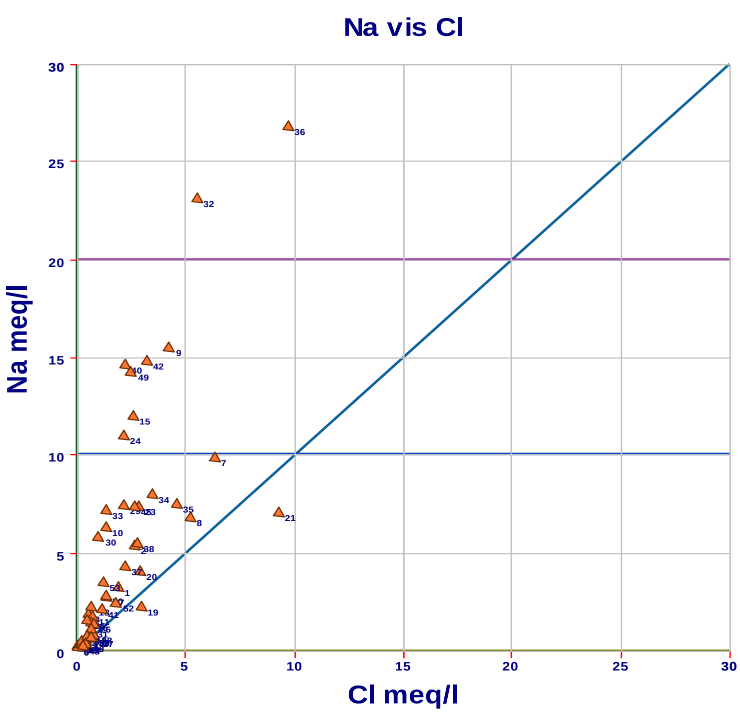

Fig.(3): Sodium / Chloride Relationship

b). Sodium ⁄ Sulphate Relationship

Fig. (4) shows the comparison between Na and SO_4 in all samples (except sample No. 1-Al-Makser) which shows higher concentrations of SO_4 ion. From the fig. , approximately all samples shows same concentrations of both ions (parallel line).

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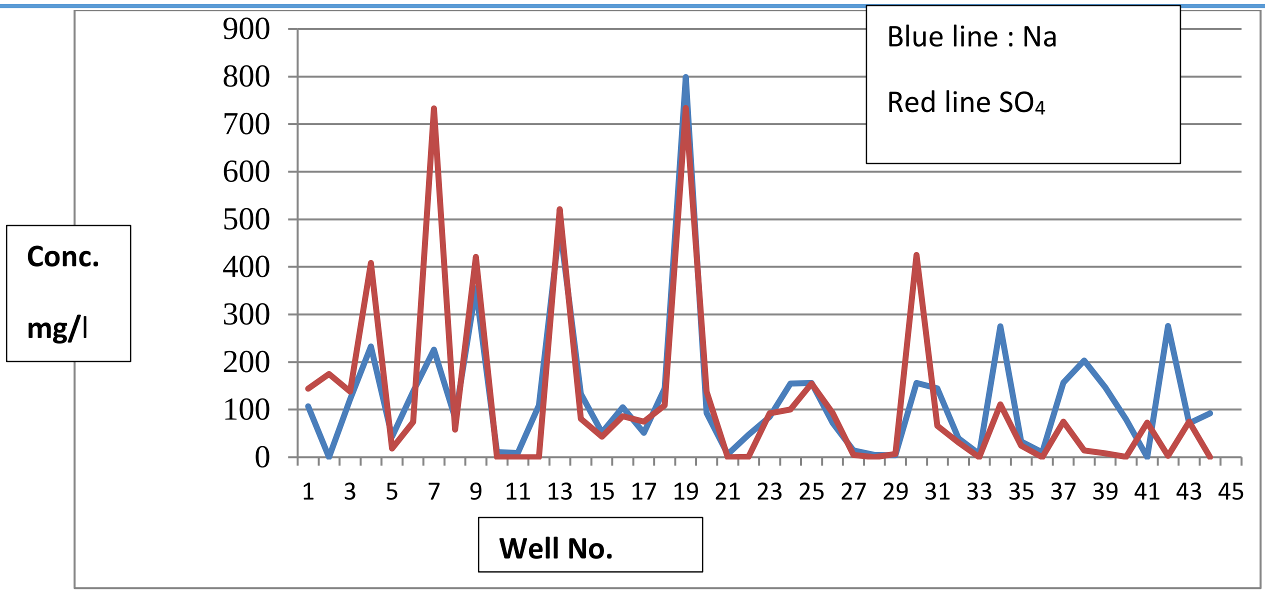

Fig. (4): Comparison between Na and SO_4

c). T.D.S / E.C Relationship

Total Disolved Solids (T.D.S) can be estimated from measurements of Electrical Conductivity (E.C at 25 C° in µS/cm) by applying a conversion factor k_e. In this paper T.D.S is acquired by taking the E.C value and performing a calculation to determine the T.D.S values, Table (1). T.D.S (mg l) = $k_e \times$ E.C (µS/cm), where k_e is a constant of proportionality (here assuming $k_e = 0.7$. From Table (1) Um-Ushara-1 (63 mg/l), Greegkh-1(83 mg/l), Greeakh-2 (65 mg/l), Al-Hadied-1 (121 mg/l)., Al-Hadied- (46 mg/l), Al-Bishiry (120 mg/l), Abu- Gaida (105 mg/l), Bara Al-rakabia (105 mg/l), Um-Zien (109 mg/l) Um - Nabag (64 mg/l), Miema (64 mg/l) showed the most good quality water with very low TDS values. With the exception of sample Nos.1,5,8,10,14,20 26 and 31) the drinking water quality sources is good from T.D.S and E.C values point of view (Table 1). T.D.S and E.C are used to describe salinity level.

Water quality classification

According to the aquifer recharge condition, two distinct water types were recorded :

- Low to absent (SO_4^{2-}) and (Cl^-) concentrations, may suggest water to be classified as Na-HCO_3^- water type.

-Present of Sulphate (SO_4^{2-}) and (Cl^-) concentrations are classified as SO_4^{2-}-Cl^- water type. The effect of mixing the two types of groundwater was well observed in many samples since they significantly differ chemically. Therefore, the two types of groundwater are :

I). Na-HCO_3 and II). Ca- Cl -SO_4 type shown in Fig. (5) Piper diagram.

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Piper diagram is currently used to classify the groundwater of the study area (Piper, A. M., 1944) [14]. The basin is characterized by good quality water in thecentre but it surrounded from four directions by high salinity zones. Ground water quality within the basin was characterized to be of good quality, fair quality , poor quality, fresh water,brackish water and salty water. Depending on the major anions content groundwater was classified into chloride water, sulphate water or bicarbonate water. Most of analyzed water samples showd high nitrate concentrations, (Omer Adam M. Gibl and Esraa Omer A. Mohamed, 2020) [4].

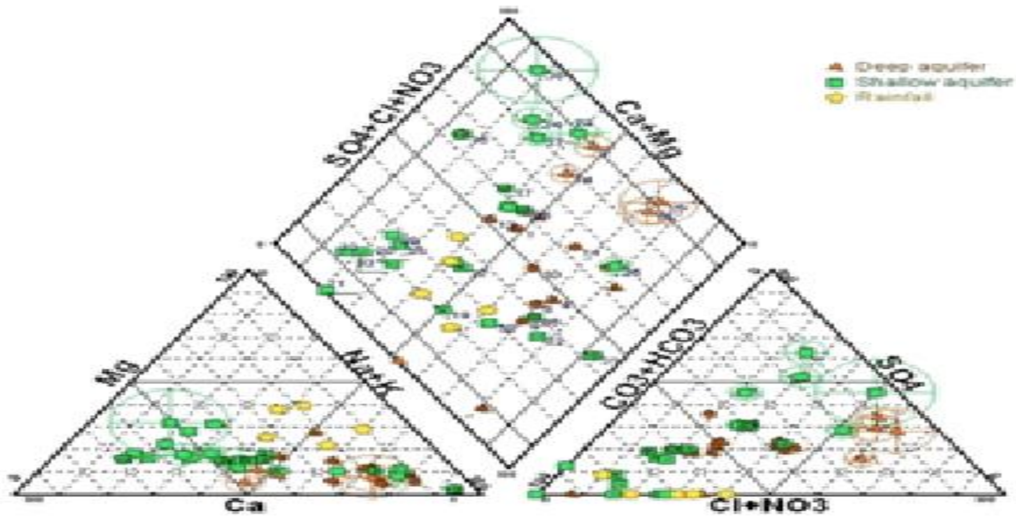

Fig. (5): Piper diagram shows types of water in Bara Basin

b = Bore hole w = Hand dug well

Fig. (6) is a Calcium distribution map; groundwater is undersaturated conditions with respect to calcite and dolomite within the direct recharge zone. The saturation indices for Calcite range between (2.2 and -1), and for Dolomite (-4.7 and -2.4) while Magnesium (Mg) concentration has the lowest values from 1 to 5 mg/l, and the (Mg/Ca) ratio is also low (0.12 to 0.45) mg/l. The highest values for Sulfate (SO_4^{2}), Chloride(Cl) and Nitrate (NO_3) have been observed at Al Makser (sample No. (1). It is also found in the north east Hamdan-2 , Um- Ushara, Al-read -1, Um-Zreega , Al-Zareeba and Um-Tagoor (Table,1),and the lowest at Greegkh 1&2, Al- Reyad-1, Al- Hideid 1&2 , Abu Gaida, Um-Dabose, Maleeha, Um-Nabag, Um-zien and Miema.

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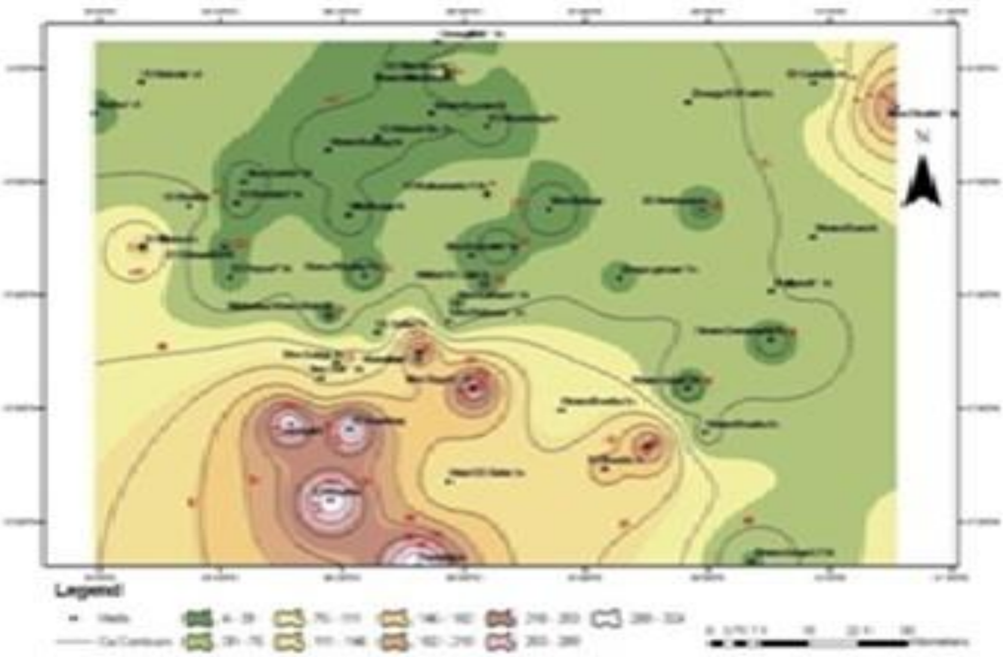

Fig. (6): Calcium distribution map of Bara Basin shallow aquifers

Table (1): Physical and chemical parameters of the water samples

S.N	Name	pH	E.C µS/cm	T.D.S mg/l	T.H mg/l	Na^{+} mg/l	K^{+} mg/l	Mg^{2+} mg/l	Ca^{2+} mg/l	Cl^{-} mg/l	HCO_3^{-} mg/l	NO_3^{-} mg/l	SO_4^{2-} mg/l
1	Al-Makser	8.1	4930	3451	151	148	6	145	377	1718	305	1328	2096
2	Um-Sot -1	7.0	765	535	24	107	4	20	69	56	232	117	144
3	Um-Sot -2	9.1	1150	805	102	0	0	102	110	113	48.8	82.5	175
4	Um- Sot-3	7.4	1055	738	21	122	3	18	11	93	238	237	138
5	Al- Reyad-1	7.2	1720	1204	19	233	4	15	211	493	153	27	408
6	Al -Reyad-2	7.6	360	252	10	43	5	5	30	19	207	12	18

7	**Hamdan-1**	**8.0**	**714**	**500**	**17**	**138**	**12**	**5**	**18**	**119**	**177**	**20**	**74**
8	**Hamdan-2**	**7.6**	**1720**	**1204**	**47**	**226**	**2**	**45**	**219**	**225**	**153**	**332**	**733**
9	**Um-Ushara-1**	**7.8**	**50**	**36**	**32**	**83**	**24.0**	**8.00**	**20**	**66.0**	**214.0**	**6.0**	**58.0**
10	**Um-Ushara-2**	**7.4**	**1690**	**1185**	**23**	**355**	**3.00**	**20.00**	**55**	**150.**	**378.0**	**180.0**	**421.0**
11	**Greegkh-1**	**7.6**	**118**	**83**	**3**	**11**	**2.00**	**1.00**	**6**	**0**	**43.0**	**22.0**	**0**
12	**Greeakh-2**	**7.8**	**92**	**65**	**5**	**9**	**4.00**	**1.00**	**4.00**	**7.0**	**31.0**	**25.0**	**0**
13	**Um-Zeeraga-1**	**8.1**	**530**	**371**	**11**	**109**	**5.00**	**6.00**	**13.00**	**18.0**	**378.0**	**0**	**0**
14	**Um-Zeeraga-2**	**8.2**	**2380**	**1666**	**37**	**487**	**12.0**	**25.00**	**117.0**	**755**	**293.0**	**0**	**521.0**
15	**Kagarat-1**	**8.4**	**810**	**567**	**18**	**133**	**6.00**	**12.00**	**33.00**	**81.0**	**329.0**	**51.0**	**81.0**
16	**Kagarat-2**	**8.1**	**513**	**360**	**12**	**52**	**2.00**	**10.00**	**47.00**	**24.0**	**189.0**	**94.0**	**43.0**
17	**Um-Namil -1**	**8.6**	**700**	**490**	**20**	**105**	**6.00**	**14.00**	**3.00**	**81.0**	**256.0**	**25.0**	**86.0**
18	**Um-Namil -2**	**8.4**	**1314**	**920**	**40**	**51**	**10.00**	**30.00**	**214.0**	**105**	**153.0**	**710.0**	**75.0**
19	**Al-Zareeba-1**	**8.1**	**890**	**623**	**10**	**145**	**3**	**7**	**57**	**137**	**214**	**73**	**109**
20	**Al-Zareeba-2**	**7.0**	**3180**	**2226**	**64**	**799**	**19.00**	**45**	**189**	**1200**	**299**	**204**	**734**
21	**Al-Zareeba-3**	**8.5**	**795**	**557**	**21**	**93**	**4**	**17**	**72**	**102**	**223**	**103**	**138**

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22	**Al-Hadied-1**	**8.0**	**173**	**121**	**8**	**6**	**3**	**5**	**14**	**8**	**37**	**67**	**0**
23	**Al-Hideid-2**	**8.4**	**65**	**46**	**0**	**47.4**	**0**	**0**	**18**	**31.9**	**24.4**	**56.1**	**1**
24	**Um-Dam**	**8.3**	**820**	**575**	**20**	**85**	**3**	**17**	**84**	**79**	**244**	**168**	**92**
25	**Abu -Socka**	**7.6**	**890**	**623**	**11**	**155**	**5**	**6**	**35**	**162**	**214**	**25**	**100**
26	**Khabur-Khali**	**8.0**	**1700**	**1190**	**45**	**156**	**19**	**26**	**164**	**448**	**281**	**203**	**155**
27	**Um-Gigi**	**7.8**	**775**	**543**	**17**	**72**	**2**	**15**	**85**	**67**	**146**	**202**	**93**
28	**Al -Shiwaifia**	**8.2**	**225**	**158**	**10**	**14**	**5**	**5**	**27**	**13**	**116**	**0**	**5**
29	**Al-Bishiry**	**8.4**	**170**	**120**	**12**	**5**	**7**	**5**	**21**	**0**	**85**	**10**	**0**
30	**Abu- Gaida**	**7.8**	**150**	**105**	**5**	**4**	**2**	**3**	**18**	**0**	**61**	**22**	**7**
31	**Um-Tagoor**	**7.8**	**1760**	**1232**	**56**	**156**	**2**	**54**	**276**	**185**	**177**	**739**	**425**
32	**Um-Laham**	**8.1**	**790**	**554**	**12**	**145**	**1**	**11**	**32**	**46**	**256**	**134**	**66**
33	**Um-Dabose**	**8.1**	**415**	**291**	**14**	**40**	**5**	**9**	**31**	**25**	**159**	**52**	**31**
34	**Bara-Al-rakabia**	**7.8**	**150**	**105**	**7**	**7**	**2**	**5**	**11**	**5**	**24**	**58**	**0**
35	**Wad -Alzki**	**8.2**	**1126**	**789**	**6**	**275**	**2**	**4**	**12**	**92**	**403**	**125**	**111**
36	**Um-balagi**	**8.2**	**233**	**162**	**12**	**33**	**9**	**3**	**5**	**23**	**128**	**15**	**24**
37	**Zerega - Gezanu**	**7.4**	**280**	**196**	**8**	**10**	**3**	**5**	**32**	**7**	**61**	**102**	**0**
38	**Alsider**	**8.1**	**570**	**400**	**10**	**157**	**0**	**10.70**	**52**	**110**	**76.1**	**123**	**75**
39	**Maleeha**	**8.7**	**225**	**158**	**0**	**203**	**0**	**0**	**30.80**	**33.5**	**54.9**	**396**	**14**

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40	**Um-Zien**	**7.1**	**155**	**109**	**0**	**147**	**0**	**0**	**24**	**24.8**	**36.6**	**298**	**8**
41	**Um-Nabag**	**6.9**	**90**	**64**	**0**	**79.6**	**0**	**0**	**24.8 0**	**24.8**	**24.4**	**172. 7**	**1.**
42	**Um- Dayoka**	**8.2**	**635**	**445**	**530**	**0**	**0**	**530**	**24**	**67.5**	**30.5**	**240. 9**	**73**
43	**Miema**	**8.3**	**90**	**64**	**0**	**276**	**0**	**0**	**18.4 0**	**21.3**	**13.3**	**71.5**	**3**
44	**Dameera Abed**	**7.9**	**390**	**275**	**0**	**71.3**	**0**	**0**	**51.2 0**	**46.2**	**36.6**	**60.5**	**75**
45	**Um –Gerif**	**7.2**	**600**	**420**	**38**	**92**	**29**	**9**	**23**	**73.**	**232.0**	**64.**	**0**
	Average	**7.9**	**843. 4**	**590**	**33.5**	**126.3**	**5.22**	**28.3**	**66.4 1**	**159**	**165.3**	**156. 7**	**164. 7**
	Maximum	**9.1**	**4930**	**3451**	**530**	**799**	**29**	**530**	**377**	**1718**	**403**	**1328**	**209 6**
	Minimum	**6.9**	**50**	**36**	**0**	**0**	**0**	**0**	**3**	**0**	**13.3**	**0**	**0**

CONCLUSIONS & RECOMMENDATIONS

The results of analysis show that the drinking water quality is generally good according to drinking water standards established by WHO, (1984) [9] , European standards for drinking water (1970) [18] and Sudanese Standards and Metrology Organization (2002) [18]. The results also showed existence of some pockets with significantly high salinity : (E.C 4930 µS/cm^3,), T.D.S (3451 mg/l), Cl (1718 mg/l), NO_3 (1328 mg/l) and SO_4 (2096 mg/l) in Al-Makser village. In certain areas the water quality was found to range from unsafe for human use to brackish water.

The basic information on the concentrations of pH, E.C, T.D.S, Na^+, K^+, Ca^{++}, Mg^{++}, Cl, SO_4 and HCO_3 at different locations of Bara basin, Kordofan State, Sudan, has been obtained in this study.

The following conclusions and observations is made on the basis of the data represented in Table (1):

- The study concludes that, water sample from Almakser village has a very high concentrations of E.C, T.D.S, Ca^2, Cl^-, NO_3^- and SO_4^{2-} which may suggest that this water sample are not suitable for human consumption according to W.H.O, (1984) [9].
- The study concludes that, water samples from Hammada, Um-Tagoor, Um-Usgara, Um-Dam, Khabur- Khali, El-Zereega ,Um-Gigi, Um-Sot, Um- Laham, Namil, Meleeha, Um-Nabag, Um- Dayoka villages have very high concentrations of NO_3^-which may suggest that water samples are not suitable for human consumption according to W.H.O, (1984) [9]. According to the results obtained from the hydrochemical relations, the main geochemical processes that control and affect the water quality in the shallow Bara basin aquifer are due to the dissolution, de-dolmitization, and ion exchange.
- The dissolution takes place throughout the whole aquifer system and dominates the chemical processes at the direct recharge zone.
- The de-dolmitization process is mainly controlled by the availability of $CaSO_4$ in the medium where the Ca^{2+} from the $CaSO_4$ facilitates $CaCO_3$ precipitation. Since the direct recharge zone record is low to absence of SO_4^{2-} concentration this process dominates the lateral recharge zone.
- The geochemical studies of this paper conclude that, the chemical characteristics of the saline water of Bara shallow aquifers are mainly due to presence of Sulphate (SO_4^{2-}), dissolution, and dolmitization processes.
- According to the aquifer recharge condition, two distinct water types were recorded these are:
- Depth to water varies from 4 meters to 70 meter depending on topographical elevations and proximity to recharging sources. There are two types of the aquifer exist:

1). The upper aquifer is confined to the Qoz deposits and upper Um-Ruwaba sediments. Here, ground water occurs in the, well sorted sand , Qoz deposits and the coarse sandy layers of Um-Ruwaba formation. Ground water occurs under free water table conditions at depths varying from 10 m. at Bara town to a maximum of 48 m. along Qoz El-hagiz, south of Um-Dam.

2) The deeper aquifer is separated from the upper one by a clay layer of Um-Ruwaba sediments acting as an aquiclude. The thickness of the aquiclude varies from 70 m. at Bara to >150 m. around Um-Ruwaba town, (Omer Adam M. Gibla, et.al, 2016).

- The area may need a further total environmental and ecosystem study from authorities of different specialization.
- The huge amount of ground water can be found for a real agricultural development.

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