Evaluation of Ground Water Quality in North East Wadi Halfa, Northern State, Sudan

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Received October 17, 2021; Revised November 20, 2021; Accepted December 01, 2021

Abstract In this current study, groundwater quality is the main hydrological problem. The study aims to define the groundwater quality in the Assessment and Evaluation of Ground water Quality in North East Wadi Halfa, Northern State, Sudan. Physical, chemical and biological analyses were carried out on 10 water samples collected from the existing wells. For investigating different cations and anions the titration, spectrophotometer and flame photometer were used. Chemical analysis shows high concentration of sulfates and nitrates. The hydrochemical classification of groundwater explained for groups: (Na + + K +), HCO₃⁻ water, (Na+ + K +), (SO₄²⁻ + Cl⁻) water, (Ca++ + Mg++), HCO₃⁻ water and (Ca ++ + Mg++), (SO++ + Cl-) water. Bacteriological analysis was made for 10 samples; water is free of contamination. A comparison has been made between two-water analysis in 1991 and 2019, as a result decreasing in the salts concentration in the latter. Therefore, according to the results of this study, it is recommended and guided for further pumping and continuous using of the water well in agriculture purposes.

Keywords: cations, anions, analysis, hydrochemical, contamination


1. Introduction

Water plays a vital role in the development of any country. Productivity of groundwater is quite high compared to surface water. The underground water is considered to be the main water source in arid and semi-arid regions in Sudan. In the study area, the aquifer belongs to the Nubian sandstone Nile aquifer. The recharge source is The Nubian lake through the sedimentary beds and fractured basement rocks. This aquifer extends from east Kordofan basin to the Egyptian border. The quality of water is depending on its physical and chemical properties to be use. Climatic condition in the study area is predominantly arid to semi-arid, in summer temperature ranges 47°C – 30°C while in winter ranges 20°C – 5°C, rarely annual rainfall, drainage system is very poor and humidity sometimes high up to 83% due to the great surface area of Nubian lake.

2. Study Area Description

2.1. Location and Accessibility:

The study area is located in north east of Wadi Halfa city cutting the international Sudan – Egypt road confined between latitude 21° 59' 58" , 21° 42' 30" and longitude 31° 30' 40", 31° 19' 60" in the north situate Ashkiat village near the Ashkiat customer towards south Dabroosa, Diegem and Angash villages. It can be easily accessible from the international Sudan – Egypt road going to sandy road by four-wheel car.

3. Study Problem

It’s noticed that from the few drilled wells the salinity of water is very high. The current study searches for solving this problem, which will be, shear by addition quantity of water for future irrigation projects in Wadi Halfa town.

4. Objectives of the Study

The Objectives of the study are to:
1- Evaluate the groundwater quality based on physical, chemical and biological properties of the groundwater.
3- Treatments of the water salinity.
4- Detect its suitability for different uses.
5. Method and Materials

The following steps have been adopted to achieve the objectives.

5.1. Field Work

1- Number of water samples collected from the wells in 1991.
2- *pH* meter is used for Physical properties measurements as pH, EC and temperature.
3- Groundwater level measurements.
4- GPS measurements and geological survey.

5.2. Laboratory Work

1- Hydrochemical analysis of water samples to define the concentrations of different cations and anions by means of:
   • Two titration methods:
     - Precipitation reaction method for detecting Ca**, Mg**, Cl⁻ and total hardness
     - Neutralization reaction method to determine HCO₃⁻, CO₂⁻
   2- Spectrophotometer method, based on photosensitivity of chemical compounds to light spectrum for NO₃⁻, NO₂⁻, SO₄⁻, Fe**, Cu** detecting
   3- Flame photometer for Na⁺, K⁺ detection
   4- Biological analysis of 16 samples was made for determining biological contamination e.g: coliform bacteria.

All results from both fieldwork and laboratory work were interpreted and software was used.

6. Previous Work

Dealing with the geology and hydrogeology, few studies were carried out in the study area. [1] have studied Wadi Halfa oolitic iron ore in north and north east part towards Egyptian border within the sedimentary rocks, with existence of volcano-sedimentary rocks. Schandelmeier

7. Regional Geology of the Study Area

The northern state geology composed of the following rock unites from older to younger:
1. Basement complex rocks.
2. Nubian formation.
3. Tertiary volcanic.
4. Superficial deposits.

7.1. Basement Complex Rocks

Many out crop of gneiss rocks, which as generally described as metamorphic rocks extended south Wadi - Halfa. The mineral grains in the rock were flattened through tremendous heat and pressure and are arranged in alternating gneiss [7]. Schist is metamorphic rock with well-developed foliation exist south Wadi – Halfa. At the study area they are usually of psamitic (quartz felspathic gneiss), pelitic (mica schist) and volcanic (chlorite schist) origin [8]. Emplaced into these rocks are a number of post-orogenic igneous bodies including granite and associated basic dykes and gabbro [9]. At the study area plutonic of (syn-late-post) organic intrusive rocks were prevailing, common and widely occurring many types of granite which as general intrusive, felsic, igneous rock, usually have a medium to coarse grained texture. Occasionally some individual crystals (phenocrysts) are larger than the groundmass in which case the texture is known as porphyritic. Diorite, granodiorite and rhyolite are another type of intrusion. Metasediments of metaconglomerate Scattered 10km south Halfa, few outcrops were seen, composed of metamorphosed porphoritic gravel and metaquartz black in colour shows very hard rock, Metaquartz outcropping and intruded the metaconglomerate, black hard mainly pure quartz, (Figure 3).

7.2. Nubian Formation

First time for the Nubian formation refers to the late cretaceous deposits in Nubian Desert south Egypt and it has been used from that time to north east and central Africa regions. The Nubian succession unconformable lies over the weathered basement complex surface and occurs either out-cropping in flat-topped plateau of forms the substratum over which the Pleistocene and recent deposits have been deposited [10], (Figure 3). The thickness of the Nubian successions in the area ranges from a featheredge to a maximum of 500m and are composed of slightly dipping, loosely to highly consolidated beds of sandstones, mudstones and conglomerate of extensive lateral extension, [1].

Mostly consists of alternating conglomeratic and sandstone, medium to fine massive sandstones marked with parallel lamination, cross bedding and alternating sandstone and mudstone beds.

In north Sudan Nubian Sand Stone Formation were differentiated into three depositional periods from bottom to top as follow:
- Lower cycle: containing marine deposits e.g: Kurkur-Umm ras-Wadi elmalik Formations of Ordovician-Late Carboniferous.
- Meddle cycle: consists of continental deposits of Late Carboniferous-Lat Tertiary e.g: Lagia formation.
- Upper cycle: composed of continental marine deposits Of Late Jurassic-Late Cretaceous e.g: Gielf elkbier-Selima-Wadi hower- Kababiesh-Gabel abide Formations [11,12].

All these formations include marine and continental fossils. The ground surface of the study area is generally low relief plain, many rock outcrops of small heights to high ones reaches 1500m.

7.3. Tertiary Volcanic

It extends from Late Cretaceous to Early Tertiary with definite occurrence in Sudan mainly basaltic group and rock debris, consists of basalt olivine, sheared gabbros and tricte.

7.4. Superficial Deposits

North Sudan is overlain by unconsolidated continental sand and sandy clay, which may vary considerably in lithology and thickness [13]. The Quaternary Deposits fall into three main categories namely; the alluvial Deposits of the Nile Valley and of the main wadies, the lacustrine deposits in Laqiya and Selima oases and the Aeolian sand deposits almost everywhere [14].

The Nile Alluvium varies from fine alluvium mainly of silt close to the river to coarse alluvium of pebbly sand on the old terraces along its banks. The valley fill deposits occur at the course and along the banks of Wadi Howar, Wadi El Milk and Wadi Muqaddam south the study area and extend from Karem to Dongola till Abu fatma, around the study area were found at the bank of Nubian lake and consist of silts, sand and gravel indicating their torrential nature. The Lacustrine Deposits are mostly clay and marls with variable carbonate cement and occasional gypsum streaks. The Aeolian sand Deposits occur in the form of mobile and stabilized dunes and sand sheets of variable thickness covering most of the area.

7.5. Tectonic Setting

The tectonic situation is very complex in the basement and far simpler in the Nubian formation; the basement consists of a more deformed lower Gneiss complex in tectonic contact with a less deformed upper Green schist complex.

The late Mesozoic, Tertiary and Quaternary tectonics of NE Africa in general and of the study area in particular is characterized by prevalingly vertical displacements: in fact, the Nubian formation layers are practically sub – horizontal. The main tectonic trend of North State is N - NE and this influence of the Nile here when the structures cross the river, cataract appears. East of the Nile at about latitude 21° N two granite ring structure occur [15,16].
North East Pan African Tectonism lead to opening of the Red Sea, the later caused the separation of the Arabian- Nubian shield and the collision of these two plates consist many volcanic mountains of island volcanic arc represented in Wadi ateery and Elbeer area south the study area. Abed elrahman [17] described the Ophiolite occurrence due to the collision between the Arabian- Nubian shield and the Nubian shield was formed.
Geologic field in the area has been prevailed some tectonic situations; the most important one is Wadi halfa fault in which displacement at the fault level happened, the southern block was raised where as the northern one was subside down. In such case, the southern block was exposed to weathering leaded to hidinning the sandstone formation from the basement rocks, few residual sandstone was remained on the irregular surface of the basement formation from the basement rocks, few residual sandstone was subside down. In such case, the southern block was raised where as the northern one was remained on the irregular surface of the basement block, which was subside down, was still preserved in the east. The physic-chemical and biological analysis result is summarized in Table 1 analyzed in 1991.

The measured temperature ranges (25.1°C - 25.4°C), Hydrogen Ion concentration (pH) ranges (7.40-7.80), TDS ranges (572-3376 ppm), and EC ranges (931-4065 µs/cm) high values of both are away from the Nubian lake to the east.

All samples analyzed are chemically hard over 600 ppm except one 130 ppm of pH (4). The alkali metals (Na⁺ K⁺) vary in concentration between 460 - 1000 ppm and 3.6-9.3 ppm, Alkaline earth metals (Ca ++ and Mg ++) show concentration values 85.4 - 18 ppm and 35.9 - 45.3 ppm. Sodium is the dominant cation in water, which can be produced by the dissolution of the albite feldspars, clay minerals or evaporates that normally, exists within the host rocks [18]. Fe³⁺, Cu⁺ occur as traces, Iron concentration ranges from (0.10 - 1.3 ppm), Cupper from (0.30-0.95 ppm) and NH₃⁺ concentration ranges from (0.038-0.096 ppm).

Bicarbonates concentration (HCO₃⁻) ranges from (85.5 - 145 ppm) sulphates show high values (750-1357PPm) increases outwards the Nubian lake to the east. Chloride concentration (54 - 99 ppm), Nitrate (NO₃⁻) ranges from (42-66.7 ppm) and Nitrite (NO₂⁻) ranges from (0.030-0.034 ppm).

The biological test shows the samples are free from any contamination (coliform not detected). Total dissolved salts, sulphates, bicarbonates and nitrates are plotted in (Figure 5).

8. Results and Discussion

8.1. Physio-chemical Characterization and Quality Assessment

Significance component of groundwater flow is from southwest to north east, south to north and west to east under variable hydraulic gradient, which decrease at the eastern boundary of the aquifer due to raising basement up towards the east. The main recharge source is the Nubian lake through Nubian Sandstone beds characterized by good permeability. The physic-chemical and biological analysis result is summarized in Table 1 analyzed in 1991.

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<th>BH 4 Dabrossa</th>
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Bacteriological analysis: Total coliform bacteria ml/100 ml in each sample
8.2. Hydrochemical Facies and Evolution of Groundwater

The following classification diagram [19], (Figure 4) representing the hydrochemical composition of water in the study area, according to the dominated cations and anions, four different groups of groundwater are plotted in (Figure 5):

1- (Na⁺ and K⁺) and (HCO₃⁻) group (8.85 %)
2- (Na⁺ and K⁺), Cl⁻ and SO₄²⁻ group (32.37 %)
3- (Ca²⁺ and Mg²⁺) and (HCO₃⁻) group (15.62 %)
4- (Ca²⁺ and Mg²⁺), Cl⁻ and SO₄²⁻ group (43.38 %).

8.3. Process Controlling Groundwater Chemistry

Figure 6 shows 3-D diagram of total dissolved salts, sulphates, bicarbonates and nitrates salts concentration. It is found that TDS or salinity distribution is influenced by salinity of the sedimentary rocks and the location of water close to the basement rocks where its saline water. Most of the samples analyzed are chemically hard, two samples only are soft water, and they are very close to the Nubian lake, of course due to appreciable fresh water recharge from a wide surface of the lake in the study area, Figure 7 shows TDS distribution as going farther from the lake eastward the concentration increases. Sodium, calcium, magnesium and Potassium cations corresponding to Bicarbonate, Sulphate, Chloride anions are found in equal concentrations in all wells. These substances can be derived from the rock mineralogy of the aquifer lithology or the recharge areas as well as the as upon the hydrodynamic conditions. Sodium cation produced by the dissolution of albite feldspars, clay minerals. Table 2 shows the results of physical and chemical analysis of the major cation and anions measured in ppm.
Figure 6. 3-D diagram shows total dissolved salts, sulphates, bicarbonates and nitrates salts concentration, (1991 analysis)

Figure 7. Distribution of total dissolved salts (TDS)

Table 2. Results of physical and chemical analysis of the major cation and anions measured in ppm

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<td>Ca²⁺ ppm</td>
<td>109</td>
<td>105</td>
<td>70</td>
<td>84</td>
<td>76</td>
<td>75</td>
</tr>
<tr>
<td>Mg²⁺ ppm</td>
<td>42.5</td>
<td>41</td>
<td>37</td>
<td>37</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td>K⁺ ppm</td>
<td>7.6</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5.2</td>
<td>5.1</td>
</tr>
<tr>
<td>NO₃⁻ ppm</td>
<td>63.2</td>
<td>51.3</td>
<td>50.4</td>
<td>50.5</td>
<td>54.2</td>
<td>54.5</td>
</tr>
<tr>
<td>NO₂⁻ ppm</td>
<td>0.030</td>
<td>0.030</td>
<td>0.029</td>
<td>0.029</td>
<td>0.030</td>
<td>0.030</td>
</tr>
<tr>
<td>NH₄⁺ ppm</td>
<td>0.080</td>
<td>0.086</td>
<td>0.037</td>
<td>0.040</td>
<td>0.049</td>
<td>0.053</td>
</tr>
<tr>
<td>HCO₃⁻ ppm</td>
<td>130</td>
<td>140</td>
<td>120</td>
<td>101</td>
<td>80.2</td>
<td>117</td>
</tr>
<tr>
<td>SO₄²⁻ ppm</td>
<td>830</td>
<td>755</td>
<td>760</td>
<td>654</td>
<td>745</td>
<td>740</td>
</tr>
</tbody>
</table>

The correlation of two analysis (1991) and (2019) show decreasing of the amount of salts and increasing in the water level of all boreholes in (2019) analysis. The reason is that in 2018 a great flood and very high rains occurred in Sudan and rivers over flow at the two banks damaged many building and agricultural lands, in addition to, Egypt has been closed the high dam gates, large amount of water recharge the Nubian lake the surface water level in the
lakes raised, water became nearly close to the 184 contour. The groundwater recharge ratio increased indicated by the rise of water level from 87 m to 52 m, as a result salts amount decreased where total dissolved salts and hardness decreased from 3250 ppm as a high value to 1632 ppm and 653 ppm to 587 ppm respectively.

9. Conclusions and Recommendation

9.1. Conclusions

The results show that the groundwater quality is influenced by physical and chemical properties of the geologic formations and ground water dynamics. All salinity comes from the dissolved cations and anions of the sedimentary and basement rocks and these wells is not used for different uses since they has been drilled in 1991, therefore, salts concentrated with great amount leading to high water salinity is resulted. It warranty that to say, the water wells is unfit for use, but a treatment of this problem by continuous pumping to wash up the salts and will become fresh water supported by very good recharge fresh water source of Nubian lake and the results of water analysis in 2019.

9.2. Recommendation

It is recommended to:
- Firstly, before operation for using water wells continuous pump must be done to wash up the concentrated salts and the water pumped must through away far from the dogged wells and from the plain future wells and plain future agricultural lands.
- Using stainless steel, fibreglass, thermoplastic casing and screens when wells are dug to avoid corrosive actions and should be of durable materials that will perform satisfactory for long service life.
- Exploratory drilling to detect horizons that having undesirable physical or chemical properties to be sealed off when designing wells.
- Protecting the aquifer resources from any pollution by monitoring the groundwater quality.
- The distance from a well to pollution source if found should be at great distance nearly not less than 200 m.
- Water wells should be located higher than the natural ground to avoiding any undesirable materials entering the well.

Acknowledgements

Thanks to the laboratory of the northern water authority - Dongola, also thanks conducted to engineering Abd Alla Omer for his assistance by possible available data.

References