International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 6 Issue 10, October - 2022, Pages: 103-108

Drinking Water Quality of Surface and Ground Water Samples from Gedarif State (Sudan)

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Abstract: *This work was conducted to determine the suitability of some surface and ground water sources for human consumption from quality control assessment sight of view. Fourteen surface water and twenty six ground water samples were collected from different areas of Gedarif State (Sudan). Six samples were obtained from gold mining areas. pH value, EC, TDS, TH, DO, Cl^-, CO_3^{2-} and HCO_3^- were measured. The obtained results were statistically analyzed. The mean values of pH and DO in surface water were found to be lower than that, of ground water samples. Two ground water samples showed high pH values as (8.2 and 8.9). The highest DO was shown by one surface water sample as (5.57 ppm). The mean values of TDS, EC and TH were lower in surface water than ground water. Two ground water sources showed TDS as (1042.00 and 1657.60 ppm) and EC as (1515.00 and 2590.00 µs/cm), which, exceeds the permissible WHO guidelines. High TH was shown by two ground water sources (1580 ppm). The highest, Cl^-, HCO_3^-, and CO_3^{2-} concentrations were shown by ground water sources as (343.90, 536.80 and 36.00ppm) respectively. Surface water sources showed lower mean concentrations of Cl^- and HCO_3^-, than ground water ones, whereas, the mean CO_3^{2-}content was higher in surface water. All the water sources of the analyzed samples may be suitable for human consumption, domestic use, animal intake, and irrigation purposes.*

Keywords: Gedarif basin, WHO, DO, Ground water, Surface water, Mining areas

Introduction

Water is the basic essential food constituent that make life possible on the planet Earth. Freshwater was reported to represent only (3%) of the total water on earth, and only small percentage (0.01%) of it is available for human use (Hinrich and Tacio, 2002). Unfortunately, this small portion is facing high demand due to the rapid population growth, urbanization and unsustainable consumption of water by industry and agriculture (Azizullah et al., 2011). Reliable drinking water is now considered as one of the basic human rights (UN, 2011). According to United Nations reports, the world population is increasing exponentially while the availability of fresh water is declining. The most problematic challenge of current water research is dealing with elevated arsenic concentrations in drinking water (WHO / UNCEF, 2010). Globally the most serious problem is the consumption of drinking water containing too much Arsenic (As) by millions of people and many countries in Africa, Middle East and South Asia may face serious threats of water shortage in the next two decades (Hirner and Hippler, 2011). In the developing countries the problem is more complicated, due to the lack of proper management, unavailability of professionals and financial constraint (PCRWR, 2005). According to (GEO-2000, 2011) reports, 1.6 million children die every year from diseases associated with contaminated drinking water, because water resources worldwide are influenced by human activities, including, construction of dams and canals, large irrigation and drainage systems, changes of land cover in most watersheds, high inputs of chemicals from industry, agriculture, mining, and depletion of aquifers. In addition, heavy metals pollution is becoming serious, because heavy metals represent potential contamination-source of drinking water (GEO-2000, 2011). About 884 million people still do not get their drinking water from approved sources (WHO/UNICEF, 2010). In Africa, substantial amounts of national budgets are used to treat waterborne diseases (Cobbina et al., 2013).

The study area

Health problems linked to drinking water in Gadarif State are clinically well documented (Abdellah A M et al., 2014). Al-Gedarif State is located in the Eastern part of Sudan. It lies between the longitude 33.3 -36.3, and latitudes 12.4 - 15.4, with total area as (71,000 Km^2) and estimated population as 1.148 million people. The climatic conditions are characterized by seasonal changes. It is semi dry in the North and humid in the South of the State, with maximum and minimum average temperature as 40°C in summer (April – June) and 20°C in winter (December - February). The annual rainfall is ranging between 100 and > 800 mm. The rainy season extends from April to October, with heavy rain fall during June – September, to reach it is maximum rates in August, with an annual average as 650 mm (ACSAD, 2006). The distribution of the rain fall reaches it is maximum rates as 1100 mm in the Southern parts of the State, and gradually decreases, to reach the lowest rate , as 200 mm at the Northern parts. In spite of the higher rates of rainfall, an increase rates of evaporation and transpiration is reported, which, exposes the plants to water diligence during the periods of growth (ACSAD, 2006). About 70% of the rain fed area is cultivated by different crops each year, representing about 17-20% of the total cultivated area in Sudan. The crops production of Gedarif State represent about (30-40%) sorghum, (40-50 %) sesame and (20-30 %) millet from the total production of the whole Sudan. The use of traditional technologies in food production and rainfall fluctuations affect the stability of production levels of the major cereals, especially, sorghum and millet (ACSAD, 2006). The State is divided into ten administrative localities, including, Gedarif , Gedarif center , Rahad, Pasenda, Al- Qurasha, Al-Fashqa, Western Gallabat, Estern Gallabat, Butana, Galaa –Elnahal (ACSAD , 2006).

Geological background

Figure 1. Shows the location and general geology of the Gedaref basin.The geology of the area consists of basic rocks, as the oldest rocks which, date back to the Precambrian, and consist of quartz, marble, gabbro, granite, gnis, and sodicgranite. It is interspersed with sedimentary rocks and limestone. In some parts of the State, the base rock is covered with Nubian sandstone, basalt, and ⁄ or modern surface formations (Ali Abd El-Rahman, 2018). The Nubian stone formations cover the east area of the meridian approximately 35Bc and back to the Mesozoic era. They differ from the Nubian stone in the North of Sudan and referred to as Gadarif formations, which, consists of categlomerites and sandstone. The sandstone and mudstones, cover approximately (70%) of the area occupied by these sediments, and are rarely visible on the surface because they are covered with basalt and modern surface formations which extend horizontally over the bedrock. The densest volcanic formations are located in the South Eastern part of the State. Thus, they form chains and mountains with a Southeast and Northwest direction, reaching a height of 600 meters above sea level and at the same time being a water dividing line between Atbara River in the East and Rahad River in the West (Ali Abd El-Rahman, 2018).

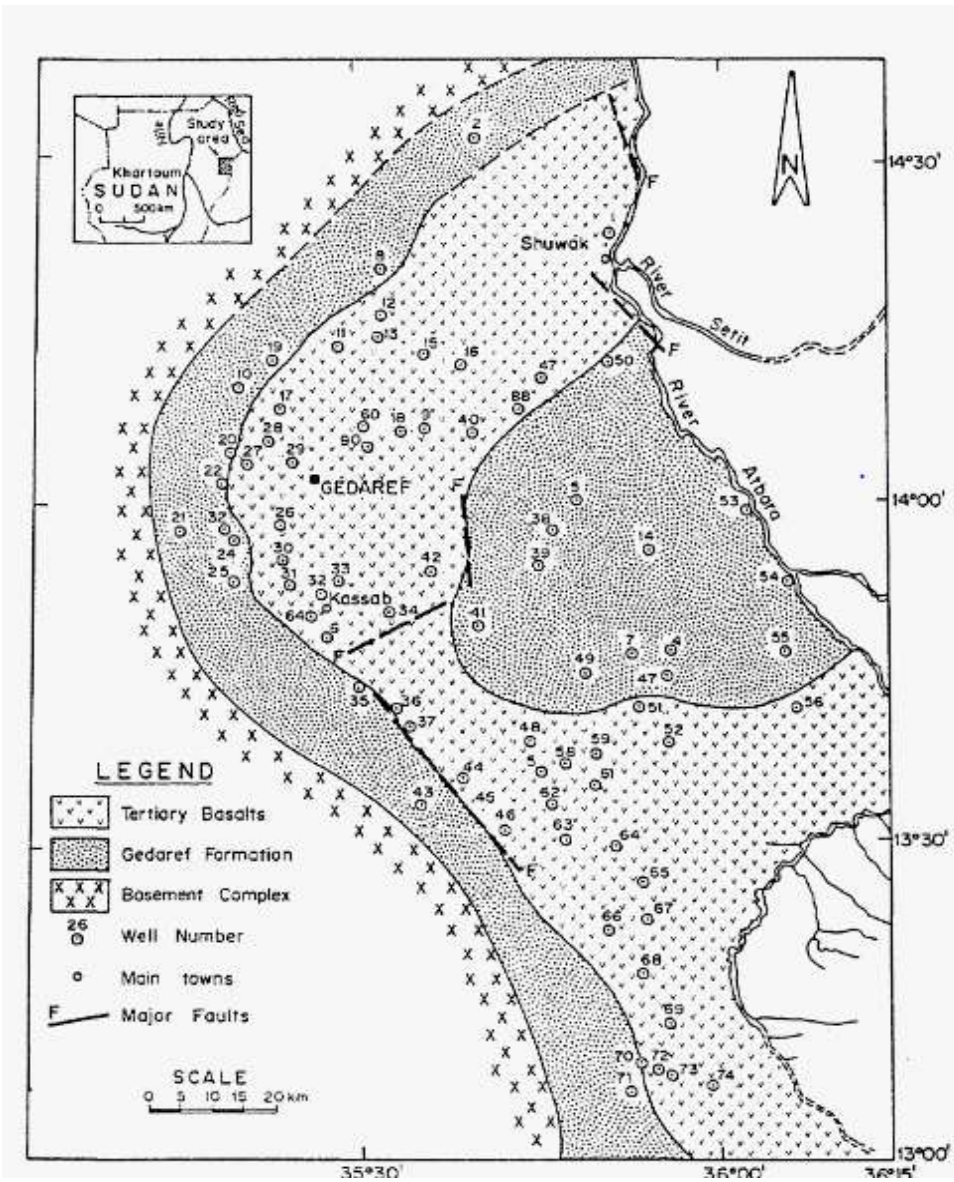

Fig. 1. Location and general geology map of the Gedaref basin, Sudan

Water resources and quality

International Journal of Academic and Applied Research (IJAAR)
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Citizens of Gedaref State obtain their water demand directly from the sources without any pretreatment. The main drinking water sources include boreholes, hand pumps, hand dug wells, dams and hafirs (Figure .2). Rain fall is the main water source for human drink, domestic use, animal watering, irrigation and other economic activities. Valleys and creeks represent the major surface water sources, where, water is stored in small dams and hafirs during their seasonal flow, (Ali Abd El-Rahman, 2018). Irrigation water quality is generally judged by its total salt content as (TDS), electrical Conductivity (EC), sodium absorption ratio (SAR) and bicarbonate and boron content (Michael, 1999). The agricultural activities depend on seasonal rain fall, but water supply systems for big towns and villages far from the rivers are increasingly depend on groundwater. The Gedarif basin consists of two main hydraulically connected aquifers, known as, Gedarif sandstone aquifer system and a basaltic aquifer. Groundwater abstraction has now increased and more drilling has taken place, to provide fresh water, which is suitable for various uses. Some wells showed relatively high salinity, and that make them less suitable for drinking and other household purposes (Hussein and Adam, 1995). According to Hussein and Adam (1995), TDS varied from (250 to 2730 ppm) throughout the study area and ranged from (280 to 1800ppm) within the sandstone aquifer. Salinities ranging from (550 to 1800 ppm), and above (2000 ppm) were reported in the basalt aquifer and some pockets within the sandstone aquifer. The anions of the sandstone aquifer were in the order, $HCO_3^- > Cl^- > SO_4^{2-} > CO_3^{2-}$, while those of the basalt aquifer were $HCO_3^{2-} > CO_3^{2-} > SO_4^{2-} > Cl^-$ (Hussein and Adam , 1995). Ramsis B. Salama (1977), reported that, Gedarif water chemistry is good with low (TDS) values ranging from (400 – 500ppm) in the Gedarif formation, whereas in the basalt the salinity ranges from (1000 to 3000ppm). Basheer A. Elubid et al., (2019), studied, groundwater quality parameters in sandstone, alluvium and basalt aquifers as primary sources of drinking water and agricultural activity in El Faw, El Rahad El Qalabat and El Quresha localities in the southern part of Gedaref State. Basheer et al., (2019), reported that, the groundwater in this area was controlled by sodium and bicarbonate ions which, defined the composition of the water types as (40%) Na-Mg-HCO_3 and (35%) Na-HCO_3 water and concluded that, the majority of groundwater samples were suitable for drinking purposes in El Faw, El Rahad El Qalabat and El Quresha areas, where the alkalis (Na^+, K^+) content, appear considerably over the alkaline earth elements (Ca^{2+}, Mg^{2+}), and the weak acidic (HCO_3^{2-}) appear considerably over the strong acidic anions (Cl^- and SO_4^{2-}). In a study carried by ACSAD (2006) for ground water quality in EL Gedarif basin, the ranges of drinking water quality determining parameters were found to be, pH (7.34 to 8.93) , TDS (280 to 2500 ppm) , EC (490 to 2180 µs/cm) , Cl^- (7.0 to 234 ppm) , CO_3^{2-}(12.0 to 36.0 ppm) and HCO_3^- (201.3 to 512.4 ppm).

Figure. 2. Um Belail hafeir, for drinking water
Source: (ACSAD, 2006)

Methodology

Fourty (40) drinking water samples were collected from (14) surface and (26) ground water sources. Six samples were from gold mining areas. P^H values, TDS, EC, DO, TH, CO_3^{2-}, $HCO_3^-$and Cl^-were determined for each sample. The obtained results were statistically analyzed using (SPSS) version 20 program.

Results and discussion

Table 1. The mean values of pH, TDS, EC, DO and TH for surface water

Parameter	Minimum	Maximum	Mean	SD
pH	6.20	7.90	7.18	± 0.53

International Journal of Academic and Applied Research (IJAAR)
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TDS	95.50	304.00	179.78	± 66.77
EC	142.00	473.00	282.14	± 102.14
TH	26.10	1580.00	214.72	± 197.45
DO	1.97	5.57	2.81	± 0.92

As shown by (Table 1), the pH values were ranging from (6.2 to 7.9) with a mean value as (7.18) , TDS from (95.50 to 304.00 ppm) with a mean value as (179.78 ppm), EC ranges from (142.00 to 473 µs/cm) with a mean as (282.14 µs/cm). Relatively high (TH) was shown by one sample as (640ppm), whereas the lower value was (20.00 ppm) and a mean as (214.72ppm). The dissolved oxygen (DO) was ranging from (1.97 to 5.57 ppm), with a mean value as (2.81). All the surface water samples showed, pH, TDS, EC, TH and DO values within the acceptable guideline ranges (WHO, 1983).

Table 2. The mean values of pH, TDS, EC, DO and TH for ground water.

Parameter	Minimum	Maximum	Mean	SD
P^H	6.70	8.90	7.53	± 0.51
TDS	134.00	1657.60	527.95	± 306.25
EC	202.00	2590.00	794.81	± 471.55
TH	26.10	1580.00	526.41	± 421.65
DO	2.00	4.98	3.01	± 0.81

Ground water samples showed, pH range of (6.7 to 8.9) with a mean value as (7.53), TDS range of (134 to 1657.60 ppm) with a mean as (527.95 ppm), EC range of (202 to 2590 µs/cm), with a mean as (794.81 µs/cm), TH range of (26.10 to 1580 ppm) with a mean value as (526.41 ppm). Eleven ground samples showed relatively high total hardness (TH) compared with the permissible guideline range (500 to 1500 ppm). The dissolved oxygen (DO) ranges from (2.00 to 4.98 ppm) with a mean as (3.01 ppm). The highest DO of ground water was shown by two samples obtained from gold mining areas as (4.48 and 4.98 ppm). Abdellah A M et al., *(*2014) reported ranges of pH value as (6.9- 9.5), TDS (172- 652 mg/l), EC (0.25- 0.98dS/m), TH (75.0- 560mg/l), in Alhwata area.

Table 3. The concentrations of Cl^-, $CO_3^{2-}$and HCO_3^- in surface water (ppm)

Parameter	Minimum	Maximum	Mean	SD
Cl^-	56.70	163.30	86.87	± 27.17
CO_3^{2-}	0.00	36.00	17.14	± 14.67
HCO_3^-	12.20	402.60	54.90	± 100.35

Table 3. shows the concentrations of Cl^-, $CO_3^{2-}$and HCO_3^- in surface water samples. Cl^- ranges from (163.30 to 56.70 ppm) with a mean as (86.87 ppm), CO_3^{2-} ranges from (12 to 36 ppm) with a mean as (17.14 ppm) and HCO_3^- ranges from (12.20 to 402.60 ppm) with a mean as (54.90 ppm). The availability of Cl^- , $CO_3^{2-}$and HCO_3^- was within the accepted guideline values (WHO 1983, SSMO2005). The CO_3^{2-} content was found to be exactly typical to that reported by ACSAD (2006).

Table 4. The concentrations of Cl^-, $CO_3^{2-}$and HCO_3^- in ground water (ppm).

Parameter	Minimum	Maximum	Mean	SD
Cl^-	7.10	343.90	87.17	± 63.08
CO_3^{2-}	0.00	36.00	11.54	± 9.88
HCO_3^-	12.20	536.80	55.92	± 98.74

In ground water samples, Cl^- ranges from (7.10 to 343.90 ppm) with a mean as (87.17 ppm), CO_3^{2-} ranges from (12.0 to 36 ppm) with a mean as (11.54 ppm) and HCO_3^- ranges from (12.20 to 536.80 ppm) with a mean of (55.92 ppm). The availability of Cl^- , $CO_3^{2-}$and HCO_3^- is within the accepted guideline values (WHO, 1983, SSMO, 2005). The CO_3^{2-} content was similar to that of surface water above (Table. 3) and exactly typical to that reported by ACSAD (2006). The studied ground water sources may be described as chloride and bicarbonate water sources. The measured parameters: pH, DO, TDS, EC and TH showed higher mean values in ground water than that of surface water (Fig. 3 and Fig. 4). The mean values for Cl^- and HCO_3^- in surface and ground water were almost similar whereas the mean concentration of CO_3^{2-} was higher in surface water than ground water (Fig. 5).

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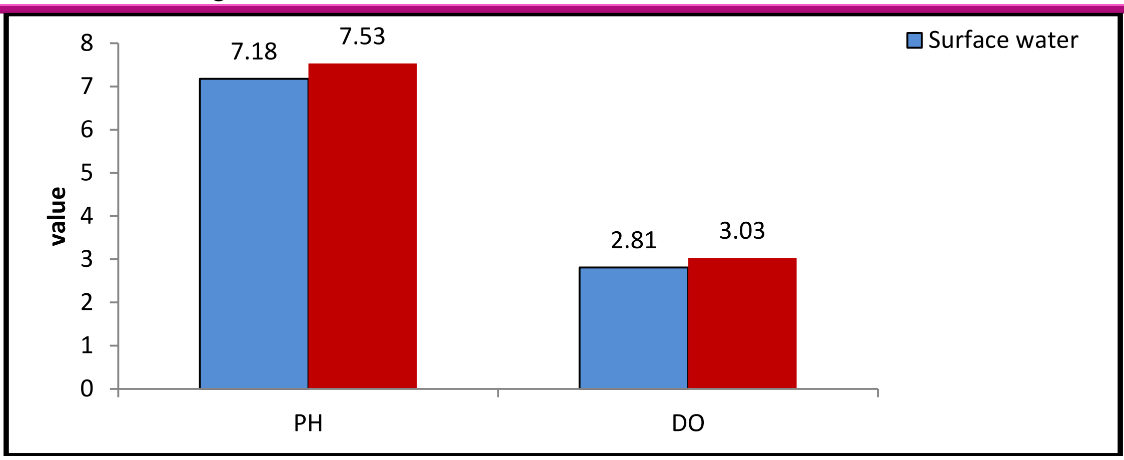

Figure 3. pH and DO mean values in surface and ground water samples.

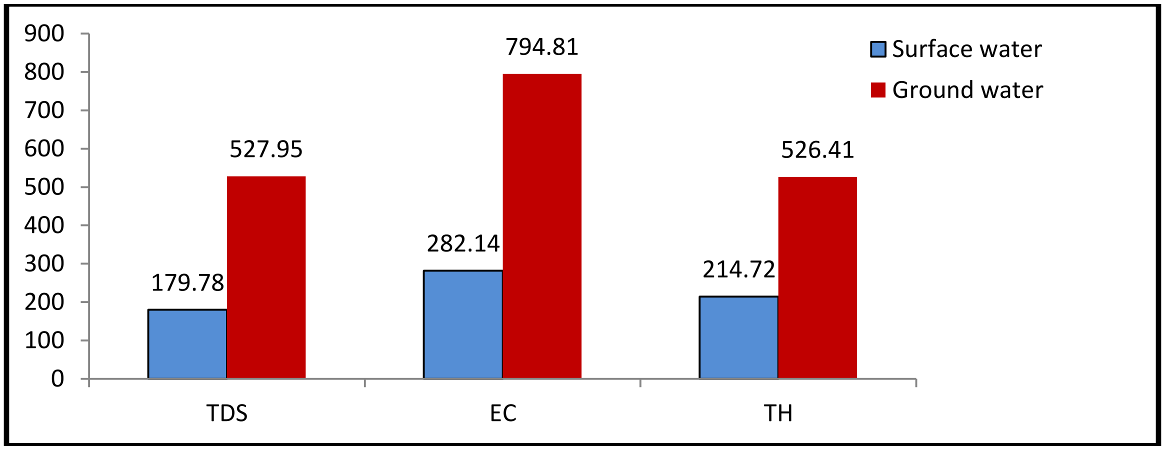

Figure 4. TDS, EC and TH mean values in surface and ground water samples.

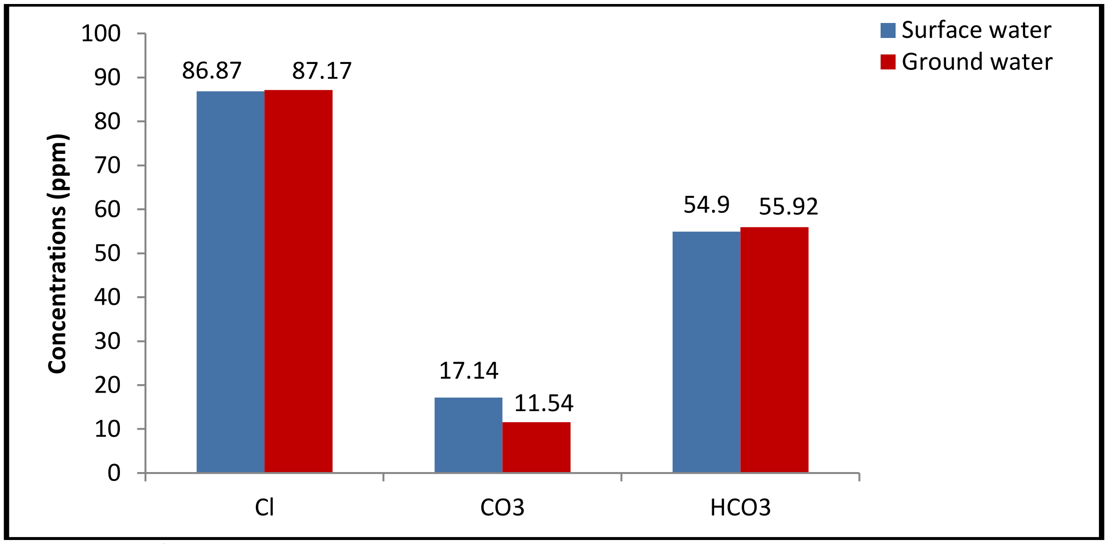

Figure 5. Cl^-, CO_3^{2-} and HCO_3^- mean values in surface and ground water samples.

Conclusion

All the sample sources may be described as suitable and safe for use, from drinking water quality and human health sight of view. One ground water sample showed pH value slightly higher than the permissible guideline. Higher TDS and EC values were shown by one ground water sample. One surface water sample showed high TH. Further studies and wide range of sampling may be needed to cover more drinking water sources throughout Gedarif State.

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