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Ground water salinity in bara basin

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Abstract
Bara basin covers a highly populated area in northern Kordofan. The area depends completely on ground water as a source for human drinking, animal watering and to a lesser extent for irrigation. Ground water here used as raw water by consumers without any treatment. The bore holes occurrence is limited. The most available wells are open shaft wells (hand dug wells), or pump wells. Within the basin, there are many zones or pockets which are characterized by high salinity. The basin is now one of the main choices to solve the problem of drinking water deficiency in El-Obeid town. The depth of the wells in the area varies considerably from (10- 20 meters) in some areas and from (40- 70 meters) or more and this may be a reason for some changes in the ground water quality depending on type of soil layer or water bearing rocks formation. The aim of this study was to measure the most essential parameters that determine drinking water quality. The study also aimed to determine the extent of salinity in certain zones and pockets in the area. Fourty five water samples were collected from four sections. Two sections showed fresh and moderate saline properties. The other two sections showed high salinity which can be compared to that of sea water. The measured variables include pH values, turbidity, total dissolved solids (TDS), electrical conductivity (EC), and total alkalinity. The results of analysis show that the drinking water quality is generally good according to drinking water standards established by WHO, (1984, 1993) [8], European standards for drinking water (1970) [7] and Sudanese Standards and Metrology Organization (2002). The results also showed existence of some pockets with significantly high salinity. In certain areas the water quality was found to range from unsafe for human use to brackish water.

Keywords: Salinity, Turbidity, Basins, Topography, Groundwater, Aquifers

Introduction

Ground water constitutes nearly half the world's drinking water and much of the world irrigation water supply. Population growth, over exploitation, salinization, nonpoint source pollution from agricultural activities impact to surface water and ground water quality and quantity conflicts at the urban-rural interface have reached a global dimension, and threaten the health and the livelihood at this planet (Tomands sustainable, ground agriculture conference, sanfrancisco, CA 2010) [14]. Sudan depends upon ground water aquifers, for human use, animal consumption, and irrigation (in some areas) most of the year (Abdeen M. Omer, 2013 [3]; Wheater, 2007). Just few kilometers from the Nile, ground water aquifers provide the only permanent stocks of water. Where they guarantee the existence of almost 75% of the population and the livestock whose as well as the needs of wild animals, supplementary irrigation, industry and losses due to evapo-transpiration, infiltration and wastage.

Ground Water in Africa

There are so many factors controlling the formation of ground water in Africa which include; the African continent, Africa's symmetrical situation on both sides of the equator, Regional factors which include: (Climate, topography, vegetation, soils, water bearing rocks, earth gravitation and human activity), local factors such as; (microclimate relief, stream flows, mineral deposits, the action of thermo-mineral water and brines in places of their discharge), topography which plays significant role in the formation of groundwater in Africa, the recharge of the basins which considerably influence the surface channels and reservoirs especially in arid, semi-arid, and humid climates, and finally the water bearing rocks which play a major role in the formation of ground water resources and their chemical content. The Umm Ruwaba formation in the Sudan depression, the upper section of the Chad and kerry-Kerry formation in the Chad depression, the alluvial deposits in the Congo depression are among the biggest water bearing complexes in Africa (UN. 1988).

Geology and geological history of the Sudan

Sudan has the following geological units of structure: Crystalline basement rock (Precambarian), Nawa formation and Paleozoic sandstones (Cambrian-carboniferous), Nuri sandstone (Jurassic – Cretaceoua) altic out crops (Tertiary), Basaltic out crops (tertiary), Coastal deposits (Late Tertiary), Umm Ruwaba formation (Pliocene – Pleistocene), and Surface deposits (Late Pleistocene) (Sir Alexander, 1979; Ali H.O., 1981).

Umm Ruwaba Formation

This formation covers 20% of the country forming two big trenches in the center and south. The main trench covers most of Kordofan, Darfur and the South Sudan, the other trench is found in the area of Blue Nile and its tributaries, Rahad, and Dinder. These are unconsolidated series with little stratification consisting of sand, silts and clays. The sand or clay content is probably due to the Nubian sandstone and the clay content to basement rock.

The study area (Bara Basin)

Bara basin is about 60 Km North of El-Obeid covering an area of about 6000 km^2 of semi desert terrain with sparse vegetation (H.O. Ali and R.J. Whiteley (1981). The basin occupies a trench of 6800 km^2 running North-West/South-East in central Kordofan and eastward as far as the White Nile south of Kosti (UN 1988). It is bounded in the North West by Nubian sand stone and by the crystalline base rock on the other sides. The basin is divided into two sub-basins by a north-east saddle produced by an uplift of the basement rock, but they remain in hydraulic contact with each other. Bara basin comprises mainly the localities of Bara and Umruwaba of Kordofan state. It extends between latitudes 12˚ – 10˚ and 48˚ – 10' North and longitudes 28- 50 and 32 East (IFAI, 1993) [11]. It is a semi closed system with an outlet only in the South easterly direction. It composed of fine unconsolidated sediments that attain a maximum thickness of about 1.4 km around the central part of the basin. The water level varies from 50 – 70 m and occurs under confined conditions (H.O. Ali, 1983) Bara aquifer complex is the main water bearing zone within Um ruwaba and Bara localities. It is composed of Nubian, Umruwaba and Qoze sands that filled the Bara structural traugh and form a multi-layer aquifer system (IFAD, 1993) [11].

Ground water studies of local problems have been carried out in Kordofan province since 1905, it was not until the 1930's that the first reports describing the regional occurrence of ground water in the province were published. As part of a report on the water resources of Sudan, Graham (1934) described the general occurrence of ground water.

Basin Topography

Topographically the area covered by white sands and sand dunes which form a rough surface with general elevations varying from 540 m (a.m.s) in the south to 480 (a.m.s.) in the north. Annual rain fall in the region is 300 mm (H. O. Ali and Whiteley, 1981). IFAD (1993) [11] describe the surface of the area as largely undulating plain of low relief, punctuate by Jebels of basement complex rocks, which appear as a chain extending along the Northern, Western and Southern boundaries of the area. This includes Jebel Eldair, Dumbair, Kon, Zalata, Muginus, and Hemaui. The land surface, generally, slopes in an easterly direction towards the White Nile, falling from 540 m above mean sea level in the West to 400 m on the Eastern border. The area is characterized by the presence of longitudinal sand dunes (qozes), generally extending North-South. GozeElhagize.g extends for more than 300 km North South of Khor Abu Habil. El-Kheiran, a topographical depression, extends for more than 100 km west of Bara town, and from Ashaf in the south to Sharshar in the North. It forms 108 clay depressions separated by invading sand dunes. (It can be described as Wahat or Oasis's). The mean rain fall (1912-1993) over the basin area varies from 150 mm in the North to 350 mm in the South. Ninety percent of the total rains fall in July, August and September (With rainy days average of 28 day/annum). Although the area lies in water shed of White Nile, permanent surface drainage courses are absent. This is mainly due to seasonality of rain falls and the sandy nature of the soil cover. The major drainage system is Khor Abu Habil system, with its major tributaries, Kageer and Tagerger, draining the Northern slopes of the Nuba Mountains and the scattered Jebels South of El-Obeid water divide. During wet periods Abu Habilused to spill into the White Nile. But recently it used to disappear under creeping sands at Tendelti 40 kms east of the basin (IFAD, 1993) [11]. Minor drainage systems exist at Khor El-Teina, Khor Elhamra and Khor Shashar that spill into El-khaeiran depression. Khor El-Karta that drain the area east of El-Obied used to spill into Bara depression, but recently it used to infiltrate in the Qozes 30 km south of Bara.

Geology of the Basin Area

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. Towards the end of Paleozoic, shallow seas invaded the southern parts of the area and deposited Nawaformation. Uplift and erosion removed most of Nawa formation leaving only isolated remnents. During Mesozoic time shallow continental seas covered the Northern parts of the area and Nubian sediments were deposited. The area was subjected to uplifting, seas receded and the area experienced, a prolonged erosion that stripped away most of Nubian sediments.

Mid and late tectonic movements in east Africa had formed the rift system and created structural basins. Rifting process gave rise to fracturing, faulting and subsidence to form Bara trough. The trough was filled during Pleistocene and early Pleistocene time with fluvial and lacustrine deposits that now comprise the Um-Ruwaba formation. Subsidence continued with the deposition of Um-Ruwaba sediments. In late Pleistocene time, the area was subjected to a wide spread and recurrent flooding and deposited (silts) and clays. Concurrent with flooding, strong Northerly winds denuded the Nubian sediments and deposited "Qoze" sands, that later moved southwards. Deposition of Wadi-fill deposit along the water courses still continuing (NKRDP, 1993). Geologically the bulk of the basin is composed of relatively fine consolidated sediments known as Umruwaba formation (Whiteman, 1971, H.O. Ali, 1983) and overlain by thin superficial deposits of windblown sands. The sediments are bounded from the Western and Southern parts by the basement complex formation and from the north by the Jurassic. Gretaceous Nubian sandstone formation (Fig.1) quantitative geophysical survey (Ali and Whitley, 1981) 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 (Fig. 1). Around its central part the basin attains a maximum thickness of about 1.4 km. To the North and the South, the basin has steep side walls suggesting that the basin is bounded by the faults which may well be related to the African rift system. (Ali and Whitley, 1981). Ali, (1981) reported that 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 the South by metamorphic and igneous rocks and to the North by relatively thin sediments of the Nubian sandstone formation (Whiteman, 1971). NKDP of IFAD (1993 - 2002) [11] reports 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. The East-West faulting system controlled the protrusion of basement inliers within the sedimentary basin (Fig. 1). With the exception Um Ruwaba fault, all the North

East – South West faults have down through South-East wards. The axis of Bara trough extends from Elbashiri south east wards passing Bara town, and then bifurcates into a southern and Northern branches. The southern branch passes south-east wards through Eltayara, UmRuwaba and continues into the White Nile boundaries. The Northern branches continue east wards to join Abu-Tenetin depression which is controlled by North West – South East faulting system and finally continues east wards. The two branches of Bara trough are separated by a North West – South East trending basement ridge extending from Jebel Kon to Magrurbarried ridge. The extension of the ridge North West wards to jebel Muginus was terminated by the East-West faulting system.

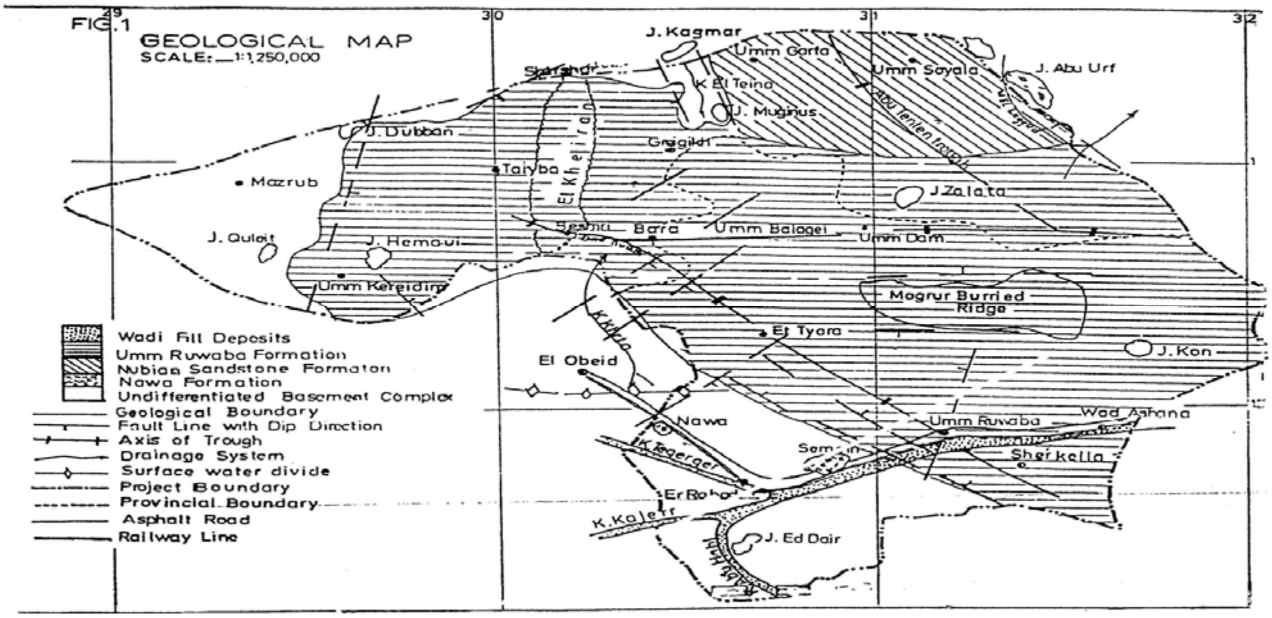

Fig 1: Geological Map of Bara Basin (Source: Special Identification Mission Reports, IFAD, ROME, 1993) [11]

Geological Formation

The geological formation of the area can be characterized as follows

Superficial Deposits (Pleistocene to date)

These include clay plains, Qoz sands and Wadi-fill deposits. The clay plains that had extensively covered the whole area were eroded from the Northern parts by the action of winds. In the Northern part only reminent of clay layers were prescured along the interdunal hollows or in the depressions of El-Kheiran, Khor El-Terna etc., south of khor Abu-Habil clay layers dominated the top soil and with thickness rarely exceeding one meter. Their presence, with swelling character impedes rainfall in filtration to recharge the underneath layers. Qozes are made of well graded and well sorted, medium to coarse sands with thickness up to 50 meters. The most famous Qoz El-Hagiz extends for more than 300 km from North of the area to South of Khor Abu-Habil. Their hydrological significance is that they act as a permeable layer through which rainfall infiltrates and thus no run off can develop. Wadi-fill deposits cover the beds and the banks of the present and older drainage systems. They vary from medium to coarse sands and upstream to silts and clays in flood plains and deltas. This thickness rarely exceeds 20 meters. Older Wadi-fill deposits might have occurred in the Northern part of the area, but presently buried under the sands and can only be detected by geophysical surveys. Khor Abu-Habil is the most important modified deposit within the area.

Um-Ruwaba Formation (Plio-Pleistocene)

No surface out crops of the Um-Ruwaba formation is known. Its existence and lithology are known only from bore hole logs. The formation consist of flat lying sequence of unsorted or unconsolidated gravels, sands, sandy clays and clay containing characteristic carbonate nodules or Kankers. The unsorted nature of the sediments indicated rapid deposition under torrential continental fluriatile or lacustrine conditions. Although rapid facies change is characteristic of Um-Ruwaba sediments, thick (>100m) and continuous coarse sandy and gravelly layers were encountered from bore holes logs in Bara and Um-Ruwaba areas. The maximum Um-Ruwaba thickness encountered by bore holes is 500 m. At Um-Balagei, east of Bara town, geophysical investigations indicated a thickness up to 1000 meters (Ali, 1981).

Bara Basement Aquifer Complex (pre-Cambarian to Cambarian)

This is the oldest and most extensive rock unit in the area. Basement composed of geneinsses, Schists, granites, crystalline lime stone and other igneous and metamorphic rocks. Basement crops out as mountainous terrain along the Northern, Southern and Western boundaries of the basin area such as Jebel Dumbair, El-Dair, Abu-Urf, Muginus, Kogmar, and Quleit. It also occurs as inliers within the sedimentary basin as Jebel Kon, Zaluta and Hemawi. It’s hydrogeological significance is that, it forms the base of Bara trough as well as causing damming to ground water movement. Under specific geological and by hydrogeological conditions it contain minor aquifers. A.R. Mukhtar (2001) referred to the presence of two aquiferous zones within Bara basin. One deep and extends under most of Bara and Um-Rawaba provinces and the other 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 isformed mainly from Um-Ruwaba sediments with Nubian sediments filling the base of structural depressions. Both areas are covered by Qoze deposits. Ground water occurs in the three formations (Bara, Nawa and Abu-Habil aquifer), as a single hydrolic unit and under free water table conditions. Depth to water varies from 4 meters to 70 meter depending on topographical elevations and proximity to recharging sources. South and South east of the aquifer divide two 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, 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 Quze El-hagiz, south of Um-Dam. The upper extends as an extensive sheet over most of the area (and with thickness varying from 30 to 100 meters. Along the eastern boundary of the area, when the Qoz diminishes the upper aquifer is dominated by clays of the Um-Ruwaba formation
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 meters at Bara to >150 meters around Um-Ruwaba town.
3) Along the deep aquifer ground water occurs in multi-layers of Um-Ruwaba and Nubian sediments under hydrolic connection. Ground water generally occurs under semi-confining conditions and at depths of 10 meters at Bara to over 100 meters south of Um-Ruwaba. An artisan aquifer was tapped within Um-Ruwaba formation at depth of 500 meters, by two bore holes at Um-Balagei east of Bara and ground water level rises 2.5 meters above ground level.

Hydrological Characteristic of Bara Basin

Hydrologically, Bara basin is not fully developed (H.O.Ali and R.J. Whitley, 1981). This indicates that the bulk of basin is filled with sediments of Um-Ruwaba formation and that aquifers associated with gravels and sands have been found at depths greater than 60 meters. In most cases, shallow Bara basin sediments are poorly sorted clay beds and/or sandy clays in which vertical and lateral facies changes are common.

According to IFAD (1993) [11] the accurate determination of aquifers characteristics are faced by the following constituents:

- Most of existing bore holes did not tap the full aquifer thickness.
- High hetero-genecity of the deep aquifer material and variation of aquifer characteristics from place to place.
- The deep aquifer permeability and storativity are expected to reduce along the eastern boundary of the area due to domination of clays over the aquifer material (Fig. 2).
- Fluid resistivity logging applied in El-Obeid wells near Bara indicated a complete separation between the shallow and deep aquifers of Bara aquifer complex.
- Ground water flow direction is generally controlled by the surface topography of the basement complex (IFAD, 1993) [11].

Within Bara aquifer complex, ground water flows from the recharge areas along the northern and western aquifer boundaries towards its center (Fig. 2).

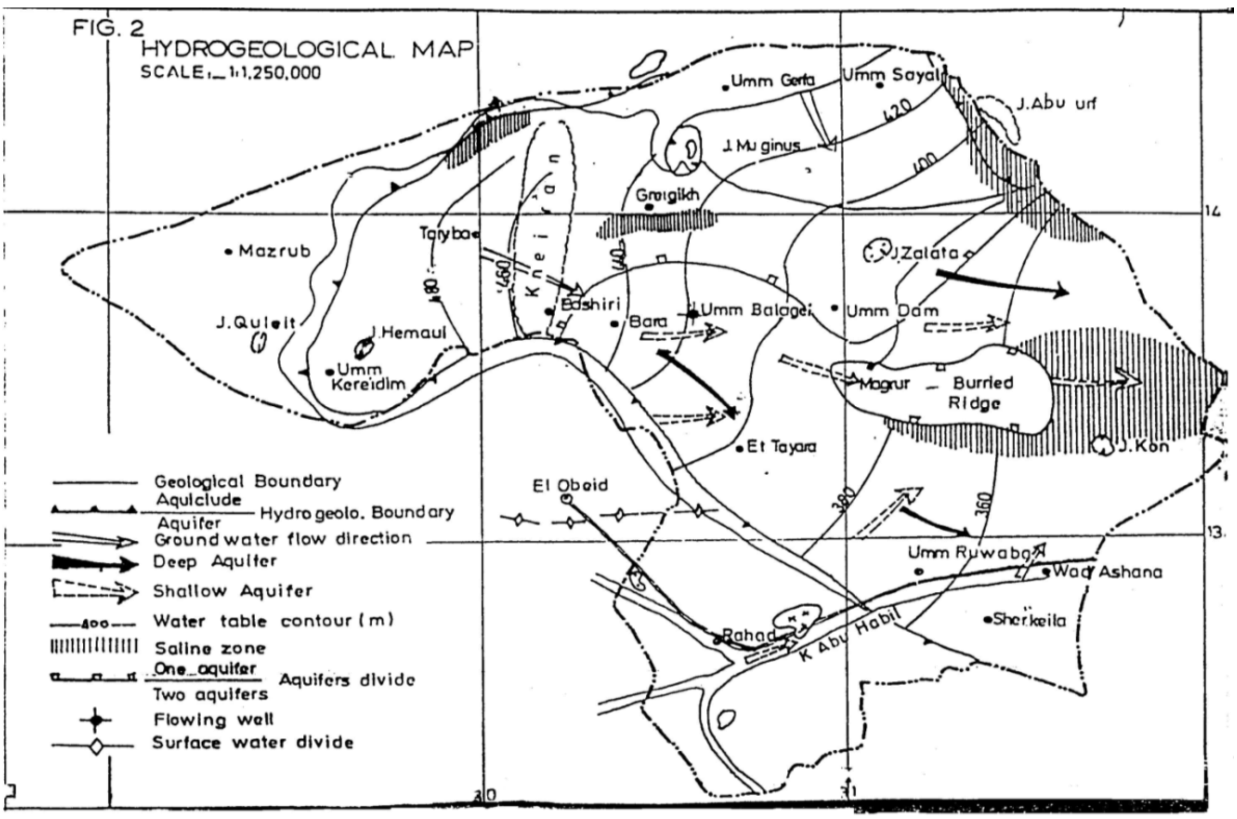

Fig 2: Hydrological Map of Bara Basin (Source: Special Identification Mission Reports IFAD, ROME, 1993) [11]

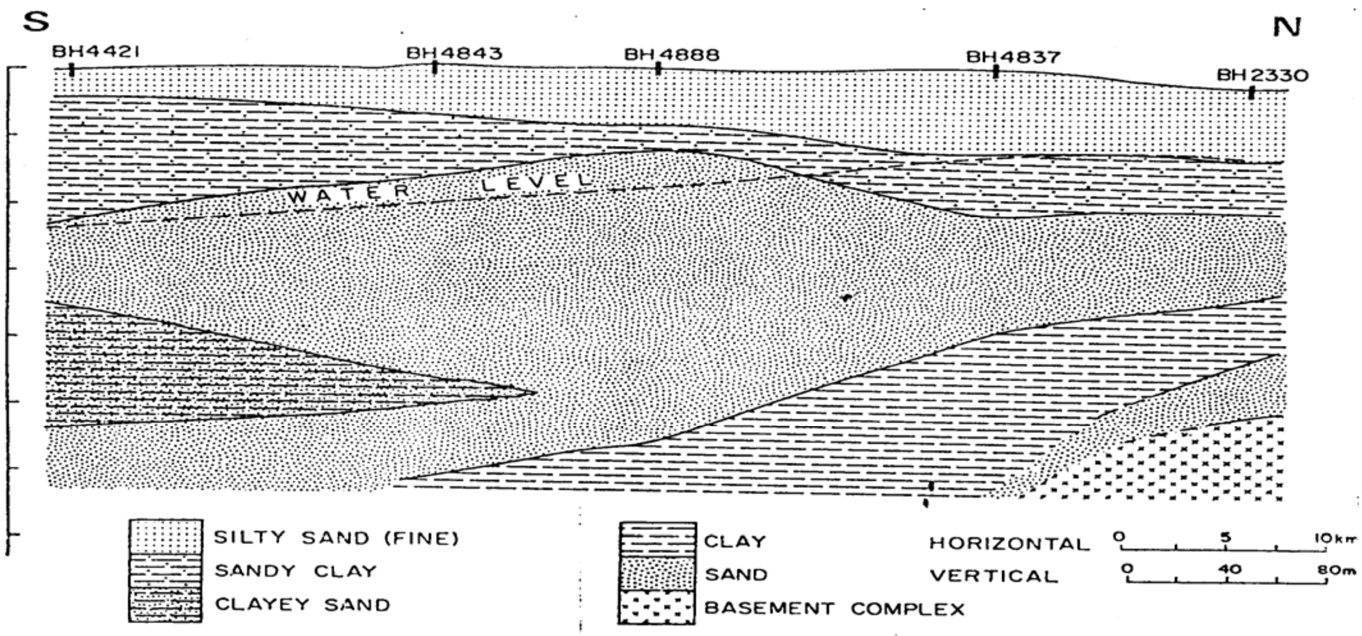

Fig 3: Geological Cross-section across the Bara basin (Source: Geoexploration, 19, (H.O.Ali, 1981), p 139)

Ground Water Quality

Umm Ruwaba aquifer include; Bara, Atshan, Baggara, and Sudd basins. Groundwater of the aquifer is generally of good quality, with total dissolved solids content usually below 1000 ppm, and below 80 ppm in some areas. There are some pockets of high salinity (up to 6000 ppm). This may be due to salts deposited by evaporation prior the deposition of Umm Rwaba formation itself. At Bara Basin salinity is generally low near the recharge areas (150 ppm), but it gradually increases towards the basin outlet. Saline pockets (5000 ppm) occur north of the saddle of the crystalline basement rock which divides the basin into two sub-basins. Other pockets occur near JabalKon (6000 ppm).

Raw drinking water supply

Drinking water criteria define a quality of water that can be safely consumed by humans throughout their lifetime. Such criteria have been developed by international organizations and include WHO guidelines for drinking water quality (WHO, 1984, 1993 and the EU Council Directive of 15 July 1980) [8]. Relating to the quality of water intended for human consumption (*0/778/EEC), which covers some 60 quality variables.

According to Newport and Haddor (1963), Rodis (1964) ground water quality in Kordafan can be described by the amount of total dissolved solids (TDS) with respect to tolerance by man, plant and beast. They classified ground water as shown by Table (1).

Table 1: Ground water quality

	Rating	TDS /ppm
1.	Good quality	< 1500 ppm
2.	Fair quality	1500 ppm
3.	Poor quality	> 3000 ppm.
4.	Fresh water	< 3000 ppm
5.	Brakish (moderately mineralized water)	3000 – 6000 ppm
6.	Salty water (Highly mineralized)	> 6000ppm.

Rodis (1964) reported that the (TDS) content of water from UmRuwaba aquifers range from 420ppm to more than 3000 ppm (average 1050 ppm). Rodis *et al*. (1964) also stated that “The water from weathered basements rocks in the northern Kordofan province is commonly, brackish or salty. Typical examples are the dug wells of Jebel El-Gaa, Shershar and Jebel El-Gheraid area.

Chemical analysis of 100 representative wells in great Kordofan showed a general relationship between chemical quality of water and its geologic source (Rodis, 1964).

A.R. Mukhtar (2001 - 2002) studied many representative water sources (Bore holes, open shaft wells and pump wells, considering the electrical conductivity (EC) as a measure of ground water quality and considering ground water with EC >1500 µs/cm unsafe for human use. Accordingly he classified the ground water of the administrative localities of UmRwaba and Bara provinces to safe and unsafe.

Ground water salinity

Salinity is a measure of the amount of dissolved particles and ions in water. Salinity can be defined as the presence of salts in the land surface, in soil or rocks, or dissolved in water in rivers or ground water. The most frequently used methods for measuring salinity are total dissolved solids (TDS) and electrical conductivity (GAMA, 2010) [12]. National center for ground water research and training (NCGRT, 2012) reported total dissolved solids (TDS) and electrical conductivity (EC) as measure of ground water quality. Therefore salinity can be described as the measure of the amount of dissolved particles and Ions in water. State water resource control board, California, (2010), also considered TDS and EC as a measure of ground water salinity.

The clarity of water is unrelated to salinity e. g: the visibility in the Ocean can be hundreds of feets, although the salinity is very high (35,000mg/l). At the same time water with low visibility can have low TDS e. g (200mg/L) as it is the case in

Mississippi river (GAMA program 2010) [12] because the particles that obscure visibility are not dissolved and can be easily filtered from water. Such effect may be described as turbidity. So the amount of dissolved materials in natural water is a complex function of climate, land use patterns, human activity in the watershed and geologic make-up of the hydrologic basin (GAMA program 2010) [12].

Salinity Buildup

According to New South Wales Surveys (NSW, 1983-91) when wind and rain weathered rocks that contain salt or carry salt from the ocean, then salt is left in the landscape. A salt has also been deposited in places that were under the sea in pre-historical times. Salinity can develop naturally, but where human intervention has disturbed natural ecosystems and changed the hydrology of landscape, the movement of salts into the rivers and onto land has been accelerated. This is a beginning to dramatically affect natural environment, reduce the viability of agricultural sector and damage private and public infrastructure. The acceleration will continue until a new hydrological equilibrium is reached, but that equilibrium will impose an incalculable cost unless action is taken now and that will not be able to reverse all the damage, or do more than slow the rate of damage over the next ten to fifteen years. Salinity often occurs in the company of other natural resource problems, such as decrease in soil quality, erosion, and dieback of native vegetation. Salinity can be classified into; Dry Land Salinity, Irrigation Salinity, Urban Salinity, River Salinity, and Industrial Salinity (NSW, 1983-91).

The California department of public health (CDPH, 2007) has established EC and TDS secondary maximum contaminant level (SMCL) as drinking water standards for public water supplies. For TDS the recommended SMCL is (500mg/l) and the upper SMCL is (1000mg/l). For EC the recommended value is (900µS/Cm) and the upper SMCL is (1,600µS/Cm). EC and TDS also have short term SMCLS that are generally allowed only under certain circumstances (2,200µs/cm; 1,500µs/cm respectively). Salinity can be categorized into dry land salinity a number of different ways.

Materials and Methods

pH meter

pH/ion meter 555, Corning Pinnacle.; Ultra-meter™ 6P MxRONL company seriw. # 609914.; 712 Conductometer/ Metrohm, was used for measuring pH values, TDS and EC values. Nephleometer was used for turbidity measurements.

Result and discussion

pH values

As one of the most important physical characteristics of water quality, pH appeared in the four sections within the acceptable ranges. For section (A) the highest value was 8.511 and the lowest was 7.516, the mean value was 8.0133. The high salinity zone samples of section (B) showed the highest pH value in sample (No. 18) as (8.315) and the lowest value in sample (No. 12) as 7.453.

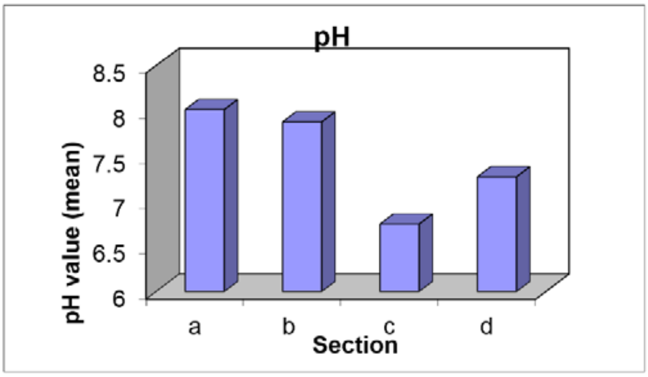

Fig 4: pH means values

All section(C) samples show pH values less than 8, with the highest value 7.10 in sample (No. 34) and the lowest reading was 6.43 in sample (No.25), with a mean value 6.75. Almost all pH values in this section are less than 7.0. This may explain the corrosively of water to metallic tanks and reservoirs, when moving ast ward from the centre of the basin. The slight acidic properties may be due to the high sulfate and chloride concentrations in this section (Gibla, 2007) [13]. Section (D) samples which are from high pH value as 7.7 in sample (No. 39) and the lowest value of 6.98 in sample (No. 35) with a mean value 7.27.

Total alkalinity

Total alkalinity ingredients are $CO_3^{=}$, HCO_3^{-}, and OH^{-} - content of water sample. Though out and the studied areas the hydroxide content in zone (A) carbonate ions are not detected in all section (A) samples. In section (C) there are only two samples showed carbonates content as 62.52 mg/l and 31.26 mg/l. in samples No.21 and No.32 respectively. Samples of section (B) and (D) which are saline zone contain considerable concentration of carbonate ranging from 156 to 1750mg/l for (D) (mean 254.248mg/l). This clear difference may be due to seasonal variations (December 2004 and July 2005). Bicarbonate (HCO_3^{-}) concentration in section (A) has the highest value 258mg/l in sample (No. 8) and the lowest 51.0mg/l (mean 166.5mg/l). For section (C) the highest bicarbonate concentration was 476.7mg/l in three samples (No 31, 33, 34), the lowest concentration is 63.6mg/l (mean 254.248mg/l) Table (2).

Total alkalinity in these two sections (A and C) may be as bicarbonate salinity (PRC Engineering consultants 1981, IFAD 1993 [11], North Kordofan rural development project, IFAD 2004, IFAD 2003, and NKRDP 2001).

Table 2: Concentration of Hydroxide, Hydrogen Carbonate, and Carbonate

Sections	Carbonate mean values	Hydrogen Carbonate mean values	Hydroxide mean values
Section (A)	0.00 mg/L	166.5 mg/l	0.00 mg/L
Section (B)	64 mg/L	1068 mg/l	0.00 mg/L
Section (C)	6.6986 mg/l	254.2079 mg/l	0.00 mg/L
Section (D)	468.895 mg/l	2100.293 mg/l	0.00 mg/L

Bicarbonate concentrations of section (C) samples showed inverse relationship with pH. This agreed with IFAD reports 2003, 2004. Such phenomena was also reported by Edmund, 2001 on studying an aquifer beneath Mexico City, the studies stated that there is an overall increase in HCO3- across the aquifer with an inverse relationship with pH. This may be due to CO2 concentrations which increase the amount of TDS (Masal and Crue1969, Rudolph *et al*., 1989). Section (B) and (D) samples showed high HCO3 concentrations and respectively low CO3= content. This may be due to carbonic acid bicarbonate buffering system.

$$HCO_3^- + H_2O \leftrightarrow H_2CO_3 + OH^-$$

TDS, EC and turbidity values

For section (A); sample (No. 1) and (No. 10) showed the most good quality water with TDS values of 218 and 220mg/l. The highest TDS values are shown in samples (No. 7 and 8) 910mg/l and 1690mg/l (mean TDS values 661mg/l). The lowest electrical conductivity value was 411.3µs/cm (sample No.1) and the highest value was 791.8 µs/cm (mean EC 306.2139µs/cm) (sample No.1). With the exception of sample No.8 and to less extent sample (No. 7) the drinking water quality of section (A) sources is good from TDS and EC values point of view Table (3).

Table 3: Electrical Conductivity, Total Dissolved Solid, and Turbidity Values

Sections	EC mean values	TDS mean values
Section (A)	47108.94µs/cm	660.3 mg/L
Section (B)	126.499 ms/cm	108.7 g/L
Section (C)	3178.7 µs/cm	310.4264 mg/l
Section (D)	133.527 ms/cm	160.805273 g/l

For section (C) samples No.24 and 26 showed very low TDS values which were 92, 75 and 111.4ppm respectively. The highest TDS value in this section is 1193ppm in sample No.32. The highest EC value is 1674µs/cm in sampleNo.32 and the lowest is 535.9µs/cm in sample (No.27). These results achieve the expected relation between the amounts of total dissolved solids and electrical conductivity in fresh water samples as a general rule. For this reason EC values may sometimes considered as a measure of water quality (Mukhtar A.R. 2002, Rodis *et al*., 1964).WHO 1993 stated that, reliable data on possible health effects associated with ingestion of TDS in drinking water are not available and no health based guideline value is proposed. However, the presence of high level of TDS in drinking water may be objection able to consumers. SSMO (2002) considered the acceptable TDS value for drinking water to be 1000ppm and 80-500ppm for packed drinking water. So with respect to TDS values section (A) and (C) sources can be classified as safe for human drinking, domestic use, animal watering, and irrigation except the cause of samples 7, 8 and 32.

The samples from the saline zones of sections (B) and (D) showed very high TDS and EC values. TDS values in this two sections can be compared with those of sea water they range from 70.4 to 163.0g/L or (PPT) part per thousand for section (B) and from 106.12 to 243.9 g/L for section (D) with EC values ranging from 89.39 to 169.3ms/cm for (B) and from 120.7ms/cm to 163.5ms/cm; the variations in TDS values at the same field may be due to variations in well depth or the water bearing formation. E.g. claylences. People in the area classify the saline water to heavy water when the bowel produce 125 to 175 Lb of salt, and light water when the barrel produces 75 to125Lb of salt, according to these classifications the price of a barrel of water or jercan differs in the local market of salt production. The abnormal salinity of ground water in these areas is questionable. Is it just a result of water-rock interaction? And which type of rock.

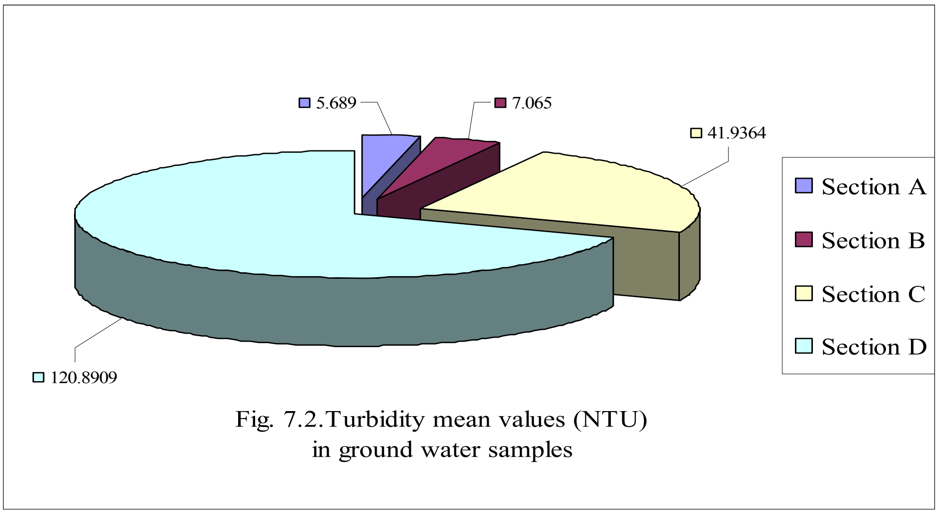

Fig 5: Turbidity means values

Or it is a result of some geological changes, or the water bearing –rock is a basement complex formation aquifer, lastly, is there is an ancient saline lake or sea evaporites under the soil accumulations. Total dissolves solids values reported in this area is 3000-6000ppm. Mukhtar A.R, 2004 reported that ground water salinity is believed to be partly due to stagnation. Ali H.O and Whiley (1981) reported that, the water quality of bara basin varies between 500 and 1200ppm as TDS, suggesting that the relatively high salinity may be due to low estimated velocity of the water (0.1-0.3 m/year), low infiltration and high clay ratios in some places. They referred a satisfactory relationship that has been found to exist between salinity (TDS), depth and clay ratio. IFAD, (1993) [11] considered ground water quality in the basement rocks as a function of basement composition and annual recharges.

Referring to high salinity (1000- 3000ppm) in this study the relationship between TDS and EC values can be clearly observed. Table. (3). IFAD 1991 reported that along the Bara aquifer complex the shallow aquifer contain fresh ground water with TDS of 200-400ppm. This may be exactly true for sample No.1 (218ppm), sample No.3 (396ppm), sample No.9 (423ppm),sample No.22 (148ppm), sample No.23 (226ppm), sample No.28 (366ppm), sample No.33 (334ppm), sample No.34 (317ppm). According to IFAD, (1993) [11] ground water from deep aquifer of Bara basin is generally fresh, with salinity (TDS) varying from 80 to 2000ppm with average salinity of 700ppm (TDS). In this study the bore holes which are generally of deep depths may agree with this fact e.g. In samples No.2(368ppm),sample No.4(805ppm), sample No.5(699.98ppm), of section (A) samples No.7, and No.8 which are from open shaft wells with 15- 20meter depth showed high salinity, with TDS values960 and 1690ppm respectively (IFAD 2003/2004). Section (C) samples generally showed TDS values ranging from 74.87 to 515ppm, with an exception of sample No.32 which was from an open shaft well with 40meter depth, which showed TDS value of 1193ppm.

This well and the sources of samples7 and 8 in section (A) are used locally for animal watering only.

Conclusion and Suggestions

- The analysis show general suitability of fresh ground water at section A and C samples from physical and chemical characteristic point of view.
- Relativly low pH values were observed in section (C) samples and it may be due to high CO_2 content causing carbonic acid –bicarbonate buffering.
- The literature survey shows inavailablility of information about brine ground water chemistry in general and in the case of Sharshar and El-Ga’a specially.
- The high salinity of ground water at El-Ga’a and Sharshar may be due to presence of evaporate layers (ancient barried sea or saline lake) or due to basement fracture bed rocks.
- The salinity content of ground water on moving from the center of Bara basin towards the boundaries (El-Mazroub, El-Gaat, Um-Garfa, Greigikh and Jebel Kon areas).
- The area may need a further total environmental and ecosystem study from authorities of different specialization.
- The huge amount of ground water can be employed for a real agricultural development.
- Further studies may also be needed to determine the possibility of purifying such salt for use as alternative table salt.
- Further research may be required for determination of floride and iodide content in drinking water.

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