

Geographical and hydrological effects of nubian sandstone formations on ground water in Khartoum State – Sudan

Abstract

The research deals with the geographical and hydrological location of Khartoum state within the scope of the Nubian sandstone extension, and the effects of this on groundwater. To achieve this, 9 samples were analyzed from the wells dug in Omdurman, Khartoum and Bahri to identify the structure and composition of layers and depths of water, in addition to 30 other samples for chemical analysis And the physical of some elements to know the specifications of water and its suitability for human use. The research concluded with a number of results, including that there is a difference in the components of the Nubian sandstone, as its percentage in Omdurman is 67%, the number of layers 10 and Khartoum 71% and the number of layers 16, and in Bahri 82% and the number of layers 21 and thus it is higher than Omdurman and Khartoum. Water levels vary even within the region from one well to another in Omdurman, which is located at depths of 490, 690, and 800 feet, and in Bahri, it is located at depths of 530, 690, and 725 feet, and the hose is located at depths of 340, 505, and 585 feet. Soluble, nitrite and mineral compounds are good according to Global standards for water except for a few of them, with the high level of ammonia in Omdurman and Khartoum higher than 0.1mg/l, which is an indicator of pollution.

Keywords: geography, hydrology, geological, wells, groundwater, Nubian sandstone

Volume 4 Issue 6 - 2020

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Received: September 27, 2020 | **Published:** November 06, 2020

Introduction

The Information Center and Groundwater Management in Khartoum¹ explained that the Nubian sandstone basins, the Gezira formations, valley sediments and some types of basic rocks from the aquifer layers in the state of Khartoum. The Nubian Sandy Basin has a storage capacity of about 77 billion cubic meters, and a depth of more than 150 meters below the basin surface.² While the Gezira basin has a capacity of about 8,3 billion cubic meter^{3,3} The annual flow from the aquifers in Khartoum State of the basin water is about 70 million cubic meters, The annual variable of stock in the areas bordering the Nile is estimated at 100 million cubic meters.⁴ The quality of the water varies according to the classes, as the percentage of salts in the base rocks ranges between 1400-100mg per liter, and the Nubian Sandy Basin between 200 – 500mg per liter and may increase from 700 to 5500mg per liter in some areas. As for the carrier layer to the components of the Gezira, the percentage of salts ranges between 200-200 mg per liter. Therefore, there is a high percentage of dissolved salts in the state.⁵ Joseph Roosper in 1837 was the first to mention the term Nubian sandstone, which was used as an indication of fossil sandstone within sections of the Paleozoic period.⁶ They are flat sedimentary rocks found at the top of the basement complex and spread over large areas, as they cover 55% from the surface of the earth, and constitute most of the North African formations.⁷ The Nubian sandstone is part of this large formation and covers in Sudan the northern state, Khartoum and parts From North Darfur and North Kordofan (Figures 1&2). The formation of the Nubian sandstone is characterized by the horizontal and sometimes inclined layers above the basement complex, and its layers are on average about 105 meters thick. The composition of the Nubian sandstone is characterized by homogeneity in the composition, with differences in the rock composition, as well as interspersed with some coverings of mudstone.⁸

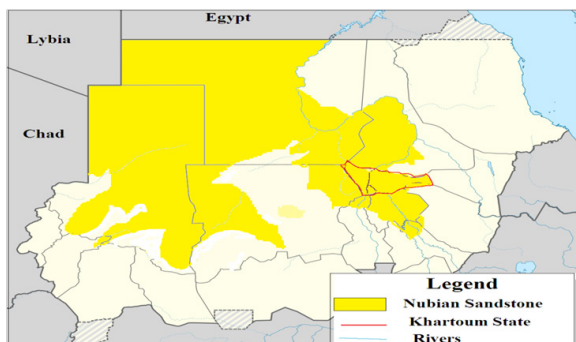
Researchers differed in the nature of the conditions in which the Nubian sandstone was formed, and some believed that it was

deposited by the air, and that it was ancient sand dunes. The lack of fossils in this formation was one of the reasons that led to this belief, as most of the excavations that were dated are fixed and difficult to distinguish, such as tree trunks found in the Al Markhiyat Mountains west of Omdurman in Sudan.⁴ Some believe that the formation of the Nubian sandstone is marine due to the nature of its precipitation in the form of rings and layers, and these air sediments are excluded because the winds carry large granules.⁹ We find that the sedimentation is aerobic if more than 50% of the sediment components have diameters ranging from 0.02 – 0.05g, and that the aerobic sediments may be transported and re-deposited by water.^{10,11} Distinguished a difference between aqueous and aerobic sediments that may be transported, and found that the components dominated by granules with diameters greater than 0.03mm lived a long distance water transport process, while those of sediments with a diameter of less than 0.067mm were transported and deposited by wind.

Regarding the age of formation of the Nubian sandstone, Whitemam⁸ indicated that its age dates back to before the beginning of the third geological time, Tertiary. Medani¹² states that the period during which sandstone, mudstone, and limestone was deposited, spanned about 80 million years. Abu-Zeid¹³ referred to the Nubian sandstone at the end of the second geological time and the sediments spread over it during the Jura and Cretaceous periods. Edwards,¹⁴ considered the potassium and basalt intersecting the formation of the Nubian sandstone to be dated to the per-late cretace. Cox also explained that the age of formation of the Nubian sandstone dates back to the Oligocene and Pliocene periods.

The formation of the Nubian sandstone includes multiple resources, including the ecological soil at the starting point below the surface. In the surface of the soil, bicarbonate is clearly concentrated, and soils are poor in organic resources. Sandy soils in the Nubian sandstone formation are raised by wind, with a high percentage of lime. Celtic soils were formed by rivers and clay soils in the formation of Nubian

sandstone are characterized by brown to red brown and large areas in the formation surface covered by gravel and stone soils, and the soil in most areas of formation contains between 85-90% of the dark iron minerals, and it also contains Lime and gypsum in clay have higher dark levels and the degree of alkalinity (H. P) is low.¹⁵



Source: From the researcher's work, depending on the information of the.²⁶
Figure 1 The Limits of the Nubian sandstone in Sudan.

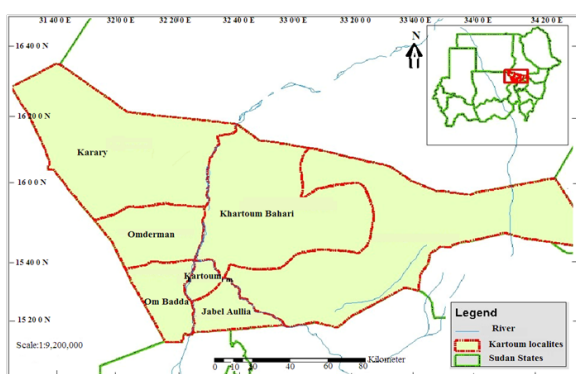


Figure 2 Source: Survey and Urban Planning Department, Khartoum, 2001.²¹



Source: Survey and Urban Planning Department, Khartoum, 2001.¹⁶
Figure 3 Selected wells in Khartoum State.

The soils of the Nubian Sandstone Formation have rapidly evolved in their ancient ranges due to the predominance of wetter climatic conditions during their formation in previous geological ages. While its modern ranges were slowly colored due to the arid climate, silt and clay constitute 30-50% of the types of soils present in the Nubian sandstone formation. It also contains calcite clay of limestone origin, in addition to iron and ultrahite soils.⁸ Ruxton,¹⁰ identified three types of clays in the formation of the Nubian sandstone:

- a. It is found in low-lying areas and waterways, and is dominated by fine clay sand at a rate of 25-50%, which is poor in stone, and

its alkalinity decreases to reach (7-8) and its minerals are more likely to reach the lower extended rocks.

- b. It is found between hills and flood plains with a slope rate ranging between 1: 400 – 1: 100, and its thickness reaches three meters on average, and the percentage of clay in it reaches 60%, lime between 2-4% and the degree of alkalinity (H. P) It has about 0.08 of its minerals Local rocks. This mud is slowly transported down the gradient by overlying surface drainage, sometimes with weeds.
- c. It is found in the erosion and flood plains, and the thickness of the clay in it is about five meters on average. Its consistency is 70% heavier; it is rich in salts and sometimes contains gypsum.

The basement complex and sandy and clay stones change frequently and are 500 meters in thickness, their color is between light yellow or gray and pink, and their texture is very rough to smooth according to the size of the particles and have high water storage properties.¹⁶ Strips of Ironstone sit alongside white, red and pink clay rocks, along with wireline sand rocks.⁸ With regard to groundwater resources in the formation of the Nubian sandstone, we find that the formation is the richest of groundwater reservoirs with its regularity and homogeneity of its composition and its extension over large distances, and the coefficient of water infiltration within it is considered high, when it reaches 18-900 meters³ per day and this is due to the high permeability of the formation rocks. Between 0.05-19m/day. The depth of the aquifers ranges from a few meters to 2000 meters.¹⁷ The Arab Region for Agricultural Development in Khartoum¹⁸ indicated that groundwater accumulation in the formation of the Nubian sandstone is close to the surface in some areas, as is the case in the oases of the Sahara Desert, and its temperature ranges between 30-35 Celsius, and it is fresh and suitable for use in general. Where the amount of dissolved salts ranges between 80-300 parts per million, and carbonate, calcium bicarbonate and sodium are the most important components of the dissolved mineral salts in them.

Study area

Khartoum State lies between longitude 31.5 – 34.45 degrees east and latitude 15.8 – 16.45 degrees north. It is bordered from the west by the state of North Kordofan, by the Gezira and the White Nile from the south, by Kassala and Gedaref from the east, and the River Nile, Northern from the north. Its position is at the intersection of the Blue and White Niles extending from south to north at Muqrin at Totti Island, then across the River Nile in the north. The transverse axis extends from west to east at a height of 380m above sea level.¹⁹ One of the most important features of Khartoum State's location is that the surface of the earth is flat. Its three cities are Khartoum, Khartoum North, and Omdurman on the banks of rivers.²⁰ The area of Khartoum State is about 20.726 km² (10.883) ml², equivalent to 4.9 million acres, and it is the smallest state in Sudan. The state is divided administratively into seven governorates and 36 localities.²¹ It is located in the southern margin of the desert, within the Sudanese range that extends in Africa from west to east between latitudes 11-16 north. In Khartoum State, the continental climate is hot and dry in most months of the year.²²

Taha,¹⁶ stated that the land in most parts of Khartoum State is flat. There are some isolated hills in the plains that were formed by weathering and erosion factors over a stable formative period. In the east of the capital, we find rocks of loosened soil with different base rocks. As for the northwestern part of the capital, there are Goz Abu Dhulou', which are made of silt, mud and sand behind the rivers in

Past eras and that there are several geological units in Khartoum state:

- a. Wind washed sand and surface gravel.
- b. Muddy plains sediments, or what is known as the Black Island soil.
- c. Volcanic rocks related to the third era.
- d. Nubian sand rock formations that were formed in the Cretaceous period.
- e. Volcanic mountain formations.
- f. Base formations and igneous rocks

Soil types and characteristics in Khartoum State are a mixture of rock fragments with different amount of organic matter. This mixture forms the surface layer of the earth's crust. FAO and UNESCO organizations²³ clarified that there are four types of soil identified in central Sudan:

- a. River soils, which are newly formed calcareous soils.
- b. Raqsulat soil, which is soil composed of sand, loosened to some extent, such as Goz Abu Dhulou 'soil.
- c. Cracked soil is a clay-based soil that is dark and light in color
- d. Desert soil, which is dry soil containing little organic matter. It is found in northern Sudan.

There are few valleys that overflow after the many rains in the autumn season, and are clearly visible to the west of the White Nile and the main Nile, including Khor Shambat, Khor Omar and Khor Abu Anja in Omdurman. As for the area east of the Nile, a little slope to the Nile, except for Khor Al-Kadro, north of Khartoum Bahri and north of Al-Jaili, few wadis descend from the west.²⁴ The vegetation consists of a wide variety of weeds and trees. That the area covered by natural vegetation amounts to (2.1) million acres, representing 40% of the state, and it is variable and decreases clearly with the urban expansion. Harroison and Jackson in²⁵ counted and classified the vegetation cover in the area to Samar and *Maerwa Crassifolia* They are desert plants, and they emphasized that *Acacia tortillis* is the most dominant plant in the sandy soil, and *Ziziphus spina -christi*, *Acacia nobica* and *Balanites aegyptiaca* trees there are valleys with clay soils, and A lot and *Calo-tropis procera* in the areas of intensive grazing, and *Acacia nobica* on the banks of the White and Blue Nile and the Nile River.

Methodology

Information was collected from the field survey by private and governmental companies in Khartoum State for the years 2009, 2011, 2010, 2012, 2013, 2014, 2015, as well as from the National Water Authority of Khartoum. Nine wells were selected for each of Khartoum, Omdurman, and Khartoum Bahri, at the rate of three wells for each area, to study the geological composition of the Nubian sandstone by taking the depth, composition and content of the layers, and analyzing the data statistically by taking depth, composition and density, using the system of ratios and graphical figures to infer the Spatial relationships. . In addition to taking samples of groundwater from 30 wells at a rate of 10 wells for each area in order to find out the components of some chemical and physical elements of groundwater from the information from the Groundwater Management Information Center in Khartoum State. It was classified in order to help in concluding the relationships and differences in the Nubian sandstone

formations and to know the specifications and quality of water in wells in order to gain knowledge of:

- i. Nubian sandstone formations and the extent of homogeneity and differences therein.
- ii. Water-bearing layers and their different depths in Khartoum, Omdurman and Khartoum North.
- iii. Soil and water resources as determinants of economic and environmental development.
- iv. groundwater specifications, quantitatively and qualitatively.

Discussion and results

To study the characteristics and extension of the Nubian sandstone, geographically and hydrology, and the differences in the structure and thickness of layers and depths of groundwater in Khartoum State, we will review the samples of the selected wells in Omdurman, Bahri and Khartoum, in order to compare and analyze them to arrive at results that can be useful in knowing the groundwater in quantity and quality and answer some assumptions and questions In the search problem.

Nubian sandstone formations at selected wells in Omdurman

From Tables 1-3 for the sample of selected wells in the Omdurman region, we can notice the following:

- a. The first layer is between (0 – 100) feet dominated by surface sediments to a depth of 20 feet. The soft clay appears light brown. Yellow, semi-white sandstone, and red clay stone, in addition to medium fine sand, red and brown in color.
- b. The second layer is between (100 -) 200 feet, continuous clay, mudstone and sand, all of them red and yellow.
- c. The third layer is between (200 – 300) feet, there is also a fine clay, and with rough sandstone in red and brown colors.
- d. The fourth layer is between (300 – 400) feet. Also there is sandy clay with coarse sandstone to very rough green to brown with iron oxides
- e. The fifth layer, between (400 – 500) feet, contains fine to rough to very rough sandstone, brown to white, with a circular shape.
- f. The sixth layer (more – 500) feet also contains yellow sand and whitish sand, and The levels of groundwater differ in it, as it is located at depths of 490, 690, and 800 feet, and this shows that the groundwater in Omdurman has clearly different depths, and this is due to the nature The texturalness of sandstone and the irregularity of its underground level.

Nubian sandstone formations at selected wells in Bahri

From Tables 4-6 for the sample of selected wells in the Bahri area, we can notice the following:

- The first layer is between (0 – 100) feet dominated by surface sediments to a depth of 0-10 feet, showing soft gray clay, gray sandstone to yellow and rare red.
- The second layer, between (100 – 200) feet, there is a rough sandstone, limestone, white and gray mixed with a little red, with clay lenses and some red clay.

- The third layer is between (200 – 300) feet of fine, medium and rough sandstone, yellow, gray and brown with white limestone.
- The fourth layer between (300 – 400) gray to yellow sandstone mixed with white quartz and limestone with iron oxide and clay lenses.
- The fifth layer is between (400 – 500) an extension of the fourth layer and is homogeneous with it in the components
- The sixth layer (more – 500) feet contains sandstone, mudstone and gray gravel with white quartz and red clay, and the levels of groundwater vary in it as it is found at depths of 530, 690, and 725 feet, and this indicates that the groundwater in the Bahri region also has depths Clearly different, and this is due to the nature and thickness of the Basement Complex on which the Nubian sandstone is based.

Table 1 Location:Al-Thawra Al-Hara (7), Omderman

Rock description	Depth per foot	Density
Surface sediments	Less – 100	100
SSI Soft, light brown and yellow in color	100 – 200	30 – 70
SSI Soft to med – brown in color	200 – 300	200 – 10
Reddish-colored clay	300 – 400	200 – 10
SSI Rough greenish and brown in color	400 – 500	15 – 30
Med- greenish and light brown sandstone	500 – 600	20
-	More – 600	-

Source: Mam Company for Excavations, 2009, Khartoum²⁷

Table 2 Location: Dar El-salam, Omderman

Rock description	Depath per foot	Density
Surface sediments, sandy clay,sandstone, fine to coarse, light to reddish	Less – 100	5 – 72
Clay stone, fine to medium sand, yellow to reddish in color	100 – 200	85
Rough to very rough sandstone	200 – 300	85 – 200
Reddish clay stone, coarse to very rough brown sandstone	300 – 400	40
Clay sandstone, medium soft brown clay, circul and semi-circular sandstone,brown color.	400 – 500	10- 20
Medium to coarse sandstone with some iron oxide light yellow in color, medium sand, white to pink in color	500 – 600	60 – 20
Medium sandstone, whiteish, reddish-colored clay stone	More – 600	30- 20

Source: Foras Engineering Company for Services and Investment Ltd., 2014, Khartoum²⁸

Table 3 Location:Abu Saaed (33), Omderman

Rock description	Depath per foot	Density
Surface sediments, Brown sandy clay	Less – 100	50
Brown sandy clay, different color clay	100 – 200	40
Different color clay,Very coarse sand with gravel	200 – 300	80
Clay sand with iron oxide, gray sand clay	300 – 400	200
Gray sandy clay, fine to medium whitish sand	400 – 500	20
Fine to medium coarse to very coarse whitish sand	500 – 600	45
Fine to medium, coarse sand, white sand, white sandy clay	More – 600	20

Source:Al-arqam for fossils and water, 2012, Khartoum²⁹

Table 4 Location: Soba Sharig, Bahri

Rock description	Depath per foot	Density
Surface sediments, gray clay, medium to coarse yellowish fine sandstone	Less – 100	5 – 35
Medium soft sandstone to coarse yellowish, medium to coarse fine sandstone	100 – 200	160
Medium to coarse fine sandstone, white limeston, fine sandstone with limestone	200 – 300	20 – 60
Fine sandstone with limestone, medium to coarse fine sandstone with yellowish	300 – 400	60
Coarse medium soft sandstone with iron oxide, medium coarse fine sandstone with clay	400 – 500	50
Gray fine sandstone, reddish clay	500 – 600	120
Fine sandstone with clay	More – 600	80

Soure: Essam Al-Sheikh Excavations Company, 2011, Khartoum Bahri³⁰

Table 5 Location:AL-Haj yousief, Bahri

Rock description	Depath per foot	Density
Surface sediments, reddish sandy clay, whitish clay sand	Less – 100	5 – 25
White clay sand, fine whitish sandstone, fine sandstone with clay lenses	100 – 200	20 – 115
Medium fine sandstone, coarse yellowish, sandstone with reddish clay stone	200 – 300	10 – 90
Rough sandstone to very coarse, clay gray in color	300 – 400	20 – 50
Medium soft sandstone rough whitish	400 – 500	80
Medium fine sandstone rough to very coarse	500 – 600	50 – 110
A coarse medium soft sandstone, reddish clay	More – 600	30

Source:Essam Al-Sheikh Excavations Company, 2011, Khartoum Bahri³¹

Table 6 Location:AL-dorroshab, Bahri

Rock description	Depath per foot	Density
Surface sediments, gray clay sand, gray and yellow colored fine sandstone	Less – 100	10 – 50
Soft yellowish sandstone , white sandstone	100 – 200	5 – 75
White clay sand, gray sandstone, reddish sandstone and clay	200 – 300	10 -20
Fine to medium to rough sandstone, white in color	300 – 400	15 – 90
Fine yellowish sandstone ,a fine to medium to coarse white sandstone, gray clay	400 – 500	50 – 60
Soft to medium white sandstone	500 – 600	30 – 60
-	More – 600	-

Source: Mam Company for Excavations, 2012, Khartoum³²

Nubian sandstone formations at selected wells in Khartoum

From Tables 7-9 concerning the sample of selected wells in the Khartoum region, we can notice the following:

- The first layer is between (0 – 100) feet dominated by surface sediments to a depth of 0-20 feet. Gray clay appears, and sandstone is coarse to fine gray and yellow in color.
- The second layer is between (100-200) feet, sandstone with yellow clay stone, sand of various sizes, round to angular, soft to medium to coarse, dark gray in color, and there is similarity in the components between Khartoum and Bahri.
- The third layer between (200 – 300) feet sandstone and clay, soft, medium, rough, gray and yellow in color, fine to medium whitish sand, dark iron sand. Red clay.

- The fourth layer, between (300 – 400) feet, fine to medium sandstone, with gravel of yellow to light brown quartz, sand of various sizes and colors.
- The fifth layer is between (400 – 500) fine to medium to coarse yellow sandstone, which is similar to the fourth layer.
- The sixth layer (more – 500) contains clay stone with gray and dark clay, and the levels of groundwater differ in it, as it is located at depths of 340, 505, and 585 feet, and this indicates that the groundwater in the Khartoum region also has different depths, but the groundwater is closer than Those in Bahri and Omdurman, and this is due to the nature and thickness of the bedrock rocks on which the Nubian sandstone in Khartoum is based.

Table 7 Location:AL-Sajana, Kartoum

Rock description	Depath per foot	Density
Surface sediments, gray clay, medium to rough sandstone, brown to yellow in color	Less – 100	10-20
Sandstone with yellow clay stone, clay stone with gray sandstone, fine to medium gray sandstone	100 – 200	35
Gray clay stone, Soft to medium yellow sandstone , soft to medium gray sandstone	200 – 300	20
Pale brown clay stone, soft to medium sandstone with yellowish quartz pebbles	300 – 400	20 -45
Soft to medium to rough sandstone, yellow in color, Clay stone	400 – 500	10 - 50
-	500 – 600	-
-	More – 600	-

Source: Copact Infrastructure Company Ltd., 2011, Khartoum³³

Table 8 Location:AL-Gasir Algmhory, Kartoum

Rock description	Depath per foot	Density
Surface sediments, soft dark gray sandstone Dark sandy clay Soft to medium to coarse sandstone with a dark gray color	Less – 100	10 - 35
Soft to medium to coarse yellowish sandstone in color; a fine, yellowish sandstone, medium fine sandstone with clay, clay sand to a reddish color	100 – 200	15- -35
Red clay, fine yellowish-gray sandstone, white-colored soft sandstone, dark sandstone	200 – 300	20 - 65
Dark colored clay	300 – 400	10 - 70
-	400 – 500	-
-	500 – 600	-
-	More – 600	-

Source: Rawasi Company for Excavations and Investment, 2012, Khartoum⁷

Table 9 Location:AL-Tayief, Kartoum

Rock description	Depath per foot	Density
Surface sediments, gray clay stone with gray gravel, gray sandy clay, fine to medium yellowish sandstone	Less – 100	5 - 70
Gray sandy clay ,fine to medium yellowish sandstone,	100 – 200	15- 45
Soft to medium yellowish sandstone, brown clay stone, gray clay stone	200 – 300	10 -50
Gray clay stone, brown sand clay	300 – 400	40 - 60
Soft to medium to coarse clay stone with round to angular whitish quartz	400 – 500	20 - 50
-	500 – 600	-
-	More – 600	-

Source: Foras Engineering Company for Services and Investment Ltd., 2014, Khartoum³⁴

Chemical analysis of groundwater in some wells in Khartoum State Omdurman area

Ratio (10), (11) and (12) n we find in the different waters according to the location of the well and the layered structure and mineral compositions of the Nubian sandstone in the three cities. This is evident in the increase or decrease of some of the elements contained in the water, whose rates appeared, such as electrical conductivity, pH, dissolved salts, nitrite, carbonate, bicarbonate, chlorine, calcium, potassium, chloride, fluoride, ammonia, chlorine, phosphates, sulfates, iron, magnesium, sodium and manganese. General remarks We find that the rates of salinity, acidity, alkalinity and some chemical elements vary, but they did not exceed the standards of the World Health Organization, with the exception of some cases, and this will be evidenced by the results of the analysis in the cities of Khartoum, Omdurman and Bahri.

From the Tables 10-12, we find that the quality of water varies and changes according to the location of the well and the structure of the layers and mineral compositions of the Nubian sandstone in the three cities as this is reflected in the quality, quantity and quality of groundwater, and this is evident in the increase or decrease of some elements The water contains, whose rates have appeared, such as electrical conductivity, pH, dissolved salts, nitrite, carbonate, bicarbonate, chlorine, and the proportions of calcium, potassium, chloride, fluoride, ammonia, chlorine, phosphates, sulfates, iron, magnesium, sodium and manganese. General remarks We find that the rates of salinity, acidity, alkalinity and some chemical elements vary, but they did not exceed the standards of the World Health Organization, with the exception of some cases, and this will be evidenced by the results of the analysis in the cities of Khartoum, Omdurman and Bahri.

Table 10 Results of laboratory analysis of some elements in mg/l in the wells of Omdurman area

Sample	EC	PH	TDS	No ₃	HCO ₃	Co ₃	C ₁	K	Ca	F ⁻	Cl ⁻	NH ³
Althora,7	1040	8,23	728	77,4	170,8	12	21	7,29	6,4	0,27	60	0,068
Fatasha	562	6,84	393,4	21,6	244	-	137,7	7,08	5,2	0,33	44	0,123
Aboseed	533	7,2	373,1	17,6	195,2	6	21,3	8,1	6,2	0,23	35	0,078
Gmarab	1745	7,39	1221	34,4	317,2	18	37,63	9,4	4,7	0,28	33	0,075
Sarorab	408	7,32	285,6	18,8	317,2	-	198,8	7,3	7,1	0,34	45	0,069
Shehanap	339	7,71	237,3	13,4	219,6	-	14,91	10,3	6,3	0,29	50	0,056
Althora,34	357	7	249,9	14,0	146,4	-	12,91	11,3	6,6	0,31	47	0,761
Beatalmal	430	7,29	301	14,8	134,2	-	19,88	9,5	7,1	0,34	39	0,090
Ombada,8	661	7,24	462,7	62,4	170,8	-	12,07	8,7	7,2	0,25	45	0,086
Al fath	397	7,12	277,9	16,4	195,2	-	48,99	7,5	5,9	0,37	52	0,079

Source: From the researcher's work, depending on the information of the Groundwater Management Information Center, Information Book, Khartoum State - Sudan (1991).¹

Table 11 Results of laboratory analysis of some elements in mg/l in wells in Bahri area

Sample	EC	PH	TDS	TH	HCO ₃	Co ₃	C ₁	K	Ca	F ⁻	Cl ⁻	NH ³
Algadesia	614	7,65	429,8	312	244	-	17,04	3,5	37,2	0,28	12	0.109
Shigla	605	7,32	423,5	228	614	6	92,3	4,5	41,0	0,32	14	0.155
Ebabiker	630	6,62	441	198	207,4	-	39,05	6,1	45,1	0,22	13	0,134
Droshab	902	6,75	131,4	232	219,6	-	39,76	4,2	33,4	0,25	10	0,110
Haj yosif	644	7,07	450,8	238	183	-	80,23	3,3	29,3	0,38	18	0.121
Soba,E	579	7,5	405,3	266	244	-	42,6	5,6	31,3	0,25	19	0,156
Esalat	394	7,4	275,8	268	256,2	-	20,59	4,2	24,3	0,21	16	0,176
Mahas	572	7,2	400,8	180	207,4	-	18,46	5,1	56,5	0,31	18	0,190
Abosalih	818	7,44	572,6	302	292,8	-	59,64	4,6	55,7	0,27	17	0,146
Abogroon	413	7,04	289,1	130	195,2	-	25,65	4,4	39,5	0,31	11	0,119

Source: From the researcher's work, depending on the information of the Groundwater Management Information Center, Information Book, Khartoum State - Sudan (1991).¹

Table 12 Laboratory analysis of some elements in mg / l in the wells of Omdurman area

Sample	EC	PH	TDS	No ₃	HCO ₃	Co ₃	C ₁	K	Ca	F ⁻	Cl ⁻	NH ³
J.awlia	250	7,52	175	8,4	134,2	6	12,68	63,3	39,2	0,58	62	1.10
Gabra	441	7,8	308,7	15,6	134,2	9	14,2	41,5	43,2	0,42	56	1.15
Segana	567	7,7	403,2	11,6	207,4	9	17,75	62,1	46,1	0,52	55	1,13
Soba,W	212	7,5	148,1	10,4	256,2	6	8,52	43,2	39,4	0,45	45	0,99
Greef,W	384	7,2	286,8	18,0	207,4	9	8,52	34,3	28,3	0,48	38	1.12
Alazhary	401	7,5	280,7	170	97,6	6	10,65	51,6	39,3	0,55	49	1,15
Kalakla	766	7,4	536,2	17,8	183	9	12,87	43,2	29,3	0,61	46	0,87
Algasir	330	7,5	231	12,0	195,2	6	9,94	51,1	51,5	0,51	58	1,09
Azhaty	482	7,3	337,4	20,0	268,4	6	44,2	42,6	53,7	0,57	57	0,19
N.Dobat	1517	7,5	1061	46,8	170,8	12	191,7	45,4	47,5	0,41	61	1,18

Source: From the researcher's work, depending on the information of the Groundwater Management Information Center, Information Book, Khartoum State - Sudan (1991).¹

Bahri area

10 subterranean wells were selected: Al-Qadisiyah, Shaqla, Adabakir, Al-Droshab, Haji Yusuf, Soba Sharq, Al-Slit, Al-Mahs, Dabusaleh, and Abugron, and the study found that the percentage of Nubian sandstone in the Bahri area is 82% with 18 layers, which is the highest percentage compared to Omdurman and Khartoum, and this indicates The abundance of water in the Bahri area and that the Nubian sandstone is one of the most water-bearing layers. We note that the electrical conductivity (E.C) ranged between (300-1000)mg/liter. The pH is between (6-8) in second place after Khartoum and it is neutral, while Total Dissolved Salts (TDS) are good below 500mg/liter, with the exception of the Officers Club at a rate of 1016 mg/liter. According to the Khartoum State Authority report, the gray color of The most dominant color in the soil and it represents the total percentage of elements in its water, the element sodium 23.5mg/l, iron 0.025mg/l, and nitrate mg/l 1.45, while ammonia is slightly more than 0,1 in most samples, at a temperature of 27 The rest of the elements. They do not have excessive rates and are considered natural. We find the water chemically suitable for human drinking, and gray is one of the most common colors in the soil.

Khartoum region

The study indicated that the proportion of Nubian sandstone in Khartoum is 67%, and the average number of layers is 16. The study indicated that the proportion of Nubian sandstone in Khartoum is 67%, and the average number of layers is 16. We note that the electrical conductivity (EC) ranged between (200-800), with the exception of the officers' club sample, reaching 1517 mg/liter, and the pH between (7-8) in the second place after Khartoum, which is neutral, while Total

Dissolved Salts (TDS) They are good below 500 mg/L, except for the Officers Club, at a rate of 1016 mg/L. In the Khartoum Water Authority report, the element sodium represents 33 mg/1 in its water, in addition to 0.045 mg/1 iron. Nitrates did not exceed 50 mg/liter. As for ammonia, it was high and exceeded 1.0 in 70% of the samples at a temperature of 24.6. As for the rest of the elements, they do not have excessive rates and are considered natural. We find water chemically suitable for human drinking, and gray is one of the most prevalent colors in the soil.

Comparative qualitative differences of some chemical elements of groundwater in Khartoum state

From Figure 4 related to the electrical connection (E.C) of water, we note that all rates are normal, but they rise in the Omdurman area, reaching a maximum of 1745mg/l in the Gammaraab sample, followed by Bahary and then Khartoum, despite their high in the officers 'club sample 1517mg/l. By comparing (TDS) in Figure 5, we notice that it increases in Omdurman, where it reached the highest rate in the Gammaraab sample 2121 mg/l, followed by Bahri and then Khartoum, despite its increase in the officers' club sample as well 1061mg/l. From the inverse relationship between them at the site of the three sample. From Figures 6&7, we note that the TDS rates in Omdurman, Bahri and Khartoum were reflected in the similarity of (F⁻) and (Cl⁻) in the samples and their rates were normal.

By comparing the (PH) rates in Figure 8, we find that 90% of the samples in all sites do not exceed or be less than the normal range for them (6.5 - 7.5)mg/l, except for the revolution sample Al thora 7 in Omdurman, and it is considered that this is related to carbonate rates as they are normal rates in most samples In Figures 9-11, we note that

they vary in the three sites, where the highest is the HCO_3 sample at a rate of 614mg/l in Bahri, followed by Omdurman and then Khartoum, and as for (C_1) we find that Omdurman recorded the Sorrab sample The highest rate is 198.8mg/l , as well as (CO_3) at a rate of 18mg/l in gambling, and we note that it also does not contain increases from normal rates.

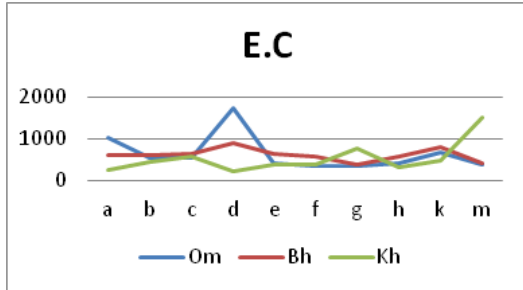


Figure 4

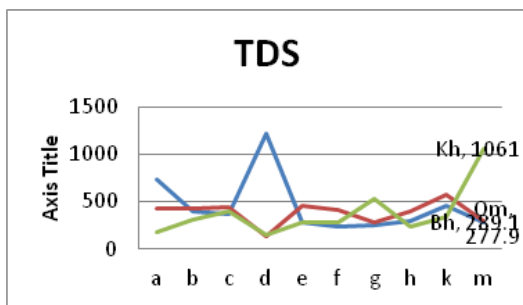


Figure 5

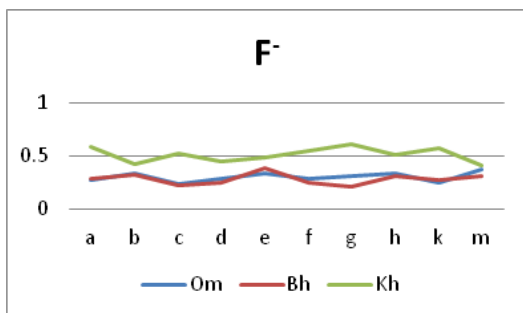


Figure 6

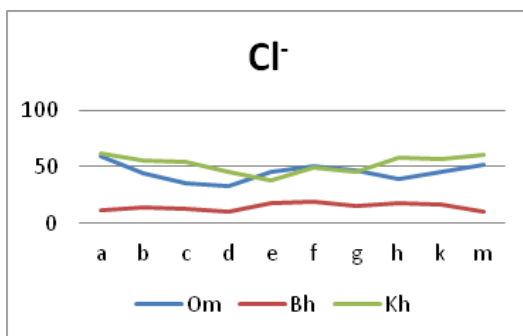


Figure 7

Also, we find from Figures 12&13 that the rate of potassium in the three sites is normal, and Khartoum samples recorded the highest rates between 30mg/l to 70mg/l, with clear differences from Omdurman and Bahri that were confined between 1mg/l to 10mg/l. Bahri and Khartoum, and it decreased in Omdurman to below 10mg/l . From

Figure 14 we notice that there are many Khartoum samples that rose above the normal rate 1.5mg/l, which is an indicator of pollution. As for Omdurman and Bahri, their rates are normal.^{35,36}

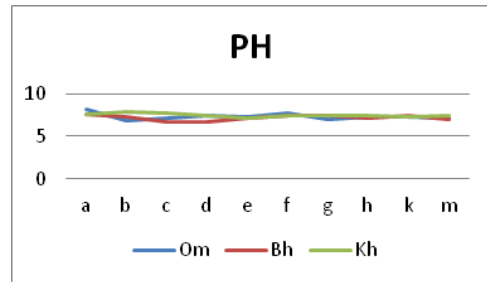


Figure 8

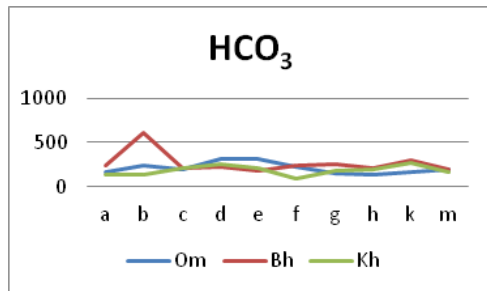


Figure 9

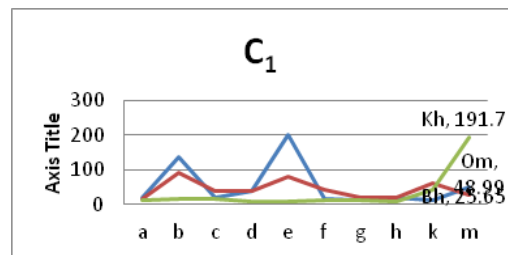


Figure 10

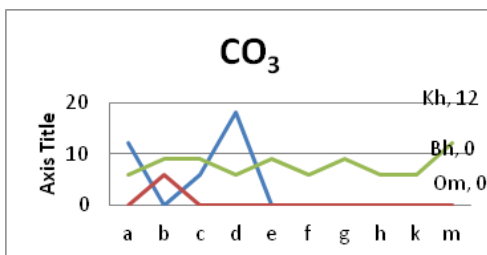


Figure 11

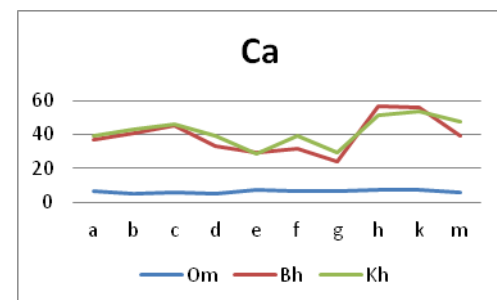


Figure 12

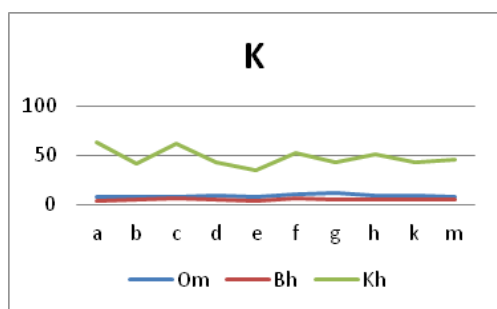


Figure 13

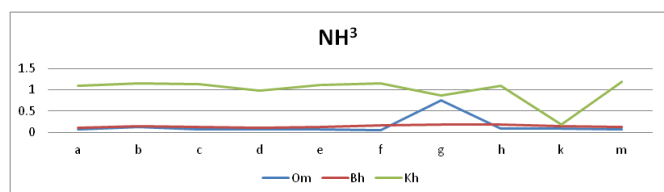


Figure 14

Conclusions and recommendations

- i. Khartoum State has about more than 300 underground wells, and most of these wells come from the Nubian Sandy Basin.
- ii. There is a high concentration of ammonia in Omdurman water compared to other regions, as it reached 0.1305, while Khartoum 1.35, and Bahri 0.044.
- iii. Geographically, Khartoum State is located in the southeastern part of the Nubian Basin, and that has led to a difference in the structure and composition of the strata.
- iv. Nubian sandstone formations are among the most water-bearing layers, as they have a storage capacity of about 77 million cubic meters and a depth of more than 150 meters below the surface of the earth. However, there is a variation in levels, quantities and depths in Khartoum State.
- v. Nature of the geological structure and erosion factors affected the qualitative differences in the layered composition and water depths in the state.
- vi. geological structure and erosion factors have affected the qualitative differences in the structure of layers and water depths in the state.
- vii. Sandstone, clay, sand, clay and gravel formations formed a large part of the Nubian sandstone composition.
- viii. Number of classes in Khartoum is higher than in Omdurman and Bahri. Khartoum 18, Omdurman 10, and Bahri 16.
- ix. The percentage of sodium in the waters of Bahri area is low compared to the area of Omdurman, as the percentage of sodium in Bahri water is 23.5 mg/l, while Omdurman is mg/144
- x. surface runoff towards the Blue Nile and White Nile and the Nile River affected the stratigraphy structure, especially in Omdurman.
- xi. presence of the Blue Nile and White Nile and the Nile River did not significantly affect the underground stock of Nubian sandstone in the state.

- xii. The groundwater extracted from the Nubian sandstone is suitable for drinking and agricultural water according to WHO standards, with few exceptions.
- xiii. Digging wells far from pollution sources to obtain healthy water and reduce some elements such as ammonia.
- xiv. Conducting a ground and geological survey to find out groundwater pools in and around Khartoum State, in order to develop plans for their sustainability.
- xv. Planning to find sanitation that does not depend on drilling wells to reduce pollution risks.

Acknowledgements

None.

Conflicts of interest

Authors declare no conflict of interest exists.

Funding

None.

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